DESCRIPTION

Title of Invention

DETECTING METHOD OF LIFE ACTIVITY, CONTROLLING METHOD OF LIFE ACTIVITY, AND TRANSMISSION METHOD OF INFORMATION CONCERNING LIFE ACTIVITY

Technical Field

The present invention relates to, a measuring method or a control method for measuring (in vivo measurement) or controlling, in a living state, dynamical life activities changing at high speed in a life object such as an animal including a human or a plant or changes thereof by a non-contact and noninvasive method.

Background Art

An example of dynamical life activities changing at high speed in a life object is activities of the nervous system. Methods for measuring an intracerebral activity include a blood oxygen analyzing of blood with near infrared light (hereinafter referred to as "Conventional Technique 1") and oxygen analyzing of blood with a functional Magnetic Resonance Imaging (fMRI) method (hereinafter referred to as "Conventional Technique 2"), which are representative examples of conventional techniques.

According to Conventional Technique 1, the oxygen concentration in blood is measured by use of a change of a near infrared light absorbing spectrum of oxyhemoglobin and deoxyhemoglobin (see Non Patent Document 1). That is, the oxyhemoglobin which is a particular hemoglobin bonding to an oxygen molecule has a maximum absorption at a wavelength of 930 nm, and the deoxyhemoglobin which is other particular hemoglobin separated from an oxygen molecule has maximum absorption at wavelengths of 760 nm and 905 nm. A head is illuminated with each light of 780 nm, 805 nm, and 830 nm as a light source (a semiconductor laser) for measurement, and changes in intensity of respective beams of transmitted light are measured. Signals relating to cortex areas of the brain at 3 to 4 cm in depth are hereby obtained from a surface of the head.

Except the method using near infrared light, there is a method using Nuclear Magnetic Resonance to perform the measurement of the oxygen concentration in blood. That is, when

adsorption of oxygen molecules is switched to release of oxygen molecules, electron orbitals in hemoglobin molecules are changed, which changes magnetic susceptibility and shortens T2 relaxation time of MR.

According to Conventional Technique 2, a location (activation area) where an oxygen consumption rate has increased in the nervous system is estimated by use of this phenomenon (see Non Patent Documents 2 and 3). When this method is used, a measurement result can be obtained by a computer process and the oxygen concentration distribution in blood in the head can be exhibited in a three-dimensional manner.

Meanwhile, as a method for controlling dynamical life activities in a life object, there has been known medical treatment.

Citation List

Non Patent Literature

NPL 1: Yukihiro Ozaki/Satoshi Kawata: Kinsekigaibunkouhou (Gakkai Shuppan Center, 1996) Section 4.6

NPL 2: Takashi Tachibana: Nou Wo Kiwameru Noukenkyu Saizensen (Asahi Shimbun Publishing, 2001) p. 197

NPL 3: Masahiko Watanabe: Nou Shinkei Kagaku Nyumon Koza Gekan (Yodosha, 2002) p. 188

~~**Summary of Invention**~~

~~**Technical Problem**~~

However, according to Conventional Techniques 1 and 2, a temporal resolution and a spatial resolution for the active state measurement of the neuron are low.

In order to facilitate the understanding of the problem, the following initially explains that the oxygen analyzing of blood is indirect measurement. The measurement of the oxygen concentration in blood is based on a tacit hypothesis that "when a neuron is activated, hemoglobin should be deoxygenated to supply its activity energy."

However, as described in Chapter 4 of the B. Alberts et. al: Essential Cell Biology (Garland Publishing, Inc., 1998), energy caused at the time of hydrolysis from ATP (Adenosine triphosphate) to ADP (Adenosine diphosphate) is used for the activity energy of the neuron.

The ADP is generated in the course of an oxidation process of Acetyl CoA occurring in

Mitochondria existing in the neuron. Further, the neuron does not contact with blood vessels directly, and oxygen molecules are transmitted into the neuron via glial cells intervening between the neuron and the blood vessels. The transmission of the oxygen molecules is involved with the activity in the neuron via such a complicated course.

Accordingly, it is considered that a phenomenon that the oxygen concentration in blood is changed (decreased) occurs only around a local area where a large amount of cells are activated in the nervous system at the same time. For this reason, it is difficult, in Conventional Techniques 1 and 2, to observe instant changes of a few cells in the nervous system, such as short-term action potentials from a few neurons. That is, since only a local area where a large amount of cells are activated at the same time can be detected, it is theoretically difficult to raise the spatial resolution. As such, in Conventional Techniques 1 and 2, the activity of the neuron is observed not directly but indirectly, so that the measurement accuracy is poor.

(Regarding temporal resolution)

According to the report of Nikkei Electronics (Nikkei BP), p. 44, published on May 3, 2010, a hemoglobin level in blood which changes about 5 s after a neuron became active is detected in accordance with Conventional Technique 1. Therefore, in the detection based on Conventional Technique 1, a large delay occurs from initiation of the activity of the neuron.

Further, according to Conventional Technique 2, the use of a BOLD (Blood Oxygenation Level Dependent) effect causes a similar situation to the above. The BOLD effect is as follows: when a neuronal activity increases due to a brain activity, an oxygen consumption increases at first. As a result, a deoxyhemoglobin concentration slightly increases, and several seconds later, a cerebral blood flow in capillaries in vicinal areas increases rapidly, thereby causing a supply of a large amount of oxygen which greatly exceeds the oxygen consumption. This rapidly increases the oxyhemoglobin concentration, and consequently, fMRI signals are enhanced and relaxation time thereof is made longer. That is, even in Conventional Technique 2, the detection of the increase in the oxyhemoglobin concentration requires several seconds after the activity of the neuron has started due to the brain activity, and thus, Conventional Technique 2 also causes a delay of several seconds for the detection, similarly to Conventional Technique 1.

As such, as long as Conventional Techniques 1 and 2 measure the oxygen concentration in

blood, there is a delay for the hemoglobin level in blood to change after the initiation of the activity of the neuron. In view of this, the temporal resolution in either of Conventional Techniques 1 and 2 is about 5 s, which is very low.

(Regarding spatial resolution)

The spatial resolution of Conventional Technique 1 is determined by a distance between a light source and a photodetector for measuring an intensity change of light passing through the head (See p. 43 of Nikkei Electronics (Nikkei BP) published on May 3, 2010). As the distance between the light source and the photodetector becomes smaller, a penetration depth of a measuring beam into the head becomes shallower.

Accordingly, if the distance between the light source and the photodetector is shortened to raise the spatial resolution, it becomes impossible to measure the nervous system in the head. As described earlier, in a case where measurement is performed on an area inside the head which is at a depth of 3 to 4 cm from a surface of the head, the light source should be placed so as to be distanced from the photodetector by about 3 cm, and thus, the spatial resolution is about 3 cm.

On the other hand, the spatial resolution in the case of Conventional Technique 2 is determined by a wavelength of a detecting transaction magnetic field (an electromagnetic wave) according to a diffraction theory of the electromagnetic wave, and the wavelength of this detecting transaction magnetic field is determined by a DC magnetic field intensity to be applied. Even if the DC magnetic field intensity is raised using a super conductive magnet, there is a theoretical upper limit of the spatial resolution due to a technical limitation. According to p. 42 of Nikkei Electronics (Nikkei BP) published on May 3, 2010, which is mentioned above, the spatial resolution is a few mm at best, even in an fMRI device having the highest spatial resolution.

The following describes a penetration depth into a life object regarding Conventional Technique 1. As apparent from the skin color of a human, visible light is easy to be reflected diffusely on a surface of a life object and is hard to penetrate the life object. In the examples described above, light of 780 nm, light of 805 nm, and light of 830 nm are used as measuring beams. The light of 830 nm, which has the longest wavelength among them, is near infrared light, but is close to a visible light area. Therefore, the penetration depth thereof into the life object is also short. As a result, only a signal relating to the cortex area in the brain located at a

depth of 3 to 4 cm from the surface of the head can be measured at best, as previously described.

In view of this, it is an object of the present invention to provide a method and the like which can measure an active state in a life object while attempting to enhance the spatial resolution and the temporal resolution.

Meanwhile, in the medical treatment, which is known as a method for controlling life activities, it is difficult to effectively control only a particular region in a life object. This is because a medicine given by mouth or by injection circulates through the body and spreads over the body. Therefore, even medication for a therapeutic purpose, for example, not only causes a relative decrease in a medicine amount working on a target part to be cured (controlled), but also side effects due to other drug actions to other parts except the target part to be cured (controlled).

In view of this, the present invention is also intended to provide a method and the like for effectively controlling an active state of only a particular region (an area constituted by one cell or a group of a plurality of cells) in a life object.

Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each claim of this application.

Throughout this specification the word “comprise”, or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

Solution to Problem Summary

Disclosed herein is a non-invasive method applied to a life object, comprising: irradiating the life object with a first electromagnetic wave having a prescribed wavelength, the prescribed wavelength being included in a range from 1.028 μm to 2.50 μm; and detecting a signal relating to a second electromagnetic wave, the second electromagnetic wave having a wavelength same as the prescribed wavelength, the second electromagnetic wave being obtained from the life object and at least a part of the second electromagnetic wave being condensed out of the life object to generate the signal; and detecting neural activity, muscular

activity, or cellular activity based on the detected signal.

A Described herein is a measuring method of life activity or a control method of life activity according to the first aspect of the present invention which is a measuring method of life activity or a control method of life activity for measuring or controlling an active state of a life object including an animal and a plant or a change thereof, including: an illumination step of illuminating the life object with an electromagnetic wave of which a wavelength is included in a designated waveband; and a detection step of detecting a characteristic associated with the electromagnetic wave in a local area constituted by one or more cells in the life object, or a control step of controlling the active state by use of the characteristic associated with the electromagnetic wave, wherein any of the following phenomena is used for detecting or controlling the active state of the life object or a change thereof:

[1] transition energy between a ground state of a vibration mode newly occurring between atoms in a constituent molecule of a cell membrane and a plurality of excited states;

[2] transition energy between vibration modes occurring between specific atoms in a molecule corresponding to the activity of the life object or the change thereof

and

[3] a specific chemical shift value in Nuclear Magnetic Resonance,

and the designated waveband is determined on the basis of any of the phenomena.

The measuring method of life activity according to one exemplary embodiment of the present invention ismay be such that the designated waveband is determined under such a condition that the potential change of the cell membrane is accompanied with a phenomenon in which a specific ion is attached to or detached from a specific substance in the local area.

The measuring method of life activity according to a first aspect of the present invention is may be such that the designated waveband is determined under such a condition that the specific substance and the specific ion is at least one of a combination of Phosphatidylcholine or Sphingomyelin and a chlorine ion, a combination of Phosphatidylserine and a sodium ion or a potassium ion, and a combination of Glycolipid and a sodium ion.

The measuring method of life activity according to the first aspect of the present invention ismay be such that: the designated waveband according to attachment or detachment of the

chlorine ion with respect to the Phosphatidylcholine is determined on the basis of a wavenumber of 2480 cm^{-1} or a chemical shift value from δ2.49 to δ2.87 ppm or a chemical shift value related to δ3.43 ppm to δ3.55 ppm; the designated waveband according to attachment or detachment of the chlorine ion with respect to the Sphingomyelin is determined on the basis of a wavenumber of 2450 cm^{-1} or a chemical shift value from δ2.49 to δ2.87 ppm or a chemical shift value related to δ3.43 ppm to δ3.55 ppm; the designated waveband according to attachment or detachment of the sodium ion with respect to the Phosphatidylserine is determined on the basis of a wavenumber of 429 cm^{-1}; the designated waveband according to attachment or detachment of the potassium ion with respect to the Phosphatidylserine is determined on the basis of a wavenumber of 118 cm^{-1}or 1570 cm^{-1}; and the designated waveband according to attachment or detachment of the sodium ion with respect to the Glycolipid is determined on the basis of a wavenumber of 260 to 291 cm^{-1}.

The measuring method of life activity ~~according to the first aspect of the present invention is~~ may be such that the designated waveband is determined so that at least a part of a waveband corresponding to a wavenumber range having a margin of 10 to 20% with respect to a wavenumber to be the basis or a range of a chemical shift value having a margin of 0.45 ppm to 0.49 ppm with respect to a chemical shift value to be the basis is included therein.

The measuring method of life activity ~~according to the first aspect of the present invention is~~ may be such that the designated waveband is determined such that wavebands of electromagnetic waves absorbed by other substances including at least water constituting the life object are removed.

The measuring method of life activity ~~according to the first aspect of the present invention is~~ may be such that the designated phenomenon is a phenomenon to occur within a designated response time in a range of 4 to 200 ms after the active state of the life object has changed.

The measuring method of life activity ~~according to the first aspect of the present invention is~~ may be such that the detection step is a step of detecting an absorption characteristic of the electromagnetic wave in the local area at any cross section in the life object by using a confocal system.

The measuring method of life activity according to the ~~first aspect of the~~ present ~~invention~~ disclosure further include~~s~~: a step of acquiring, by the illumination step and the detection step,

designated information representing a spatial distribution aspect and an aspect of a time dependent variation of the absorption characteristic of the electromagnetic wave in the life object; and a step of specifying life activity information of the life object or environmental information defining an environment surrounding the life object, by referring to a data base in which to store a relationship between the life activity information or the environmental information and the designated information, based on the acquired designated information.

The measuring method of life activity ~~according to the first aspect of the present invention~~ may further include~~s~~: a step of recognizing the life activity information or environmental information of the life object; and a step of setting or correcting the relationship between them to be stored in the data base, based on the recognized life activity information or environmental information and the acquired designated information.

A measuring method of life activity ~~according to a second aspect of the present invention is~~ may be such that a dynamical activity of a life object is detected by use of a characteristic in a local area corresponding to an electromagnetic wave having a wavelength of not less than 0.84 μm but not more than 110 μm or a characteristic in a local area corresponding to an electromagnetic wave associated with a chemical shift value in a range of not less than δ1.7 ppm but not more than δ4.5 ppm.

The measuring method of life activity ~~according to one exemplary embodiment of the present invention is~~ may be such that a time dependent variation of the characteristic in the local area of the life object is measured.

The measuring method of life activity ~~according to the second aspect of the present invention is~~may be such that at least a part of the life object is illuminated with a modulated electromagnetic wave having a basic frequency in a range of 0.2 Hz to 500 kHz.

The measuring method of life activity ~~according to the second aspect of the present invention is~~may be such that a time dependent variation of the characteristic in one fixed local area in the life object is detected or a set of individual time dependent variations related to the characteristic in a plurality of local areas fixed to different positions in the life object are detected.

~~The~~ In measuring method of life activity, ~~according to the second aspect of the present invention~~ at least one of the fixed local areas may correspond~~s~~ to one cell or a part of the cell and ~~is~~may be illuminated with a modulated electromagnetic wave having a basic frequency in a range

of 0.2 Hz to 500 kHz.

The measuring method of life activity ~~according to the second aspect of the present invention is~~may be such that the local area corresponds to one cell or a part of the one cell, and a change of the characteristic to occur according to a potential change of a cell membrane constituting the cell is detected.

The measuring method of life activity ~~according to the second aspect of the present invention is~~may be such that the life object is illuminated with electromagnetic waves including electromagnetic waves having a plurality of different wavelengths or electromagnetic waves having a plurality of different frequencies so as to detect characteristics in the local area of the life object corresponding to the electromagnetic waves having the plurality of wavelengths or the electromagnetic waves having the plurality of frequencies.

The measuring method of life activity ~~according to one exemplary embodiment of the present invention~~may include~~s~~: a generation step of generating dynamical life activity information from the obtained detection signal.

A measuring device of life activity ~~according to a first aspect of the present invention is~~ may be a measuring device of life activity for measuring an active state of a life object including an animal and a plant, including: an illuminator for illuminating the life object with an electromagnetic wave of which a wavelength is included in a designated waveband; and a detector for detecting a characteristic associated with the electromagnetic wave in a local area constituted by one or more cells in the life object, wherein: any of the following phenomena is used for detecting or controlling the active state of the life object or a change thereof:

[1] transition energy between a ground state of a vibration mode newly occurring between atoms in a constituent molecule of a cell membrane and a plurality of excited states;

[2] transition energy between vibration modes occurring between specific atoms in a molecule corresponding to the activity of the life object or the change thereof; and

[3] a specific chemical shift value in Nuclear Magnetic Resonance,

and the designated waveband is determined on the basis of any of the phenomena.

~~A~~ Disclosed herein is a measuring device of life activity, ~~according to a second aspect of the present invention,~~ having a detecting section for life activity and performing a predetermined

process based on a detection signal related to a life activity obtained from the detecting section for life activity is such that: the detecting section for life activity is constituted by a light emitting section and a signal detecting section; the light emitting section generates electromagnetic waves illuminated to a life object; the electromagnetic waves include an electromagnetic wave having a wavelength of not less than 0.84 μm but not more than 110 μm or an electromagnetic wave associated with a chemical shift value in a range of not less than δ1.7 ppm but not more than δ4.5 ppm; and the signal detecting section detects an electromagnetic wave including the detection signal related to the activity of the life object obtained as a result of the illumination of the electromagnetic waves.

The measuring device of life activity ~~according to the second aspect of the present invention is~~ may be such that the local area corresponds to one cell or a part of the one cell, and a change of the characteristic to occur according to a potential change of a cell membrane constituting the cell is detected.

The measuring device of life activity ~~according to the second aspect of the present invention is~~ may be such that the light emitting section generates electromagnetic waves including electromagnetic waves having a plurality of different wavelengths or electromagnetic waves having a plurality of different frequencies.

According to the present disclosure, ~~A~~a transmission method of a life activity detection signal is such that: a life object is illuminated with electromagnetic waves including an electromagnetic wave having a wavelength of not less than 0.84 μm but not more than 110 μm or an electromagnetic wave associated with a chemical shift value in a range of not less than δ1.7 ppm but not more than δ4.5 ppm; a life activity detection signal related to a characteristic in a local area of the life object is detected; and the life activity detection signal is transmitted.

The transmission method of a life activity detection signal ~~according to one exemplary embodiment of the present invention is~~may be such that: the local area corresponds to one cell or a part of the one cell; and a change of the characteristic to occur due to a potential change of a cell membrane constituting the cell is detected.

A transmission method of life activity information ~~according to one exemplary embodiment of the present invention is~~may be such that a life object is illuminated with an electromagnetic wave

having a wavelength of not less than 0.84 μm but not more than 110 μm or an electromagnetic wave associated with a chemical shift value in a range of not less than δ1.7 ppm but not more than δ4.5 ppm, so as to obtain a life activity detection signal related to a local area of the life object, life activity information is generated from the obtained life activity detection signal, and the life activity information is transmitted.

The transmission method of a life activity ~~detection signal according to one exemplary embodiment of the present invention is~~may be such that: life activity detection signals related to respective characteristics in a local area of the life object corresponding to electromagnetic waves having a plurality of wavelengths in a range of not less than 0.84 μm but not more than 110 μm or electromagnetic waves associated with a plurality of chemical shift values in a range of not less than δ1.7 ppm but not more than δ4.5 ppm are detected; and the life activity detection signals related to the respective wavelengths or the respective frequencies are transmitted.

A service based on life activity information ~~according to one exemplary embodiment of the present invention is~~may be such that: a life object is illuminated with electromagnetic waves including an electromagnetic wave having a wavelength of not less than 0.84 μm but not more than 110 μm or an electromagnetic wave associated with a chemical shift value in a range of not less than δ1.7 ppm but not more than δ4.5 ppm; a life activity detection signal related to a characteristic in a local area of the life object is detected; and based on a result of generating life activity information from the life activity detection signal, a service corresponding to the life activity information is provided, or the life object is illuminated with the electromagnetic wave to provide a service corresponding to control of the life activity.

A service based on life activity information ~~according to one embodiment of the present invention is~~may be such that a service is provided based on detection or measurement results, or control of a life activity occurring in the local area constituted by one or more cells.

~~Advantageous Effects of Invention~~

According to ~~the~~ a measuring method of life activity or the control method of life activity of the present ~~invention~~ disclosure, a life object is illuminated with an electromagnetic wave of which a wavelength is included in a designated waveband, and a characteristic in a local area of the life object corresponding to the electromagnetic wave or a change thereof is detected or

controlled. The "designated waveband" is a waveband determined on the basis of transition energy between vibration modes formed between specific atoms in a local area which can occur associated with an active state of a life object or a change thereof or on the basis of a specific chemical shift value. A "local area" is an area constituted by one or more cells.

Consequently, according to the present ~~invention~~ disclosure, characteristics associated with electromagnetic waves and appearing rapidly or in a very short time according to changes of an active state of a life object can be detected. That is, it is possible to measure an active state of a life object while attempting to enhance the temporal resolution. Further, according to one embodiment ~~of the present invention~~, since only a minute local area is illuminated with the electromagnetic wave by use of convergence properties of the electromagnetic wave, not only the spatial resolution for the detection or measurement of the life activity is improved, but also the life activity is controllable only in a minute local area. Further, if this control method or this detection result is used, the recognition accuracy for an active state of a life object can be improved and an appropriate service can be provided to the life object or a person concerned.

Brief Description of Drawings

[Fig 1] Fig. 1 illustrates a charging model on both surfaces of a neuronal membrane in case of action and resting potentials.

[Fig. 2] Fig. 2 is an estimated molecular structure of PCLN in case of Cl^- ion attachment and

detachment.

[Fig. 3] Fig. 3 illustrates infrared spectral characteristics estimation of PCLN in case of Cl^- ion attachment and detachment

[Fig. 4] Fig. 4 is a flow chart used for originally calculating near infrared spectral characteristics based on anharmonic vibrations.

[Fig. 5] Fig. 5 illustrates a relative static molecule energy vs. distance deviation between carbon and hydrogen atomic nucleuses.

[Fig. 6] Fig. 6 is an explanatory view of Cl^- position fluctuation dependent on distance deviation between carbon and hydrogen atomic nucleuses.

[Fig. 7] Fig. 7 illustrates amplitude distributions of wave functions $|m>$ regarding anharmonic vibrations.

[Fig. 8] Fig. 8 illustrates net atomic charges vs. distance deviations between carbon and hydrogen atomic nucleuses.

[Fig. 9] Fig. 9 illustrates amplitude distributions of molecular orbitals whose eigen values of energy correspond to HOMO and the minimum.

[Fig. 10] Fig. 10 illustrates electric dipole moments vs. distance deviations between carbon and hydrogen atomic nucleuses.

[Fig. 11] Fig. 11 illustrates a comparison in spatial resolution between membrane potential changing detection and oxygen concentration change detection in blood.

[Fig. 12] Fig. 12 illustrates a comparison in temporal resolution between membrane potential changing detection and oxygen concentration change detection in blood.

[Fig. 13] Fig. 13 is an explanatory view of comparison in detection accuracy between membrane potential changing detection and oxygen concentration change detection in blood.

[Fig. 14] Fig. 14 is an explanatory view of a first principle of a monitoring method of a detected point for life activity.

[Fig. 15] Fig. 15 is an explanatory view of a first principle of monitoring method of a pattern of a detected point for life activity in a depth direction.

[Fig. 16] Fig. 16 is an explanatory view of a second principle of a monitoring method of a marked position on a life-object surface.

[Fig. 17] Fig. 17 is an explanatory view of a principle (using a confocal system) of a first exemplary embodiment regarding an optical system for life activity detection.

[Fig. 18] Fig. 18 is an explanatory view of an operation principle of the first exemplary embodiment regarding the optical system for life activity detection.

[Fig. 19] Fig. 19 shows a relationship between a liquid crystal shutter pattern and a photo detecting cell in the first exemplary embodiment of the optical system for life activity detection.

[Fig. 20] Fig. 20 is an explanatory view of an operation principle regarding an applied embodiment of the optical system for life activity detection.

[Fig. 21] Fig. 21 is an explanatory view of a configuration of a photodetector in the applied embodiment of the optical system for life activity detection.

[Fig. 22] Fig. 22 is an explanatory view of a detailed optical arrangement regarding the applied embodiment of the optical system for life activity detection.

[Fig. 23] Fig. 23 is an explanatory view illustrating a method for detecting a local change of a Nuclear Magnetic Resonance property in a life object at high speed.

[Fig. 24] Fig. 24 is an explanatory view regarding a method for detecting a location where the Nuclear Magnetic Resonance property changes.

[Fig. 25] Fig. 25 is an explanatory view illustrating a relationship between facial expression and emotional reaction.

[Fig. 26] Fig. 26 is an explanatory view of a method for obtaining life activity information from movement of a facial muscle.

[Fig. 27] Fig. 27 is an explanatory view of a light emitting pattern of illuminating light for life activity detection in detection of life activity.

[Fig. 28] Fig. 28 is an explanatory view of an appropriate wavelength range for detection/control of life activity in the present exemplary embodiment/applied embodiment.

[Fig. 29] Fig. 29 is an explanatory view of a mechanism for ATP hydrolysis by Myosin ATPase.

[Fig. 30] Fig. 30 is an explanatory view of a reason why an absorption band wavelength varies depending on to which a residue of Lysine is hydrogen bonded.

[Fig. 31] Fig. 31 is an explanatory view of a relationship between a hydrogen-bonding partner and an anharmonic vibration potential property.

[Fig. 32] Fig. 32 is an explanatory view of an exemplary detection signal related to a movement of a mimetic muscle.

[Fig. 33] Fig. 33 is an explanatory view of a relationship between a location of a mimetic muscle which contracts on a face and a facial expression.

[Fig. 34] Fig. 34 is an explanatory view of a positional relationship between a detectable range and a detection target by a detecting section for life activity.

[Fig. 35] Fig. 35 is an explanatory view of a measuring method 1 of life activity in the applied embodiment.

[Fig. 36] Fig. 36 is an explanatory view of a measuring method 2 of life activity in the applied embodiment.

[Fig. 37] Fig. 37 is an explanatory view of a configuration in a life activity control device in the present exemplary embodiment.

[Fig. 38] Fig. 38 is an explanatory view of an applied embodiment of the life activity control device.

[Fig. 39] Fig. 39 is an explanatory view of a gating mechanism of a voltage-gated ion channel and a control method from its outside.

Description of Embodiments

A table of contents which provides an outline of the embodiments described below is listed before the embodiment descriptions. In addition, the embodiments described later relate to a measuring method of life activity, a measuring device of life activity, a transmission method of life activity detection signal, or a service based on life action information.

2] Action Potential Model regarding Neuron

2.1) Structural peculiarity of neuronal membrane based on background information

2.2) Electromagnetical analysis regarding action potential

2.3) Charging model on both surfaces of neuronal membrane in case of action and resting potentials

2.4) Ion concentrations in cytoplasm and extracellular fluid which are described in background information

2.5) Molecular structures of Phospholipids and ion attachment locations in Phospholipids

3] Infrared Spectral Characteristics Estimation based on Action Potential Model

3.1) Calculation method with quantum chemistry simulation program

3.2) Attachment model of Cl^- ion to $-N^+(CH_3)_3$ group and wave number estimation of corresponding absorption band

3.5) Infrared Spectrum changing based on attachment model of K^+ ion to Phospholipid

4] Near Infrared Spectral Characteristics Estimation based on Action Potential Model

4.2) Describing outline of original calculation method based on anharmonic vibrations

4.3) Schrodinger equation indicating particular normal vibration

4.5) Obtaining Einstein's transition probability

4.6) Substituting estimation results from quantum chemistry simulation program

4.6.1) Numerical analysis method with quantum chemistry simulation program

4.6.2) Estimating anharmonic potential

4.6.3) Estimating dipole moment characteristics

4.6.4) Light absorption wavelengths and light absorbances of corresponding absorption bands

4.7) Discussion about detectable range in present exemplary embodiment

5] NMR Spectral Characteristics Estimation based on Action Potential Model

5.1) NMR Spectral Characteristic changing and estimated chemical shift values regarding action potential

5.1.1) Prospect for changing NMR Spectral Characteristics regarding action potential

5.1.2) Calculation method with another quantum chemistry simulation program

5.1.3) Estimating chemical shift values in NMR Spectral Characteristics

5.2) Discussion about measurable range in present exemplary embodiment

6] Technical Features of Detection/Control Method of Life Activity and Measuring Method of Life Activity in Present Exemplary Embodiment

6.1) Content of life activity to be measured and features of detection/control method of life activity

6.1.3) Life activity in life object from surface area to very deep area to be taken as detection/control target

6.2) Alignment and preservation method of detected/controlled point for life activity

6.2.1) Method for setting detection position by detecting cross-sectional image including detected/controlled point

6.2.2) Method for estimating and setting position of detected point by detecting specific position on life-object surface

6.3) Photoelectric conversion method for detection of life activity

6.3.1) Utilization of confocal system

6.3.2) Extraction of spatial variations and time dependent variations by imaging optical system

6.3.3) Method for detecting high-speed change of Nuclear Magnetic Resonance property

6.3.4) Method for reducing interference from other adjacent life activity detection systems

6.5) Measuring method of life activity

6.5.4) Other measuring methods of life activity

11] Other Applied Embodiments regarding Detection/Control of Life Activity

11.1) Other life activity phenomena of which contracted and relaxed states of skeletal muscle are to be detected/controlled

11.3) Movement mechanism of Myosin ATPase

11.4) Characteristics of detection/control of life activity

11.5) Features of detection method of life activity

12] Control Method of Life Activity

12.1) Outline of basic control method of life activity

12.3) Molecular structure of ion channel and gating control method

12.4) Characteristic of control of life activity

2] Action Potential Model regarding Neuron

First of all, sections 2.1 and 2.4 describe well-known information regarding the structure of a neuronal membrane and environmental conditions thereof. Subsequently, section 2.2 describes an electromagnetical analysis regarding a widely known part of action potential phenomenon. Then sections 2.3 and 2.5 describe a neuronal action potential model which is originally proposed.

This neuronal action potential model is based on a concept of charging model proposed in section 2.3.

2.1) Structural peculiarity of neuronal membrane based on background information

First of all, structural peculiarities of a neuronal membrane which are well-known are described. The neuron has a common membrane which can be included in another kind of cell except the neuron, and the common membrane comprises: Phospholipids; Glycolipids; Cholesterol; and Membrane proteins including ion channels.

Lipid bilayer, which comprises the Phospholipids, the Glycolipids, and the Cholesterol, is configured to be split into an outside layer facing an extracellular fluid and an inside layer facing a cytoplasm. The outside layer includes particular molecules which belong to the Phospholipids, and the particular molecules are rarely included in the inside layer. Fig. 1 (a) shows what kind

of molecules belonging to the the Phospholipids or the Glycolipids are located in the outside and inside layers. The outside layer principally comprises Phosphatidylcholine PCLN, Sphingomyelin SMLN, and the Glycolipids, and the inside layer principally comprises Phosphatidylserine PSRN, Phosphatidylethanolamine PEAM, and Phosphatidylinositol PINT (a content by percentage of PINT is relatively small). According to Fig. 1, the double lines indicate Fatty acid parts which are packed into the Lipid bilayer.

Ganglioside belongs to the Glycolipids and particularly has a negative electric charge, and a content of it is biggest in any kinds of molecules belonging to the Glycolipids. It is said that total weight of Gangliosides in the neuronal membrane is 5% to 10% of total weight of Lipids. Therefore, the Ganglioside can be seemed to represent the Glycolipids in this embodiment. Moreover, it is reported that a content by percentage of Ganglioside type D1a (GD1a) is biggest in the neuronal membrane of Mammalia (H. Rahmann et. al.: Trends in Glycoscience and Glycotechnology Vol.10, No.56(1998) p.423), so that GD1a can represent all kinds of Gangliosides in this explanation. And another kind of molecule belonging to Glycolipids can fit into descriptions mentioned later.

2.2) Electromagnetical analysis regarding action potential

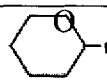
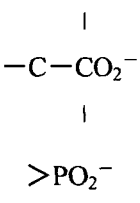
A voltage in cytoplasm is kept to be negative in case of a resting membrane potential, and the voltage changes to be positive in case of an action potential. It is known that a plurality of positive electric charges gather on a surface of the inside layer facing the cytoplasm when the action potential occurs (B. Alberts et. al.: Molecular Biology of the Cell 4th edition (Garland Science, 2002) Chapter 10).

Lipid bilayer can be presumed to function as an electrostatic capacity in case of action and resting potentials because an electrical resistance value of Lipid bilayer is very big and is bigger than 100 giga-ohms, and the electrostatic capacity value is approximately 1.0 micro-farad cm^2 (M. Sugawara: Bionics vol. 3, No. 7 (2006) p. 38 – p. 39 [in Japanese]).

Electrostatic Capacity Theory of Electromagnetics teaches us that a plurality of negative electric charges must gather on a surface of the outside layer facing the extracellular fluid in case of an action potential when a plurality of positive electric charges gather on a surface of the inside layer facing the cytoplasm, and an absolute value of the negative electric charges must be equal to the positive electric charge value.

[Table 1] Functional groups of Phospholipids relating to ion attachment or detachment in case of action potential.

	Outside layer of membrane		Inside layer of membrane	
	Negative ion	Positive ion	Positive ion	Negative ion

	attachment possibility	detachment possibility	attachment possibility	detachment possibility
Phosphatidylcholine (PCLN)	$-N^+(CH_3)_3$	$>PO_2^-$		
Sphingomyelin (SMLN)	$-N^+(CH_3)_3$	$>PO_2^-$		
Ganglioside type D1a (GD1a)				
Phosphatidylserine (PSRN)				$-NH_3^+$
Phosphatidylethanolamine (PEAM)			$>PO_2^-$	$-NH_3^+$
Phosphatidylinositol (PINT)			$>PO_2^-$	

2.3) Charging model on both surfaces of neuronal membrane in case of action and resting potentials

Section 2.3 describes an originally proposed charging model on both surfaces of the neuronal membrane in case of action and resting potentials, and this charging model was thought out by applying the electromagnetical analysis mentioned in section 2.2 to the membrane structure explained in section 2.1.

Table 1 lists functional groups of Phospholipids which a plurality of ions can be attached to or detached from when the action potential occurs, and Table 1 shows that the outside layer principally comprises PCLN, SMLN, and GD1a and the inside layer principally comprises PSRN, PEAM, and PINT, as described in section 2.1.

PSRN under water tends to have "-1" charges because PSRN comprises two functional groups $>PO_2^-$ & $-CO_2^-$ which respectively tend to have negative electric charges and one functional group $-NH_3^+$ which tends to have a positive electric charge.

PINT under water also tends to have "-1" charges because PINT comprises only one functional group $>PO_2^-$ which tends to have a negative electric charge. According to Fig. 1 (a), the "-1" charges generate a negative charge domain on the surface of the neuronal membrane, and "Minus mark" represents this negative charge domain.

Electrostatic attraction makes positive electric charges gather on the outside layer of Lipid bilayer when the negative charge domains are generated on the inside layer in case of a resting

membrane potential. Therefore, positive charge domains, which are represented by "Plus marks" in Fig. 1(a), may be generated on hydrophilic head parts of PCLNs and SMLNs.

In case of an action potential, a plurality of negative charge domains may be generated on not only the hydrophilic head parts of PCLNs and SMLNs but also GD1a, when positive electric charges gather on the inside layer and a plurality of positive charge domains are generated on hydrophilic head parts of PEAMs and PSRNs (Fig. 1 (b)).

In conclusion of this section, it is presumed that a reversible formation of positive and negative charge domains on both surfaces of membrane changes the neuronal membrane voltage.

2.4) Ion concentrations in cytoplasm and extracellular fluid which are described in background information

[Table 2] Ion concentrations in cytoplasm and extracellular fluid.

Ion symbol	Extracellular fluid (milli-mol/l)	Cytoplasm (milli-mol/l)
Na^+	145	5 - 15
K^+	5	140
H^+	4×10^{-5} (pH7.4)	7×10^{-5} (pH7.2)
Cl^-	110	5~15

This section discusses concrete carriers which generate the reversible formation of positive and negative charge domains.

As shown in Table 2, Alberts teaches the ion concentrations in a cytoplasm and an extracellular fluid of a general Mammalia (B. Alberts et. al.: Molecular Biology of the Cell 4th edition (Garland Science, 2002) Chapter 11, Table 11-1). The majority ions are Na^+ and Cl^- in the extracellular fluid and K^+ in the cytoplasm. And it is known that Na^+ ions flow from the extracellular portion into the cytoplasm when the action potential occurs. Therefore, it can be presumed that the majority carriers which generate the reversible formation of positive and negative charge domains are Na^+ or Cl^- ion attachments or detachments on the outside layer and K^+ or Na^+ ion attachments or detachments on the inside layer.

According to Table 2, it seems that H^+ ion (Hydronium ion) and OH^- ion have less influence on the action potential because concentrations of these ions are relatively small.

2.5) Molecular structures of Phospholipids and ion attachment locations in Phospholipids

This section discusses detailed structures and locations of the positive and negative charge domains on both surfaces of the neuronal membrane by combining the charging model considered in section 2.3 with the carrier model described in section 2.4.

When the resting membrane potential continues and the negative charge domains are generated on the inside layer facing the cytoplasm, Na^+ ion may be attracted to the surface of outside layer

and ionically bonds to $>PO_2^-$ groups to locally form a neutral salt $>PO_2^-Na^+$ in PCLN or SMLN. According to Table 1, both PCLN and SMLN under water comprise functional groups of $>PO_2^-$ and $-N^+(CH_3)_3$. Therefore, when PCLN or SMLN has the neutral part $>PO_2^-Na^+$, the remaining positive group $-N^+(CH_3)_3$ can generate a positive charge domain in PCLN or SMLN.

Table 1 also shows that GD1a under water hardly forms a positive charge domain because it comprises no positive group. GD1as comprise only functional groups $-CO_2^-$ which usually have negative electric charges. It is considered that a plurality of GD1as include neutral salts $-CO_2^-Na^+$ and generate no charge domain when the resting membrane potential continues.

According to this originally proposed charging model, it is presumed that the Na^+ or K^+ ion may ionically bond to the $>PO_2^-$ group of one of PEAM, PSRN, and PINT or to $-CO_2^-$ group of PSRN in case of an action potential. Furthermore, when the Na^+ or K^+ ion newly forms a neutral salt, the remaining functional group $-NH_3^+$, which usually has "+1" charge under water, generates a positive charge domain on a hydrophilic head part of PEAM or PSRN.

When the positive charge domains are generated on the inside layer facing the cytoplasm, an electrostatic repulsion may make Na^+ ions be detached from neutral salts $>PO_2^-Na^+$ of PCLNs and SMLNs and $-CO_2^-Na^+$ of GD1as on the outside layer. This Na^+ ion detachment may newly generates a negative charge domain on GD1a because the $-CO_2^-$ group which has "-1" charges remains in GD1a.

Moreover, an electrostatic attraction of the positive charge domains on the inside layer attracts Cl^- ions to the surface of the outside layer, and these Cl^- ions may be combined with $-N^+(CH_3)_3$ groups of PCLNs or SMLNs to form hydrogen (or ionic) bonds. These newly created neutral salts $-N^+(CH_3)_3\ Cl^-$ may generate negative charge domains on hydrophilic head parts of PCLNs or SMLNs in case of an action potential when PCLNs or SMLNs have both the neutral salts $-N^+(CH_3)_3\ Cl^-$ and the negative groups $>PO_2^-$ from which Na^+ ions were detached.

This charging model can be applied not only to the action potential of neuron mentioned above but also to a signal transmission through axon of neuron and a somatic neuromuscular transmission passing through a neuromuscular junction.

The axon is covered with a myelin sheath 12 which is extremely thicker than the neuronal membrane. Electrostatic Capacity Theory of Electromagnetics teaches us that an electrostatic capacity value is inversely proportional to the thickness of the myelin sheath 12, so that the density of the charged domains on a surface of myelin sheath 12 falls down. Therefore, a life activity detecting method should be devised when the signal transmission through the axon 5 of a neuron is detected. This life activity detecting method will be explained later.

Netter (F. H. Netter: The Netter Collection of Medical Illustrations Vol. 1 Nervous System Part

1 Anatomy and Physiology (Elsevier, Inc., 1983) p. 162) teaches us that the membrane potential of a muscular membrane changes when a somatic neuromuscular signal passes through the neuromuscular junction 5, so that the muscular membrane potential can be detected with this embodiment.

3] Infrared Spectral Characteristics Estimation based on Action Potential Model

Chapter 3 describes Infrared Spectral Characteristics based on the Action Potential Model proposed in Chapter 2, and the Infrared Spectral Characteristics result from computer simulations of quantum chemistry simulation program.

3.1) Calculation method with quantum chemistry simulation program

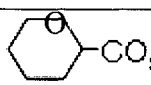
In Chapters 3 and 4, an author used "SCIGRESS MO Compact Version 1 Pro" for a quantum chemistry simulation program. This quantum chemistry simulation program is sold by Fujitsu Corporation, and "SCIGRESS" is a registered trademark. This quantum chemistry simulation program uses a semiempirical molecular orbital method.

This calculation method comprises two calculation steps to keep high calculation accuracy. A first calculation step is to optimize a molecular structure, and a second calculation step is to analyze vibration modes.

Some keywords of optimization are "PM3 EF PRECISE EPS=78.4 GNORM=0.00001 LET DDMIN=0.00001 PULAY SAFE SHIFT=1.00", wherein "PM3 EPS=78.4" means the optimization under water, "PM3" means an approximation method of Hamiltonian, and other keywords mean a setting calculation accuracy or convergent conditions of calculation. Furthermore, some keywords of vibration analysis are "FORCE ISOTOPE EPS=78.4 PM3", wherein "FORCE ISOTOPE" means the vibration analysis.

Table 3 shows the calculation results, and each calculation result is fully described after this section.

[Table 3] Calculation results regarding Infrared Spectral Characteristics

Neutral salt part of functional group	Phospholipid / Glycolipids including functional groups	Wave number (cm^{-1})	Relative light absorbance (a. u.)
$-N^+(CH_3)_3Cl^-$	Phosphatidylcholine Sphingomyelin	2480	41.0
	Ganglioside type D1a	276	5.24
	Phosphatidylserine	429	20.3

$-C(-CO_2^-Na^+)-$			
$-C(-CO_2^-K^+)-$	Phosphatidylserine	118	2.89

3.2) Attachment model of Cl^- ion to $-N^+(CH_3)_3$ group and wave number estimation of corresponding absorption band

This section describes a newly generated absorption band estimated by the computer simulation when a Cl^- ion is attached to the $-N^+(CH_3)_3$ group of PCLN. A molecular structure represented by Chemical formula 1 is used for this computer simulation.

[Chemical Math. 1]

A molecular structure used for computer simulation when the Cl^- ion is attached to the $-N^+(CH_3)_3$ group of PCLN

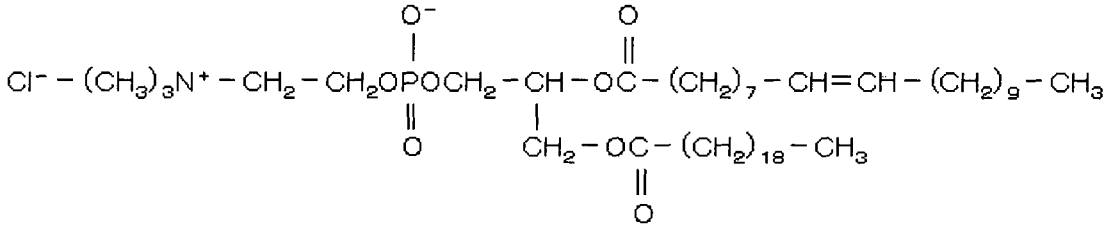


Fig. 2 shows structures optimized by computer simulation. Figure 5 (a) illustrates a Cl^- ion attachment state, and Fig. 2 (b) illustrates a Cl^- ion detachment state. As shown in Fig. 2 (a), A Cl^- ion is attached to a hydrogen atom located at the most far position from a phosphorus atom, and the Cl^- ion and the hydrogen atom form a hydrogen (or ionic) bond. Of course, the Cl^- ion can be attached to one of 8 hydrogen atoms not located at the most far position from the phosphorus atom.

Fig. 3 shows absorption spectrums estimated by the computer simulation, and resolution is set to 5 cm^{-1}. The upper part of Fig. 3 shows a Cl^- ion attachment state, and the lower part of Fig. 3 showing a Cl^- ion detachment state illustrates an absorption spectrum of a single PCLN. A particular absorption band marked with an arrow appears in the upper part of Fig. 3, but it does not appear in the lower part. Moreover, the particular absorption band results from an asymmetrical stretching of C-H-Cl^-. According to Table 3, a wave number value of this particular absorption band is 2480 cm^{-1}, and a relative light absorbance value of it is 41.0.

Another absorption spectrum is estimated when a Cl^- ion is attached to the $-N^+(CH_3)_3$ group of SMLN. A result of the another estimation shows that a wave number value of a similar

absorption band is 2450 cm^{-1} and that a relative light absorbance value of the similar absorption band is 41.0. Therefore, it is confirmed that the Cl^- ion attachment states of both PCLN and SMLN similarly generate the particular absorption bands.

As shown in the upper part of Fig. 3, the particular absorption band marked with the arrow has a big light absorbance. A reason of this phenomenon should be considered.

Table 4 shows net atomic charges calculated with Mulliken's population analysis (Y. Harada: *Ryoushi kagaku* (Quantum Chemistry) vol. 2 (Shyoukabou, 2007) Chapter 18, Section 18·6, p. 163 [in Japanese]) in case of Cl^- ion attachment and detachment, and each position of the carbon atom C, the hydrogen atom H, and the chlorine ion Cl^- is shown in Fig. 2 (a). And these carbon and hydrogen atoms, and this chlorine ion together contribute to an asymmetrical stretching of C-H-Cl^-.

[Table 4] Net atomic charges in case of Cl^- ion attachment and detachment

	Carbon atom C	Hydrogen atom H	Chlorine ion Cl^-
Cl^- ion attachment state	-0.434	0.230	-0.920
Cl^- ion detachment state	-0.251	0.109	-1.00

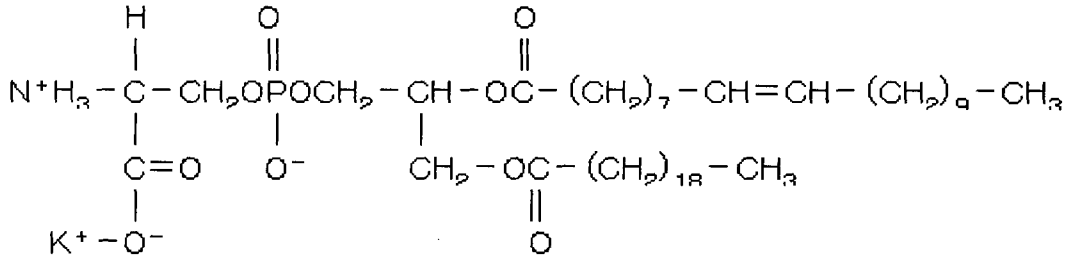
Table 4 shows that the net charge of a carbon atom C dynamically decreases and the net charge of a hydrogen atom H obviously increases when the Cl^- ion attaches to the $-N^+(CH_3)_3$ group. It is considered that molecular orbitals flow to the carbon atom C and are repelled from the hydrogen atom H in case of Cl^- ion attachment, and a reason of these phenomena will be fully described in section 4.6.3. And the variation of net atomic charges makes an electric dipole moment μ increase to raise the light absorbance.

3.5) Infrared Spectrum changing based on attachment model of K^+ ion to Phospholipid

This section describes generated and suppressed absorption bands estimated by the computer simulation when a K^+ ion is attached to the $-CO_2^-$ group of PSRN in case of the action potential. A molecular structure represented by Chemical formula 2 is used for this computer simulation.

[Chemical Math 2]

A molecular structure used for computer simulation when the K^+ ion is attached to $-CO_2^-$ group of PSRN



According to the computer simulation, an optimized molecular structure of K^+ ion attached PSRN indicates that the K^+ ion is located near only one oxygen atom of the $-CO_2^-$ group. It seems that this difference of the ionic location results from the K^+ ionic radius which is bigger than the Na^+ ionic radius.

Table 3 shows that a skeletal vibration of $-C-CO_2^-K^+$ generates a new absorption band whose wave number value is $118cm^{-1}$ and a relative light absorbance value is 2.89 which is very smaller than the corresponding value regarding Na^+ ion 20.3. It seems that this small value 2.89 results from the K^+ ionic radius which is bigger than the Na^+ ionic radius. Moreover, a computer simulation generates no new absorption band when the K^+ ion is attached to the $>PO_2^-$ group of PSRN shown in Table 1.

According to the computer simulation, K^+ ion attachment to the $-CO_2^-$ group has a distinguishing characteristic of absorption spectrum which suppresses a symmetrical stretching of Carboxyl group and drastically reduces a corresponding relative light absorbance value from 98.0 to 15.2, and a wave number value of the symmetrical stretching is 1570 cm^{-1}. It is considered that the K^+ ion located near one oxygen atom of the $-CO_2^-$ group may strongly obstruct the symmetrical stretching of the Carboxyl group.

4] Near Infrared Spectral Characteristics Estimation based on Action Potential Model

4.2) Describing outline of original calculation method based on anharmonic vibrations

This newly proposed original calculation method regarding Infrared Spectral Characteristics has the following peculiarities:

1. Using a perturbation theory of quantum mechanics, relational formulae for the n-th overtone wavelength and Einstein's transition probability are obtained from Schrödinger equation;

2. Using a quantum chemistry simulation program, an anharmonic potential property and an electric dipole moment property are calculated to substitute these properties for the relational formulae mentioned in 1;

3. Combining the properties with the relational formulae, wavelength values of the n-th overtone and corresponding light absorbances are estimated.

According to Fig. 4, an outline of the calculation method is described below.

Using a quantum chemistry simulation program, a vibrational analysis for a specific

macromolecule is executed to find out a particular normal vibration corresponding to a harmonic vibration (S3). In the meantime, The Schrodinger equation including an electro-magnetic field interaction within the specific macromolecule is set (S1). Then, using Born-Oppenheimer approximation, an atomic interaction part is extracted from the Schrodinger equation (S2). After Step 2 and Step 3 executions, a particular atomic interaction regarding the particular normal vibration is selected on the basis of S3 (S4). In this Step 4, all influence of other atomic interactions which were not selected is substituted for the anharmonic potential property.

Total static molecule energy values can be numerically calculated by using the quantum chemistry simulation program (S6). In this Step 6, the molecular structure is repetitively optimized to estimate one of the total static molecule energy values whenever a distance deviation between two atomic nucleuses is set to every incremental value, and the two atomic nucleuses relate to the particular atomic interaction selected in Step 4. In Steps 5 - 7, a substitution of the total static molecule energy values based on the quantum chemistry simulation program for the anharmonic potential property based on Quantum Mechanics combines the numerical analysis of computer simulations with the relational formulae based on the Quantum Mechanics. After Step 6, the electric dipole moment property is estimated by using the quantum chemistry simulation program (S10), and this electric dipole moment property is used for Step 11 execution.

An equation obtained in Step 4 includes the anharmonic potential property which contains the 4th-order coefficient κ_4 and 3rd-order coefficient κ_3 (anharmonic terms), and 2nd-order coefficient κ_2 (harmonic term). At first, a specific equation in which both κ_4 and κ_3 of the equation are set to "0" is solved to obtain wave functions of harmonic vibration, and these wave functions of harmonic vibration correspond to a series of basic functions. Further, using the basic functions and a time independent perturbation theory, the equation including κ_4 and κ_3 is solved to obtain wave functions of anharmonic vibration (S5).

In Step 7, wavelength values of absorption band belonging to Near Infrared light are calculated with subtracting a wave function's eigen value of energy from another wave function's eigen value of energy.

Using a time dependent perturbation theory and the wave functions of anharmonic vibration, simultaneous equations regarding a time dependent amplitude variation of each anharmonic vibration mode are formulated (S8). And then the simultaneous equations are solved to obtain relational formulae of Einstein's transition probability (S9), and a light absorbance comparison between absorption bands can be achieved from the Einstein's transition probabilities (S11).

This embodiment shows an estimation method regarding a series of wavelength values and corresponding light absorbances of n-th overtones, and the n-th overtones relate to an

anharmonically asymmetrical stretching of covalent and hydrogen bonds C-H-Cl⁻. This estimation method can be extended to estimate deformations or some kinds of combinations between deformations and asymmetrical stretchings if new wave functions are obtained to multiply wave functions indicating asymmetrical stretching by wave functions indicating deformation.

4.3) Schrödinger equation indicating particular normal vibration

As a result of process of step 1 through step 8 in Fig. 4, a Schrödinger equation related to asymmetrical stretching of C-H-Cl⁻ is given by the following formula. That is, when a reduced mass, with respect to M_C as the mass of the carbon atomic nucleus, and M_H as the mass of the hydrogen atomic nucleus, is defined as:

[Math. 16]

$$M_X \equiv \frac{M_H M_C}{M_H + M_C}. \cdots (A \cdot 16)$$

then the following formula is obtained

[Math. 27]

$$i\hbar \frac{\partial}{\partial t}\phi_X = \left\{ -\frac{\hbar^2}{2M_X}\frac{\partial^2}{\partial x^2} + \kappa_2 x^2 + \kappa_3 x^3 + \kappa_4 x^4 - (E \cdot \mu)\exp(-i2\pi\nu t) \right\}\phi_X . \cdots (A \cdot 27)$$

In Equation (A·27), E and v represents an amplitude and frequency of an external electric field vector, μ represents an electric dipole moment generated by the carbon atomic nucleus and hydrogen atomic nucleus.

4.5) Obtaining Einstein's transition probability

In eq. (A.27) when

[Math. 32]

$$\beta \equiv \sqrt{2M_X \kappa_2}\,/\,\hbar . \cdots (A \cdot 32)$$

then eigen values of energy ε_m for anharmonic vibration are

[Math. 38]

$$\varepsilon_m \cong \underline{\varepsilon_m} + < \underline{m} \mid \kappa_3 x^3 + \kappa_4 x^4 \mid \underline{m} > = \frac{2\kappa_2}{\beta}\left(m + \frac{1}{2}\right) + \frac{3\kappa_4}{4\beta^2}\left(2m^2 + 2m + 1\right) \cdots (A \cdot 38)$$

4.6) Substituting estimation results from quantum chemistry simulation program

According to Fig. 4, section 4.6 substitutes a few results of numerical analysis with computer simulations for relational formulae based on Quantum Mechanics, so that it obtains wavelength values of absorption bands and corresponding light absorbance comparison. Further, section 4.6 also describes the numerical analysis method in detail.

4.6.1) Numerical analysis method with quantum chemistry simulation program

This section describes the numerical analysis method with computer simulations.

A molecular structure model used for this numerical analysis is $Cl^-(CH_3)_3N^+CH_2CH_2OH$ under water which results from the Cl^- attachment to Choline $(CH_3)_3N^+CH_2CH_2OH$ corresponding to an ingredient of PCLN or SMLN.

Whenever a distance deviation between carbon and hydrogen atomic nucleuses composing the asymmetrical stretching of Cl^-–H–C is set to every incremental value, each molecular structure is repetitively optimized to estimate one of total static molecule energies and net atomic charges calculated with Mulliken's population analysis.

Some keywords of optimization are "PM3 EF PRECISE EPS=78.4 GNORM=0.00001 LET DDMIN=0.00001 ALLVEC". And this numerical analysis keeps a high accuracy because a molecular structure of distance deviation "0" is confirmed to have no negative wave number value regarding a vibration analysis.

4.6.2) Estimating anharmonic potential

Relating to Step 6 of Fig. 4, Fig. 5 shows relative static molecule energy vs. distance deviation between carbon and hydrogen atomic nucleuses composing the asymmetrical stretching of Cl^-–H–C, and the relative static molecule energy means a shifted value of the total static molecule energy to adjust a minimum value of the relative static molecule energy to "0". Based on Fig. 5, parameters in eq. (A·27) are associated as follows:

[Math. 57]

$$\kappa_2 \cong 8.6,\ \kappa_3 \cong -14.2,\ \kappa_4 \cong 9.3\ [eV/\text{Å}^2] \cdots (A \cdot 57)$$

Substituting formulae (A·57) for formula (A·32) obtains

[Math. 58]

$$\beta \cong 62.1\ [\text{Å}^{-2}] \cdots (A \cdot 58)$$

Fig. 5 has a seemingly discontinuous point of anharmonic potential property which occurs between α-point and β-point, and this section will describe the cause of seemingly discontinuous point.

As shown in Fig. 6 (a), the quantum chemistry simulation program " SCIGRESS MO Compact Version 1 Pro" provides the optimized molecular structure of $Cl^-(CH_3)_3N^+CH_2CH_2OH$ when the value of distance deviation between carbon and hydrogen atomic nucleuses is "0". Fig. 6 (a) shows that Cl^- ion, Hydrogen atomic nucleus H, and Carbon atomic nucleus C are approximately arranged on a straight line, so that the Cl^- ion seems to be located below an extrapolation (an alternate long and short dash line) of bonding of Nitrogen atomic nucleus N and Carbon atomic nucleus C' located on the left side of N. This arrangement continues when the distance between

carbon and hydrogen atomic nucleuses increases. On the contrary, when the distance deviation exceeds -0.1 angstrom, the Cl^- ion seems to be moved to a specific position which is located on the extrapolation (an alternate long and short dash line) of bonding of N and C', as shown in Fig. 6 (b). This seeming Cl^- ion movement causes the seemingly discontinuous point.

Figs. 5 and 6 are obtained on the basis of a semi-classical mechanics model which presumes that all atomic nucleus position is fixed in detail. According to a perfect quantum mechanics, all atomic nucleus position is not fixed in detail and is represented by each of the wave functions, and the seemingly discontinuous point substantially goes out.

Fig. 7 indicates a proof of above-mentioned explanation. Fig. 7 shows the wave functions |m> which are obtained by substituting formula (A·57) for formula (A·42),

[Math. 42]

$$|m> \cong |\underline{m}> -\frac{\kappa_3}{\kappa_2\sqrt{\beta}}G_{m3} -\frac{\kappa_4}{\kappa_2\beta}G_{m4}, \cdots (A\cdot 42)$$

and it shows that the ground state |0> has an enough existence probability on the seemingly discontinuous point. This phenomenon suggests that the position of Cl^- ion has probabilities of both Figs. 6 (a) and 6(b) in case of the ground state |0>.

4.6.3) Estimating dipole moment characteristics

Fig. 8 shows net atomic charges vs. distance deviation between carbon and hydrogen atomic nucleuses composing the asymmetrical stretching of Cl^-–H–C, and a unit of the net atomic charge is a quantum of electricity e_0.

According to a viewpoint of classical mechanics regarding atomic nucleus movements composing the asymmetrical stretching of Cl^-–H–C, as shown in [A] and [C] of section 4.3, the Cl^- ion hardly moves and the Hydrogen atomic nucleus H widely moves. Therefore, when the distance between the carbon and hydrogen atomic nucleuses decreases (the left side area in Fig. 8), the distance between the Cl^- ion and hydrogen atomic nucleus H increases, and the net atomic charge value of the Cl^- ion approaches to "-1" and the net atomic charge values of carbon and hydrogen approach to original values when the Cl^- ion detaches.

On the contrary, when the distance between the carbon and hydrogen atomic nucleuses increases (the right side area in Fig. 8), the distance between the Cl^- ion and hydrogen atomic nucleus decreases, and the net atomic charge value of carbon monotonously reduces but the net atomic charge value of the hydrogen approaches to a saturation value.

Using results of molecular orbital analysis, reasons of net atomic charge properties shown in Fig. 8 can be described below. Figs. 9 (a) and 9(b) show Highest and Lowest Occupied Molecular Orbitals.

The Highest Occupied Molecular Orbital (HOMO) shown in Fig. 9 (a) mainly comprises Atomic Orbitals $3P_X$ of Cl^- ion and $2P_X$ of carbon atom, and the red-lined and blue-lined orbitals represent negative and positive amplitudes. Further, Fig. 9 (a) shows that a boundary position between negative and positive amplitudes, where an existence probability of HOMO electron is "0", is located on the right side of the hydrogen atomic nucleus. Therefore, a surrounding existence probability of HOMO electron decreases and a net atomic charge value of hydrogen increases when the location of the hydrogen atomic nucleus is moved toward the right side in Fig. 9 (a) and the distance between the carbon and hydrogen atomic nucleuses increases. Moreover, the net atomic charge value of hydrogen approaches to a saturation value when the location of the hydrogen atomic nucleus substantially arrives at the boundary position.

The Lowest Occupied Molecular Orbital shown in Fig. 9 (b) mainly comprises Atomic Orbitals 3S of Cl^- ion and 1S of hydrogen atom, and this Molecular Orbital especially extends to the position of the carbon atomic nucleus. Moreover, the existence probabilities of molecular orbitals around the Cl^- ion which relate to not only the Lowest Occupied Molecular Orbital but also different molecular orbitals tend to flow toward the carbon atom when the location of the hydrogen atomic nucleus is moved toward the right side in Fig. 9 (b). Therefore, the net atomic charge value of carbon decreases when the distance between carbon and hydrogen atomic nucleuses increases, as shown in Fig. 8.

Fig. 8 shows electric dipole moments μvs. distance deviations between carbon and hydrogen atomic nucleuses, and the electric dipole moment μ is obtained by substituting net atomic charges of carbon and hydrogen for formula (A·13).

[Math. 13]

$$\mu = Q_H X_H + Q_C X_C \cdots (A \cdot 13)$$

Consideration is given to the case where the electric dipole moment vector μ is parallel to the X axis, that is, in the case where the electric dipole moment vector μ is expressed by Formula 50:

[Math. 50]

$$|\mu| \cong \mu_0 + \mu_1 x + \mu_2 x^2 + \mu_3 x^3, \cdots (A \cdot 50)$$

According to Fig. 10, each parameter of formula (A·50) is as follows:

[Math. 59]

$$\mu_0 \cong 0.281,\ \mu_1 \cong 0.635,\ \mu_2 \cong 0.0242,\ \mu_3 \cong -0.272\ \ [e_0 \cdot \text{Å}] \cdots (A \cdot 59)$$

4.6.4) Light absorption wavelengths and light absorbances of corresponding absorption bands

Table 5 shows wave numbers, wavelengths, and transition probability ratios regarding asymmetrical stretching of Cl^-–H–C, and the transition probability ratio corresponds to the

relative light absorbance value. Using Formula 44

[Math. 44]

$$\varepsilon_m - \varepsilon_0 = \frac{hc}{\lambda_m}. \cdots (A \cdot 44)$$

the wave numbers and the wavelengths can be calculated, and each ε_m is obtained by substituting values (A·57) and (A·58) for formula (A·38). In addition, each B_{0m} can be calculated by solving the simultaneous eq. (A·53) and substituting eqs. (A·54) and (A·55) for formula (A·56).

[Math. 53]

$$i\hbar \sum_{0 \le m \le q} g_{mu} \frac{\partial \eta_m(t)}{\partial t} \exp\left(i2\pi \left(\nu - \frac{\varepsilon_m - \varepsilon_0}{h} \right) t \right) \cong -E_X \cdot L_u, \ (0 \le u \le 4). \cdots (A \cdot 53)$$

[Math. 54]

$$i\hbar \frac{\partial \eta_m(t)}{\partial t} \exp\left(i2\pi \left(\nu - \frac{\varepsilon_m - \varepsilon_0}{h} \right) t \right) = -E_X \cdot P_m . \cdots (A \cdot 54)$$

[Math. 55]

$$\eta_m(t) = \frac{i}{\hbar} E_X P_m t . \cdots (A \cdot 55)$$

[Math. 56]

$$B_{0m} = \frac{8\pi^3}{3h^2} {P_m}^2 . \cdots (A \cdot 56)$$

[Table 5] Wave numbers, wavelengths, and transition probability ratios regarding asymmetrical stretching of Cl^-–H–C.

m	1	2	3	4
Transition mode	Fundamental	1st overtone	2nd overtone	3rd overtone
Wave number (cm^{-1})	2283	4635	7040	9487
Wavelength λm (μm)	4.38	2.16	1.42	1.05
Transition probability ratio B_{0m}/B_{01}	1	1/176	1/3480	1/3030

Table 5 shows the fundamental wave number is 2283 cm^{-1}, and Table 3 shows the corresponding value is 2480 cm^{-1}. It is considered that the slight difference between 2283 cm^{-1} and 2480 cm^{-1} occurs because Table 3 is obtained with a harmonic vibration approximation and Table 5 is obtained with taking account of anharmonic vibration terms.

Table 5 shows that the relative light absorbance value of a 1st overtone (transition probability ratio B_{02}/B_{01}) is very small and the relative light absorbance values of 2nd and 3rd overtones are smaller.

If a measuring device of life activity has a particular contrivance to detect a small signal, as described later, it can sufficiently detect absorption bands regarding the 2nd and 3rd overtones.

Table 5 relates to specific transitions from a ground state $|0\rangle$ to one of excited states $|m\rangle$ ($m \neq 0$). This embodiment, however, may detect another absorption band regarding another transition between excited states $|m\rangle$ ($m \neq 0$).

4.7) Discussion about detectable range in present exemplary embodiment

There occur large reading errors when the value obtained in formula (A 57) is read from Fig. 5 and when the value obtained in formula (A 59) is read from Fig. 10. In view of this, some differences are expected between theoretically estimated values as shown in Table 5 and actual values. The differences in such a case are generally said to be about ± 20% (± 10% at best). Accordingly, a lower limit of the near infrared light wavelength adopted in the present exemplary embodiment is estimated to be $1.05 \times (1 - 0.1) = 0.945$ μm, or $1.05 \times (1 - 0.2) = 0.840$ μm with a larger estimated error.

However, when light of the 3rd overtone shown in Table 5 is not used for measurement and only light of the 2nd overtone or less is used for measurement, the lower limit of the near infrared light wavelength adopted in the present exemplary embodiment is estimated to be $1.42 \times (1 - 0.1) = 1.278$ μm, or $1.42 \times (1 - 0.2) = 1.136$ μm with a larger estimated error.

Further, when light of the 2nd overtone or more shown in Table 5 is not used for measurement and only light of the 1st overtone is used for measurement, the lower limit of the near infrared light wavelength adopted in the present exemplary embodiment is estimated to be $2.16 \times (1 - 0.1) = 1.944$ μm or $2.16 \times (1 + 0.1) = 2.376$ μm, or $2.16 \times (1 - 0.2) = 1.728$ μm or $2.16 \times (1 + 0.2) = 2.592$ μm with a larger estimated error.

An upper limit of the infrared radiation wavelength to be used in measurement method as shown in the present exemplary embodiment will be described as follows.

As for a relationship between a wavelength (wavenumber) of an absorption band measured by infrared light and an intramolecular vibration, the following vibrations are caused in order from a shorter absorption wavelength (in order from a larger wavenumber value): a local vibration of functional groups, a principal chain vibration of molecule, a vibration of whole molecule, and a rotation of whole molecule.

Accordingly, a high-speed change along with the afore-mentioned "local state change in a

molecule" corresponds to measurement of the "local vibration" or the "principal chain vibration of molecule" among them.

In the meantime, the analysis result of a vibration mode occurring when a sodium ion is attached to a carboxyl group to form an ion bond are as follows: [A] according to section 3.3, the wavenumber values (wavelengths) of the absorption band corresponding to the skeletal vibration of > C-$CO_2^-Na^+$ are 260 to 291 cm^{-1} (34.4 to 38.5 μm); and [B] the wavenumber value (wavelength) of the absorption band corresponding to the skeletal vibration of N^+-C-$CO_2^-Na^+$ is 429 cm^{-1} (23.3 μm).

Further, the analysis result of a vibration mode occurring when a potassium ion is attached to a carboxyl group to form an ion bond is as follows: according to section 3.3, [C] the wavenumber value (wavelength) of the absorption band corresponding to the skeletal vibration of C-$CO_2^-K^+$ is 118 cm^{-1} (84.7 μm); and [D] the symmetrically telescopic vibration of the carboxyl group -CO_2^- at a wavenumber (wavelength) of 1570 cm^{-1}(6.37 μm) is largely restricted due to potassium ion attachment.

Accordingly, it is necessary to consider the above values as a part of the application range (detectable range) of the present exemplary embodiment. However, in advance of this consideration, [E] according to section 3.2, the wavenumber value (wavelength) of the absorption band corresponding to the skeletal vibration of -$N^+(CH_3)_3Cl^-$ is 2465 cm^{-1}(4.06 μm) (an average of 2480 cm^{-1} for PCLN and 2450 cm^{-1} for SMLN), whereas the waveband value is 2283 cm^{-1} in section 4.6.4. In view of this, it is necessary to take into consideration such a slight difference. As have been described in section 4.6.4, the reason of this slight difference is because "the vibrational analysis result in section 3.1 is obtained based on a harmonic vibration approximation," whereas "section 4.6.4 takes account of anharmonic vibration terms."

Accordingly, it may be said that the measurement wavelengths L listed in [A] to [D] can be changed up to (2465/2283) × L depending on a computation model. Further, the values exhibited in [A] to [E] are merely theoretically estimated values, and some difference up to about ±20% with respect to the actual values is expected, as described earlier. Thus, the lower limit of the experimental value based on [A] to [E] is estimated as L × (1 - 0.2) and the upper limit thereof is estimated as (2465/2283) × L × (1 + 0.2).

In view of this, the application ranges (detectable ranges) of the present exemplary embodiment to detect each of the phenomena [A] to [E] in consideration of the above relational formulae will be as follows:

[A] The skeletal vibration of > C-$CO_2^-Na^+$ ⇒ 27.5 to 49.9 μm (34.4 × 0.8 ≈ 27.5, (2465/2283) × 38.5 × 1.2 ≈ 49.9);

[B] The skeletal vibration of N^+-C-$CO_2^-Na^+$ ⇒ 18.6 to 30.2 μm;

[C] The skeletal vibration of C-$CO_2^-K^+$ ⇒ 67.8 to 110 μm;

[D] The symmetrically telescopic vibration of -CO_2^- ⇒ 5.10 to 8.25 μm; and

[E] The skeletal vibration of -$N^+(CH_3)_3Cl^-$ (section 3.2) ⇒ 3.25 to 5.26 μm.

From the overall view of the above, the infrared radiation wavelength to be used in the measurement method of the present exemplary embodiment is desirably at least 110 μm or less (a wavenumber value of 91.1 cm^{-1} or more), in view of the upper limit of [C].

Accordingly, to summarize the discussion as above is that a wavelength range of the light to be used in the present exemplary embodiment are "from 0.840 μm to 110 μm" as the maximum range and "from 2.592 μm to 110 μm" as the minimum range.

Subsequently, an influence of absorption wavelengths of water is added to the summary of the discussion. Most part of a life object is constituted by water molecules. Therefore, when electromagnetic waves are illuminated to measure or detect dynamical life activities in the life object, absorption of the electromagnetic waves by the water molecules will be a large problem. Accordingly, the present exemplary embodiment devises to use a wavelength region where the absorption by the water molecules is relatively small. According to B. Alberts et. al.: Essential Cell Biology (Garland Publishing, Inc. 1998), p. 68, Figs. 2 to 24, the composition of a chemical compound constituting an animal cell (including inorganic ions) is occupied by water molecules by 70% by weight. Further, 15% out of the remaining 30% of the composition is occupied by proteins, followed by 6% by RNA, 4% by ions/small molecules, 2% by Polysaccharides, and 2% by Phospholipids. Meanwhile, the light absorption characteristic of the proteins varies depending on a tertiary structure in a cell, and therefore, it is difficult to specify an absorption wavelength region of an absorption band by general proteins. In view of this, in the present exemplary embodiment, "the light absorption characteristic of the water molecule" is focused on

because [1] the water molecules are included in an animal cell overwhelmingly abundantly, and [2] the light absorption characteristic thereof is determined due to its stable molecular structure, and a wavelength region with relatively small light absorption by the water molecule is used for detection of dynamical life activities in a life object. This allows relatively stable and accurate measurement or detection while preventing detection light for life activity from being absorbed by water molecules along the way. Yukihiro Ozaki/Satoshi Kawata: Kinsekigai bunkouhou (Gakkai Shuppan Center, 1996), p. 12, p. 120, p. 122 or p. 180 describes the maximum absorption wavelength of the water molecule, and the present exemplary embodiment will provide an explanation using the values described herein.

Respective center wavelengths of absorption bands of the water molecule corresponding to a symmetrically telescopic vibration and an anti-symmetrically telescopic vibration are 2.73 μm and 2.66 μm. Further, in a wavelength region having wavelengths longer than the above wavelengths, light absorption by a rotation of a hydrogen molecule occurs. Accordingly, in the present exemplary embodiment, in order to measure dynamical activities in a life object, 2.50 μm, which is a wavelength slightly shorter than 2.66 μm, is taken as a boundary, and the measurement is performed using electromagnetic waves in a wavelength region having a wavelength shorter than the boundary value (more specifically, in a range from 0.840 μm to 2.50 μm in consideration of the discussion as above).

On the other hand, in the near-infrared region, an absorption band corresponding to combinations between the anti-symmetrically telescopic vibration and deformation vibration of the water molecule is at a center wavelength of 1.91 μm. In view of this, other embodiments can use, for measurement, electromagnetic waves in a wavelength region except for this absorption band. More specifically, light of the 1st overtone (having a wavelength of 2.16 μm) as shown in Table 5 is used for measurement. However, as having been mentioned above, a reading error of about ± 10% to ± 20% occurs when a value is read from Fig. 5. In consideration of this reading error, electromagnetic waves of not less than $2.16 \times (1 - 0.05) = 2.05$ μm but not more than $2.16 \times (1 + 0.15) = 2.48$ μm are used in another exemplary embodiment.

Further, an absorption band corresponding to combinations between the symmetrically telescopic vibration and the anti-symmetrically telescopic vibration of the water molecule is at a

center wavelength of 1.43 μm. In view of this, for another applied embodiment, light in a wavelength region between the above wavelength and 1.9 μm (more specifically, light of not less than 1.5 μm but not more than 1.9 μm to avoid a center wavelength of the absorption band of the water molecule) may be used, or light in a wavelength region having a wavelength shorter than 1.43 μm may be used. As an electromagnetic wave for measurement corresponding to the latter, light of the 3rd overtone (having a wavelength of 1.05 μm) as shown in Table 5 is used for measurement. In consideration of the above reading error, a specific wavelength to be used in this case is in a range of:

$1.05 \times (1 - 0.2) = 0.840$ μm or more but $1.05 \times (1 + 0.3) = 1.37$ μm or less.

In the meantime, other wavelength ranges may be set as an applied embodiment, as well as the wavelengths mentioned above. That is, as described below, the wavelength ranges may be set so as to avoid a wavelength region absorbed by an "oxygen concentration indicator" existing in a living tissue. For example, when a palm or a finger is illuminated with near-infrared light, a pattern of blood vessels can be observed around a surface thereof. This is because hemoglobin included in the blood vessels absorbs the near-infrared light. That is, in a case where a life activity in an area on a backside of the blood vessels (behind the blood vessels) placed in vicinity of the surface of the life object is detected, there is such a risk that detection light may be absorbed by the blood vessels in the middle of a detection light path and an S/N ratio of a detection signal may decrease. Besides the hemoglobin, myoglobin and cytochrome oxidase also have absorption bands in the near-infrared region, and the absorption spectrum of the near-infrared region varies between an oxygenation state and a deoxygenating state. For this reason, these substances are called an oxygen concentration indicator. Further, according to F. F. Jobsis: Science vol. 198 (1977), p. 1264 - p. 1267, it is said that the cytochrome oxidase and hemoglobin have a weak absorption band over wavelengths of 0.780 μm to 0.870 μm. Accordingly, in consideration of a general range of measurement errors of ±0.005 μm, if the detection light to be used in the present exemplary embodiment or the applied embodiment has a wavelength of 0.875 μm or more, a detection signal of a life activity is stably obtained without having any influence (light absorption) by the oxygen concentration indicators. From this viewpoint, the aforementioned wavelength ranges "from 0.840 μm to 110 μm," "from 0.840 μm to 2.50 μm," or

"of not less than 0.840 μm but not more than 1.37 μm" will be assumed as, respectively, "from 0.875 μm to 110 μm," "from 0.875 μm to 2.50 μm," or "of not less than 0.875 μm but not more than 1.37 μm." In a case where the using wavelengths of detection light or control light for life activity are determined as such, even if an oxygen concentration indicator exists in the middle of a detection light path or a control light path, the detection light or the control light is not absorbed, so that the S/N ratio of a life activity detection signal can be secured and stable life activity control can be performed.

Figs. 11, 12, and 13 are images showing qualitative performance comparisons between membrane potential changing detection and oxygen concentration change detection in blood from respective viewpoints of spatial resolution, temporal resolution, and detection accuracy.

As described above, the spatial resolution in Conventional Technique 1 is of the order of 3 cm (see Fig. 11), and it is said that the spatial resolution in the case of magnetic detection using an fMRI device is a few mm order. In this case, as shown in Fig. 11, a mean value of oxygen concentrations in blood flowing in a plurality of capillaries 28 in this area is detected. In comparison with that, in a case where membrane potential changing is detected, the spatial resolution is of the order of a wavelength of the detection light described above.

However, in a case where an action potential of one neuron is detected as an example of the potential changing detection of a cell membrane, an average distance between adjacent neurons corresponds to a substantial spatial resolution. It is said that an average distance between adjacent neurons in a cerebral cortex of a human is of the order of 20 μm.

Thus, there is a difference of 100 times in terms of the order between these spatial resolutions. An image of the difference is shown in Fig. 11 in a simulated manner. That is, in a case where the oxygen concentration change in blood is detected by use of near infrared light like Conventional Technique 1, a mean value within an area having a diameter of 3 cm is detected. In contrast, in this exemplary embodiment, an action potential of each single pyramidal cell body 17 or stellate cell body 18 in the area can be detected individually.

On the other hand, as will be described below in section 6.3.1, in the present exemplary embodiment in which the membrane potential changing is detected, a size (aperture size) of a light transmission section 56 in a two-dimensional liquid crystal shutter 51 as shown in Fig. 18 or

19 can be made adequate so as to detect activities of a group unit of a plurality of neurons such as a column unit (a total firing rate of a set of the plurality of neurons, such as a column). Since the column has a cylindrical shape (or rectangular solid) with about 0.5 to 1.0 mm in diameter and almost 2 mm in height, the spatial resolution can be advantageously changed freely into to the above values (or below those values) to detect the activities per column unit.

(Regarding size range of detection unit)

As described above, the detection unit in the present exemplary embodiment can be widely set from one neuron unit (or a particular region in an axon) or one muscle cell unit (or neuromuscular junction unit), to a group unit of a plurality of neurons (or muscle cells). That is, in a detected point for life activity, a local area constituted by one or more cells is set to a single unit for detection and a characteristic per detection unit (in the local area) corresponding to an electromagnetic wave is detected so as to detect a life activity.

Further, this electromagnetic wave is near infrared light or infrared light having a wavelength in a range to be described herein (section 4.7), or alternatively an electromagnetic wave with which a detected point for life activity is illuminated to detect a life activity by use of Nuclear Magnetic Resonance, which will be explain later in chapter 5. Further, when the life activity is detected by use of Nuclear Magnetic Resonance, either continuous wave CW (Continuous wave) spectroscopy or pulse FT (Fourier Transformation) spectroscopy may be used.

A size of the detection unit (a local area) in the present exemplary embodiment is desirably in a range of 1 cm from the wavelength of an electromagnetic wave used for detection, and further desirably not less than 10 μm but not more than 3 mm, for the following reason. If the size is expressed in terms of a cell number included in this detection unit (the local area), the cell number is desirably not less than 1 but not more than 100 million, and particularly desirably not less than 1 but not more than 2 million.

The following describes the size range of the detection unit (the local area). An electromagnetic wave is narrowed down to its wavelength size (diffraction limited) according to a diffraction theory. Further, it is known that voltage-gated Na^+ ion channels, which greatly relate to a neuronal action potential, are largely distributed over an axonal root site in a cell body. In view of this, in a case where an action potential of only one neuron is detected, detection

efficiency is more improved by condensing light around this axonal root rather by widely illuminating the whole cell body with detection light. Consequently, it is desirable that the size of the detection unit (the local area) in the present exemplary embodiment be larger than the wavelength of the electromagnetic wave to be used for detection.

Next will be described an upper limit of the size of the detection unit (the local area) in the present exemplary embodiment. As will be described below in section 6.5.4 with reference to Fig. 25 or 26, life activity information is obtained from movement of a facial muscle in an applied embodiment. In this case, sufficient detection accuracy cannot be obtained by the spatial resolution (about 3 cm in diameter: see Fig. 11) as described in Conventional Technique 1. Since the width of an eyelid or a lip of a human is about 1 cm, it is necessary for the upper limit of the size of the detection unit (the local area) to be set to 1 cm so as to obtain detection accuracy to some extent or more. Further, an average distance between neurons is about 20 μm, and when a deep part of the brain is measured with a cube 1 cm on a side as a detection unit, $(10 \div 0.02) \times (10 \div 0.02) \times (10 \div 0.02) \approx 100$ million neurons will be included within this detection unit (the local area).

The following assumes a case where the detection unit (the local area) is set to a unit of integral multiple of the aforementioned column. As described above, since the height of one column (a thickness of a spinal cord gray matter in a cerebral cortex) is 2 mm, $2 \div 0.02 = 100$ neurons will be aligned in the detection unit on the average. When the life activity is detected in broad perspective, activities of around 10 columns within one detection unit (local area) may be detected at the same time. In this case, one side of the length of the detection unit (local area) is $10^{1/2} \times 1 \approx 3$ mm. In view of this, $(3 \div 0.02) \times (3 \div 0.02) \times 100 \approx$ 2 million neurons will be included in this detection unit (local area). Further, when one side (or a diameter) of the detection unit (local area) is set to 0.5 mm or 1.0 mm, a life activity of one column can be detected as the detection unit (the local area) (from the viewpoint of the aforementioned column size). At this time, the number of neurons included in the detection unit (the local area) will be $(0.5 \div 0.02) \times (0.5 \div 0.02) \times 100 \approx 60{,}000$ or $(1 \div 0.02) \times (1 \div 0.02) \approx 300{,}000$. Accordingly, in a case where the life activity of one neuron to the life activity of a column unit are detected, a local area constituted by not less than 1 but not more than 60,000 to 300,000 cells is set as a

detection unit, and a characteristic thereof corresponding to an electromagnetic wave is detected so as to detect the life activity.

(Regarding temporal resolution)

The detection of an oxygen concentration change in blood by use of near infrared light or fMRI is compared with the detection of potential changing of a cell membrane by optical or magnetic means described in the present exemplary embodiment in terms of the temporal resolution.

Like Conventional Technique 1, as long as the oxygen concentration change in blood is detected, a delay of about 5 s is caused, so that the temporal resolution is restricted essentially. In comparison with that, in a case of detecting membrane potential changing, there is a temporal resolution which allows faithful reproduction of an action potential pulse waveform of about 0.5 to 4 ms occurring during the term 24 of nerve impulse.

The difference between them is shown by an image of Fig. 12(b). When stellate cell bodies 18 at a position α and a position γ or a pyramidal cell body 17 at a position β fires an action potential and a potential of a cell membrane is changed, unique vibration modes occur due to ion adsorption (or ion release), as has been described in chapter 3 or 4 (the present chapter). Accordingly, when the cell body is illuminated with light having a wavelength in the aforementioned range, this light is absorbed and causes transition between the unique vibration modes.

As a result, as shown in Fig. 12(b), a reflection light amount change 401 occurs due to a temporal decrease in the amount of reflection light. In the example of Fig. 12(b), the stellate cell body 18 at the position α starts firing an action potential at t_0 in a detection time 163, which causes the stellate cell body 18 at the position γ to start firing an action potential, followed by causing an action potential of the pyramidal cell body 17 in the position βwith a little delay. Here, one "whisker" in Fig. 12 (b) indicates "one action potential." Since the temporal resolution is very high in the present exemplary embodiment in which the membrane potential changing is detected as such, each action potential state can be detected per different neuron.

Then, at t_B, which is 5 s after t_0 at which the action potential started in the detection time 163, a reflection light amount 48 of light having a wavelength of 830 nm and a reflection light amount

47 of light having a wavelength of 780 nm start to change slowly.

It is found that after the neuron fires an action potential, the oxygen concentration change in blood will not occur if any of the following phenomena does not continue: (1) lack of ATP in the cell bodies 17 and 18; (2) lack of oxygen molecules in the cell bodies 17 and 18; and (3) lack of oxyhemoglobin in the capillary 28. That is, only when action potentials are fired frequently as shown in Fig. 12(b), the above phenomena from (1) to (3) occur continuously.

Therefore, when action potentials are rarely fired as shown Fig. 13(b), the oxygen concentration in blood does not change because the phenomena (1) to (3) do not occur. Hence, it is considered that the method for detecting the oxygen concentration change in blood has relatively low detection accuracy of the life activity. In contrast, since the present exemplary embodiment in which the membrane potential changing is detected can detect only one action potential as shown in Fig. 13(b), it is advantageously possible to improve detection accuracy drastically in either of the optical means (near infrared light) and the magnetic means (fMRI).

(Regarding detection of weak signal)

As can be seen from a value of B_{0m}/B_{01}, which is a transition probability ratio in the reference tone of the transition probability in the overtone levels described in Table 5, a very weak changing signal is detected in the present exemplary embodiment. Therefore, an electromagnetic wave (near infrared light) to be projected on a life object is modulated in advance in the present exemplary embodiment as described later.

Thus, an S/N ratio of a detection signal can be increased by extracting only a signal component synchronized with a modulation signal from detection light returning from the life object. If a modulation cycle thereof is longer than a time interval at which a measurement subject changes, it is difficult to detect time dependent variations of the measurement subject. Accordingly, in order to measure time dependent variations of the measurement subject stably, it is necessary to set a basic cycle of the modulating signal to be equal to or less than 1/5 the time interval at which the measurement subject changes.

In view of this, one exemplary embodiment has a feature in that a basic frequency of a modulation signal is set as follows: 1 Hz or more (at least 0.2 Hz or more) for an object changing at an interval shorter than 5 s; 25 Hz or more (at least 5 Hz or more) for an object changing at an

interval shorter than 200 ms; and 1.25 kHz or more (at least 250 Hz or more) for an object changing at an interval shorter than 4 ms.

Next will be described an upper limit of the basic frequency of the modulation and an interval of time dependent variations in one exemplary embodiment. Generally, it is known that analog signals having a signal bandwidth of several hundred kHz work easily and stably without oscillating a detecting circuit. Further, at such a signal bandwidth, implementation including how to connect grounds in a printed circuit or the like is stable even without careful attention. On the other hand, when the bandwidth of an operating range exceeds 20 MHz, the detecting circuit is easy to be oscillated, and considerable technique is necessary for the implementation in the printed circuit. In a case where an action potential of about 0.5 to 2 ms is measured in one example of the present exemplary embodiment, such high-speed signal detection is not required. Therefore, a detecting signal bandwidth is restrained to a minimum, so as to stabilize the circuit and reduce costs.

For the aforementioned reasons, the basic frequency of the modulation is restrained to 500 kHz or less specifically, in one example of the present exemplary embodiment, and the interval of time dependent variations of the measurement subject is set to not less than 10 ns (at least 2 ns or more).

5] NMR Spectral Characteristics Estimation based on Action Potential Model

5.1) NMR Spectral Characteristic changing and estimated chemical shift values regarding the action potential

5.1.1) Prospect for changing NMR Spectral Characteristics regarding action potential

Section 4.7 said that this embodiment shows a new measuring method of life activity which exposes a life object to an electromagnetic wave of 0.85 μm - 50 μm (or 0.84 μm - 2.5 μm) wavelength, and this new measuring method can detect time dependent variations of the electromagnetic wave indicating a life activity. And according to the new measuring method, a local property of life object can be measured in detail, and dynamical life action information can be obtained by converting the measurement results.

This chapter 5 proposes another embodiment which detects time dependent variations of Nuclear Magnetic Resonance property in a local area of a life object and converts the detection results to dynamical life action information.

According to section 3.2, a net charge value regarding a hydrogen atomic nucleus varies when

the Cl^- ion attaches to the hydrogen atom of $-N^+(CH_3)_3$ belonging to PCLN or SMLN and forms a hydrogen (or ionic) bond with the hydrogen atom. This net charge variation means a change of molecular orbitals located around the hydrogen atomic nucleus. Therefore, it is predicted that Nuclear Magnetic Resonance property and a corresponding chemical shift value change when the molecular orbitals located around hydrogen atomic nucleus change, because the change of molecular orbitals may make a magnetic shielding effect for hydrogen atomic nucleus vary.

This chapter proposes another embodiment which detects time dependent variations of Nuclear Magnetic Resonance property or a corresponding chemical shift and converts the detection results to dynamical life action information.

5.1.2) Calculation method with another quantum chemistry simulation program

In this chapter 5, Gaussian 09 is used for a quantum chemistry simulation program, and "Gaussian" belongs to a registered trademark (Gaussian 09, Revision A. 1, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, O. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, and D. J. Fox,-Gaussian, Inc. Wallingford CT, 2009).

A molecular structure $Cl^-(CH_3)_3N^+CH_2CH_2OH$ is used for this computer simulation to obtain a short time and simple estimation. And this calculation method also comprises two calculation steps to keep high calculation accuracy. The first calculation step is to optimize a molecular structure and to confirm whether the optimization is fully finished or not, and the second calculation step is to analyze Nuclear Magnetic Resonance property.

Some keywords of optimization are "#P RHF/6-31G(d) Opt Freq SCRF=(Solvent=Water,PCM)". Here, "RHF/6-31G(d)" means an approximation method and basic functions used for a series of calculations, "Opt SCRF=(Solvent=Water,PCM)" means the optimization under water, and "Freq" is used to confirm the optimized structure.

And some keywords of Nuclear Magnetic Resonance analysis are "#P RHF/6-31G(d) NMR SCRF=(Solvent=Water,PCM)". Here, "NMR" means the Nuclear Magnetic Resonance analysis

for calculating a corresponding chemical shift value. This chemical shift value is based on "δ scale" which represents a subtraction value between a corresponding output data and a basic chemical shift of Tetramethylsilane (TMS) which was previously calculated (R. M. Silverstein and F. X.Webster: Spectrometric Identification of Organic Compounds 6th Edition (John Wiley & Sons, 1998) Chapter 4, Section 4.7).

5.1.3) Estimating chemical shift values in NMR Spectral Characteristics

At first, Gaussian 09 calculated a chemical shift value regarding a hydrogen atomic nucleus belonging a methyl group which is included in a single choline $(CH_3)_3N^+CH_2CH_2OH$ without Cl^- ion attachment. And the first calculation results were between δ2.49ppm and δ2.87ppm.

Then it calculated a chemical shift value regarding a hydrogen atomic nucleus which forms a hydrogen (or ionic) bond with Cl^- ion in a molecule $Cl^-(CH_3)_3N^+CH_2CH_2OH$, and the next calculation results are between δ3.43ppm and δ3.55ppm.

Therefore, these calculation results show an obvious transition of a chemical shift between Cl^- ion attachment and detachment.

5.2) Discussion about measurable range in present exemplary embodiment

If a chlorine ion Cl^- is attached to PCLN or SMLN on an outside layer of a cell membrane at the time when a neuron fires an action potential, an NMI spectrum reaches its peak in a range from δ3.43 ppm to δ3.55 ppm temporarily (during the action potential), and a peak area in a range from δ2.49 ppm to δ2.87 ppm must be decreased by an amount corresponding to the peak area in the range from δ3.43 ppm to δ3.55 ppm.

Accordingly, in another applied embodiment of the present exemplary embodiment, a temporary increment of the peak in the range from δ3.43 ppm to δ3.55 ppm on the NMI spectrum or a temporary decrement of the peak in the range from δ2.49 ppm to δ2.87 ppm on the NMI spectrum is measured so as to measure an action potential phenomenon.

A value calculated according to a computer simulation often has some difference to an actual result of measurement. The difference is estimated to be about 0.45 to 0.49 ppm. In view of this, an applied embodiment of the present exemplary embodiment measures a time dependent variation (a temporary increase and decrease) of the peak area (or a peak height) in the range from δ2.0 ppm (2.49 - 0.49) to δ4.0 ppm (3.55 + 0.45) on the NMI spectrum.

However, the applied embodiment of the present exemplary embodiment is not limited to the measurement of a neuronal action potential, but the present exemplary embodiment is applicable

to measurement of rapid dynamical life activity changing in a life object by detecting a temporary increase or decrease (a time dependent variation) of a peak in a particular region on the NMI spectrum.

The reason is as follows: judging from the explanation in section 4.7, a phenomenon that a dynamical life activity in a life object changes in a short time (a reaction velocity is fast) often causes a change of a magnetic screening effect due to molecular orbitals located around the proton change.

Further, this another applied embodiment has a large feature in that a change of molecular state in water is detected to measure life activities. This another applied embodiment has a technical device to detect a particular change of molecular state under water, and this technical device is based on detecting spectrum peaks which are different from specific peaks corresponding to one or more water molecules in the NMR spectrum.

It is said that a chemical shift value of a hydrogen nucleus constituting a single water molecule is in a range from δ0.4 ppm to δ1.55 ppm, and a chemical shift value due to a hydrogen bond between water molecules is δ4.7 ppm (R. M. Silvestein & F. M. Webster: Spectrometric Identification of Organic Compounds, 6th edition (John Wiley & Sons, Inc., 1998) see Chapter 4).

An electronegativity of an oxygen atom related to the hydrogen bond between water molecules is large, which follows fluorine, according to the calculation result of Pauling. Thus, a chemical shift value at the time when a hydrogen bond to an atom except for an oxygen atom (for example, the aforementioned chlorine ion) is formed is smaller than δ4.7 ppm as mentioned above, and will be δ4.5 ppm or less in consideration of a margin of 0.2 ppm.

On the other hand, an upper limit of the chemical shift value of the hydrogen nucleus constituting a single water molecule is δ1.55 ppm, but should be set to δ1.7 ppm or more, to which a margin of 0.15 ppm is added, so as to avoid the peak of the water molecule. In view of the above consideration, this another applied embodiment measures a dynamical life activity in a life object by detecting a time dependent variation of the peak area (or the peak height) in a range of the chemical shift value of not less than δ1.7 ppm but not more than δ4.5 ppm on the NMR spectrum.

In this another applied embodiment, an interval of time dependent variations to be detected in a

case of detecting dependent variations of the peak area (or the peak height) on the NMR spectrum is not less than 10 ns (at least 2 ns or more) but not more than 5 s as has been described in section 4.7. Alternatively, depending on a measurement subject, the interval may be not less than 10 ns (at least 2ns or more) but not more than 200 ms, or not less than 10 ns (at least 2 ns or more) but not more than 4 ms.

6] Technical Features of Detection/Control Method of Life Activity and Measuring Method of Life Activity in Present Exemplary Embodiment

Chapter 6 explains about basic principles and technical features of a detection method of life activity and a measuring method of life activity in the present exemplary embodiment. Further, this chapter deals with an exemplary embodiment to be commonly used even in a control method of life activity.

6.1) Content of life activity to be measured and features of detection/control method of life activity

6.1.3) Life activity in life object from surface area to very deep area to be taken as detection/control target

The present exemplary embodiment assumes life activities in a life object from a surface area to very deep positions as detection/control targets. This requires an extraction technique of a life activity detection signal from a specific location in a three-dimensional space in the life object or a selective life activity control technique with respect to a specific location.

At a first stage of the present exemplary embodiment to realize that, in order to perform "alignment of a detected/controlled point for life activity and preservation thereof" in the life object, the following operations are performed: (1) interpretation of an internal configuration in three dimensions (arrangement of all parts constituting the life object); and (2) calculation of a position of a measurement subject in three dimensions and control of the position based on the interpretation in (1).

At a second stage, (3) "extraction of a life activity detection signal" or "control of a local life activity" at the position specified in (2) is performed. The first stage and the second stage may be performed in series through time, or may be performed at the same time.

Hereinafter, "position detection of a detected/controlled point for life activity" performed in the

operations (1) and (2) is referred to as a "first detection." In the present exemplary embodiment, an electromagnetic wave (or light) having a wavelength described below is used for this first detection (which will be described in section 6.2, more specifically).

Furthermore, the operation (3) is hereinafter referred to as a "second detection." For this second detection, electromagnetic waves including an electromagnetic wave having a specific wavelength or an electromagnetic wave corresponding to a specific chemical shift value are used (which will be described in section 6.3, more specifically).

In other words, "in the present exemplary embodiment, detection or control of a life activity in a life object includes 'the first detection of detecting an electromagnetic wave,' and 'the second detection of detecting electromagnetic waves including an electromagnetic wave having a specific wavelength or an electromagnetic wave corresponding to a specific chemical shift value' or 'control using electromagnetic waves including an electromagnetic wave of a specific wavelength,'" and the second detection or control will be performed based on a result of the first detection. A specific procedure thereof is performed such that a position of a measuring/control object in three dimensions is calculated by the first detection, and a detection signal related to a life activity is obtained by the second detection from the internal position thus calculated, or alternatively, the life activity is controlled locally by illuminating an area at the position thus calculated with electromagnetic waves including a specific wavelength. However, the present exemplary embodiment is not limited to the above, and may be performed such that:

[1] a position of a measuring/control object in three dimensions is calculated by the first detection;

[2] a detection signal related to a life activity is obtained by the second detection from the internal position thus calculated; and

[3] the life activity is controlled locally based on the detection signal (by changing the intensity of the electromagnetic wave for illumination).

Thus, the first detection to perform position detection and position control of a detected/controlled point for life activity is combined with the second detection to perform actual detection of the life activity.

In the present exemplary embodiment, since the first detection to perform the position

detection and position control of a detected point for life activity is performed separately from the second detection to perform detection or control of life activity, a measurement section for performing the second detection (the after-mentioned detecting section for life activity) can be fixed to a location away from a user without directly attachment to the body of the user. Therefore, the use can move around without being conscious of the detection of life activity. This largely reduces a burden on the user and greatly improves convenience.

Here, the "electromagnetic wave having a specific wavelength" indicates the "light having a wavelength in the range from 0.840 μm to 50 μm" for detection of the "membrane potential changing in nervous system", while indicating the "light having a wavelength in the range from 780 nm to 805 nm or 830 nm" for detection of "oxygen concentration change in blood in surrounding areas". Further, the "electromagnetic wave having a specific wavelength" indicates "infrared light having a wavelength of around 8.7 μm" for detection of "temperature change by thermography". The reason why the wavelength should be 8.7 μm is described below. The thermography detects black-body radiation released from a life-object surface, but a largest-intensity wavelength of this black-body radiation depends on a released surface temperature of the life object. When the largest-intensity wavelength corresponding to a human body temperature is calculated, a result thereof is 8.7 μm, and therefore this value is used herein.

On the other hand, the "electromagnetic wave corresponding to a specific chemical shift value" indicates the "electromagnetic wave corresponding to a chemical shift value in the range of not less than δ1.7 ppm but not more than δ4.5 ppm" as described in section 5.2 for detection of "activation neuron distribution by fMRI" shown, while indicating the "electromagnetic wave corresponding to a chemical shift value corresponding to the change of the magnetic susceptibility" for detection of "oxygen concentration change by fMRI".

In the meantime, in the present exemplary embodiment, the electromagnetic wave having a specific wavelength may be detected from electromagnetic waves released naturally from a life object. However, since the electromagnetic waves thus naturally released have a low intensity, it is difficult to have a large S/N ratio for a detection signal. In order to handle this, in the present exemplary embodiment, a life object is illuminated with the electromagnetic waves including the electromagnetic wave having a specific wavelength or the electromagnetic wave

corresponding to a specific chemical shift value, and the illuminating light obtained from the life object is detected, so as to perform the second detection. This can improve detection accuracy of a detection signal. Further, as has been described in section 4.7, the electromagnetic waves for illumination to the life object may be modulated by a basic frequency in a range of not less than 0.2 Hz but not more than 500 kHz so as to further improve the accuracy of the detection signal.

Meanwhile, a wavelength of the electromagnetic wave used for the first detection to set a detected point or controlled point for life activity in the life object so as to obtain a life activity detection signal by the second detection may be harmonized with a wavelength of the electromagnetic wave used in the second detection. However, in the present exemplary embodiment, the wavelength range of both electromagnetic waves are set to different values (that is, the largest-intensity wavelength of the electromagnetic wave in the frequency distribution used for the first detection is set to be different from the specific wavelength or the specific chemical shift value included in the electromagnetic waves for the second detection), so as to remove interference between the electromagnetic wave used for the first detection and the electromagnetic waves used for the second detection or the control. In this case, color filters for blocking light of specific wavelengths are disposed at first and second detection openings (an entry port of the signal detecting section), so as to prevent the electromagnetic wave used for the first detection from entering into to the second detection side and vice versa.

A specific method in the present exemplary embodiment in which the electromagnetic waves for the first detection and the second detection or control are set to have different wavelengths is such that: a position of a measurement subject in three dimensions is detected by use of a camera having sensitivity for visible light; by use of the aforementioned infrared radiation or near infrared light, a water concentration distribution in a life object subjected to life activity detection is measured by MRI, or the position of the measurement subject is determined by use of a CT scan; the water concentration distribution in the life object for which a detection signal related to a life activity at the position is detected by fMRI is measured by MRI or the position of the measurement subject is determined by use of a CT scan; and by use of infrared light or near infrared light, the detection or control of a detection signal related to the life activity at the

position is performed.

Here, the terms to be used for future explanations of the exemplary embodiments are defined as below. The same terms will be used according to the following definitions hereinafter. Initially, an operation of obtaining information (e.g., intensity, change in intensity, phase amount, phase shift, frequency value or frequency change) related to a certain electromagnetic wave is defined as "detection." In the explanation, as described earlier, this "detection" has two definitions, "the first detection" and "the second detection." Further, this second detection is referred to as "detection of life activity" in a narrow sense. However, in some cases, the first detection and the second detection may be generally referred to as "detection of life activity." An obtained signal as a result of detection is referred to as a "detection signal" and a signal obtained as a result of detection of life activity is referred to as a "life activity detection signal" in the present specification.

Accordingly, a signal directly obtained from a physical phenomenon shown in the column of "signal generative physical phenomenon and detection method" corresponds to "a detection signal obtained as a result of the second detection," but if there occurs no confusion for the interpretation of the terms hereinafter, that signal may be generally referred to as a "detection signal."

As described above, among all biosis activities, a biosis activity of which a state can change over time along with a particularly physicochemical phenomenon is included in the "life activity." An explanation focusing on the activity of the nervous system as an example of the life activity is given, but the present exemplary embodiment is not limited to that, as described above, and all detection of activities corresponding to the aforementioned life activities will be included in the scope of the present exemplary embodiment. Alternatively, in the present exemplary embodiment, "a state or a change of the state (a time dependent variation or a spatial variation) of a life object which is detectable by an electromagnetic wave in a non-contact manner" may be defined as the life activity.

In the meantime, examples of the life activity focusing on the activity of the nervous system encompass "signal transmission (a transmission path or a transmission state) in the nervous system," "reflection reaction," "unconscious activity," "cognitive reaction,"

"recognition/discrimination reaction," "emotional reaction," "information processing," "thought/contemplation process," and the like. These certain types of "controlled life activities of a higher degree" are defined as "life activity information" (the symptom of a schizophrenia patient is partially controlled to some extent, and therefore included in the controlled life activity of higher degree).

Alternatively, "interpretable or distinguishable information about a composite action which causes an activity (for example, between cells)" can be also defined as the "life activity information." Even if plant or microbial activities include some sort of controlled composite action, the activities are also included in the life activity information. In order to obtain this life activity information, it is necessary to interpret a life activity detection signal including a signal of a dynamical life activity in the life object and to generate life activity information. A process to generate the life activity information from this life activity detection signal is referred to as "interpretation of life activity." Further, a process ranging from the acquisition of a life activity detection signal to the generation of life activity information may be referred to as "biosis activity measurement."

Furthermore, a part which receives light including light having a specific wavelength with a signal associated with a life activity or electromagnetic waves including an electromagnetic wave corresponding to a specific chemical shift value with a signal associated with a life activity and detects a life activity detection signal therefrom is referred to as a "signal detecting section." Moreover, a part in the signal detection section which receives the light or the electromagnetic waves and converts it into an electric signal is referred to as a "photo detecting section of life activity" in a wide sense, and a method for receiving the light or the electromagnetic waves and converting it into an electric signal is referred to as a "photo detecting method of life activity." Further, an electric detecting section including amplification to signal processing of an electric signal obtained by the photo detecting section in the signal detecting section is referred to as a "life activity detection circuit."

In the photo detecting section of life activity having a configuration as shown in section 6.3.3 section as one exemplary embodiment, a detecting coil 84 detects an electromagnetic wave corresponding to a specific chemical shift value (the detecting coil 84 converts it into an electric

signal). On the other hand, in another exemplary embodiment, the photo detecting section of life activity having a configuration as shown in section 6.3.1 or section 6.3.2 photoelectrically converts light having a specific wavelength (near infrared light or infrared light). In the exemplary embodiments of the photo detecting section of life activity, an optical system used for photoelectric conversion of light including the aforementioned light having a specific wavelength (and placed as a front part of the photoelectric conversion) is referred to as an "optical system for life activity detection."

Meanwhile, since the life activity detection signal has a large S/N ratio in the present exemplary embodiment, there may be used such a method in which an electromagnetic wave having a specific wavelength (or corresponding to a specific chemical shift value) is modulated by a predetermined basic frequency so that a life object as a measurement subject (or a detection target) is illuminated with the modulated electromagnetic wave. A section which generates at least the electromagnetic wave (or light) having the specific wavelength (or corresponding to a specific chemical shift value) in this case is referred to as a "light emitting section." A whole section constituted by the signal detecting section and the light emitting section is referred to as a "detecting section for life activity." Here, in exemplary embodiments which do not have the light emitting section, the detecting section for life activity corresponds to the signal detecting section.

On the other hand, a section which aligns a detected point for life activity and performs the first detection to preserve the position therein as described above is referred to as a "position monitoring section regarding a detected point for life activity" or just referred to as a "position monitoring section." A whole section constituted by the "detecting section for life activity" and the "position monitoring section regarding a detected point for life activity" is referred to as a "life detecting section." A signal is transmitted between the position monitoring section regarding a detected point for life activity and the detecting section for life activity in this life detecting section. That is, as has been described in the beginning of this section, detection of life activity is performed by the detecting section for life activity based on a result of position detection by the position monitoring section.

6.2) Alignment and preservation method of detected/controlled point for life activity

By use of the first detection method as described in section 6.1.3, the following describes a method in which a spatial arrangement in three dimensions in (1) is grasped, and based on the result, a detected point for life activity or a controlled point for life activity (a position of a measurement subject) is calculated in three dimensions and position control is performed in (2).

6.2.1) Method for setting detection position by detecting cross-sectional image including detected/controlled point

The following describes a basic principle to detect a cross-sectional image including a detected point, which is used in the position monitoring section regarding a detected point for life activity in the present exemplary embodiment, with reference to Fig. 14. Note that detected points 30 for life activity described in Figs. 14, 15, 17, 18, 20, and 23 correspond to a target area for life activity control to be locally affected in a life object in the present exemplary embodiment. Light (or electromagnetic waves) is projected via an objective lens 31 toward a wide area around a detected point 30 for life activity, like a reflection-type light microscope, which is omitted in Fig. 14. Then, the light (or the electromagnetic waves) thus projected is reflected diffusely on the detected point 30 for life activity constituted by a two-dimensional plane including respective points α, β, and γ, and its peripheral area. By use of this phenomenon, the diffused reflection light on the two-dimensional plane (the detected point 30 for life activity) including the respective points α, β, and γ is used as detection light with respect to the detected point for life activity.

In the meantime, in order to find (detect) a point from which a life activity detection signal in the life object is obtained or a point where the life activity is controlled (i.e., the detected point 30 for life activity), it is necessary to interpret an internal structure on the two-dimensional plane including the respective points α, β, and γ (interpretation of each part constituting the life object and grasp of an arrangement thereof) in regard to (1) in section 6.1.3. Similarly to detection of an intensity change of light reflected diffusely on a surface when a surface structure is grasped by a conventional light microscope, an intensity change of the diffused reflection light at each point on the two-dimensional plane is measured.

However, in the present exemplary embodiment, it is necessary to detect an image (a detection signal pattern) in a specific cross section in the life object, which is different from the

conventional light microscope. Therefore, the present exemplary embodiment uses a feature of a confocal system to detect the cross section in the life object.

That is, a pinhole 35 is disposed at a rear focus position of a detection lens 32, so that only detection light passing through this pinhole is detected by the photodetector 36. The light reflected diffusely on points except for the detected point 30 for life activity and passing through the objective lens 31 becomes non-parallel beams in the middle of an optical path 33 of the detection light and forms a very wide spot cross section (a very large spot diameter) at the pinhole 35, so that most of the light cannot pass through the pinhole 35.

Accordingly, since the photodetector 36 can detect only parallel detection light in the optical path 33 for the detection light between the objective lens 31 and the detection lens 32, only detection light emitted from a position of an anterior focal plane of the objective lens 31 can be detected. Thus, by synchronizing the detected point 30 for life activity with the position of the anterior focal plane of the objective lens 31, a detection signal obtained only from the detected point 30 for life activity can be detected by the photodetector 36.

Here, a reflecting mirror (a galvanometer mirror) 34 which can be inclined in two axial directions is disposed between the objective lens 31 and the detection lens 32. Before the reflecting mirror (galvanometer mirror) 34 is inclined, only detection light emitted from the position α on the detected point 30 for life activity can be detected by the photodetector 36. Further, when the reflecting mirror (galvanometer mirror) 34 is inclined to the right side, only detection light emitted from the position γ can be detected, and when the reflecting mirror 34 is inclined to the left side, only detection light emitted from the position β can be detected.

Fig. 14 shows a case where the reflection mirror 34 is inclined in a crosswise direction, but the present exemplary embodiment is not limited to this, and when the reflecting mirror 34 is inclined in a front-back direction, detection light emitted from a position deviated in a direction perpendicular to the page space can be detected. As such, when the reflecting mirror (galvanometer mirror) 34 performs scanning in the biaxial directions and a light amount detected by the photodetector 36 is monitored through time in sync with the inclination, a two-dimensional detection signal pattern can be obtained from the light reflected diffusely on the detected point 30 for life activity.

In regard to (2) of section 6.1.3, the following describes a detection method and a correction method (an alignment method) of a displacement direction and a displacement amount of a current detection position for the detected point 30 for life activity in a two-dimensional direction at right angles to an optical axis of the objective lens 31. Although not illustrated in the optical system described in Fig. 14, a member having elasticity such as a leaf spring or a wire is disposed between the objective lens 31 and a fixing member so that the objective lens 31 can move in triaxial directions. Further, three voice coils are connected with the objective lens, and the three voice coils are partially disposed in a DC magnetic field generated by a fixed magnet (not illustrated). Accordingly, when a current flows in each of the voice coils, the objective lens can move in an individual direction of corresponding one of the three axes due to an effect of an electromagnetic force.

In the present exemplary embodiment, the detected point 30 for life activity to become a target for extraction of a life activity detection signal ((3) as described in section 6.1.3) is predetermined, and a detection signal pattern obtained therefrom is stored in advance. This detection signal pattern indicates two-dimensional image information which is obtained as a detection signal from the photodetector 36 synchronized with the scanning in biaxial directions of the reflecting mirror (galvanometer mirror) 34 and which is indicative of a distribution of diffused reflection light amount at the detected point 30 for life activity. The objective lens 31 is disposed at a suitable location close to the detected point 30 for life activity, and a two-dimensional signal detection pattern (a monitoring signal) obtained from the photodetector 36 synchronized with a biaxial-direction inclination of the reflecting mirror (galvanometer mirror) 34 obtained at this time is compared with the aforementioned detection signal pattern stored in advance.

At this time, by use of a pattern matching method, a displacement direction and a displacement amount of a detection position between two-dimensional image information indicated by the currently obtained detection signal pattern and an ideal position in a direction at right angles to the optical axis of the objective lens 31 (a center position of an image in the two-dimensional image information indicated by the detection signal pattern stored in advance) are calculated.

When the displacement direction and the displacement amount in the direction at right angles to the optical axis of the objective lens 31 are obtained as such, a current is flowed into the voice

coils integrated with the objective lens 31, so as to align the detected point 30 for life activity by moving the objective lens 31 in the biaxial directions at right angles to the its optical axis. Such electric feedback is performed continually during a detection period, and the objective lens is held at a predetermined position (where the detected point 30 for life activity can be measured).

Next will be described a monitor detection method of a detected point for life activity in a direction along the optical axis of the objective lens 31 (operations of (1) and (2) in section 6.1.3). A basic principle is such that: cross-sectional images in a plurality of areas having different depths in a life object are extracted by use of the feature of the confocal (imaging) system; a pattern equivalent level with respect to cross-sectional image information stored in advance is calculated, and a current position in a direction along the optical axis of the objective lens 31 is detected. A detailed explanation thereof is given below.

First discussed is a case where light emitted from the position α in the detected point 30 for life activity is condensed at the pinhole 35-1 as shown in Fig. 15. Light emitted from a position δ which is deeper than the position α is condensed at a pinhole 35-3 placed ahead of the pinhole 35-1, and detected by a photodetector 36-3. Similarly, light emitted from a position ε which is shallower than the position α is condensed at a pinhole 35-2 placed behind the pinhole 35-1, and detected by a photodetector 36-2. A grating 37 is disposed in the detection system in Fig. 15 to incline the optical axis so that the placement position can be changed from the pinhole 35-1 to the pinhole 35-3 in a direction at right angles to the optical axis. In such an optical arrangement, when the reflecting mirror (galvanometer mirror) performs scanning in the biaxial directions, a detection signal pattern on a plane at right angles to the optical axis of the objective lens 31 and including the position δ is obtained from the photodetector 36-3. Similarly, a detection signal pattern on a plane at right angles to the optical axis of the objective lens 31 and including the position ε is obtained from the photodetector 36-2.

Meanwhile, detection signal patterns obtained from the detected point 30 for life activity and areas at a shallower side and a deeper side of the detected point 30 for life activity are stored in advance. At this time, not only the detection signal patterns on the plane including the position δ and the position ε obtained when the objective lens is placed at an ideal position (where the detected point 30 for life activity can be measured), but also detection signal patterns obtained

from positions greatly displaced toward the shallower side or the deeper side of the detected point 30 for life activity are stored at this time.

Then, these detection signal patterns stored in advance are compared with detection signal patterns obtained from the photodetectors 36-1 to 36-3 (pattern matching in consideration of a displacement amount in the two-dimensional direction at right angles to the optical axis of the objective lens 31), it is possible to judge whether the objective lens 31 is currently positioned at the shallower side or the deeper side of a designated position in the optical axial direction.

In this pattern matching process, equivalent levels of the respective detection signal patterns currently obtained from the photodetectors 36-3, 36-1, and 36-2 with respect to detection signal patterns at corresponding positions stored in advance are calculated, and it is estimated that the objective lens 31 is located at a place where the equivalent level is the highest.

For example, assume a case where as a result of calculating the equivalent levels with detection signal patterns stored in advance, a detection signal pattern corresponding to a two-dimensional surface currently obtained from the photodetector 36-2 in synch with the biaxial-direction scanning of the reflecting mirror (galvanometer mirror) 34 has the highest equivalent level with respect to a detection signal pattern obtained from the detected point 30 for life activity stored in advance.

In that case, it is found from Fig. 15 that a current location of the objective lens 31 is too near to the detected point 30 for life activity. In the detection result as such, a current is flowed into the voice coils integrated with the objective lens 31, so as to move the objective lens backward along the optical axis. When the objective lens 31 is set at a position most suitable for the measurement of the detected point 30 for life activity, a detection signal pattern obtained from the photodetector 36-1 in synch with the biaxial-direction scanning of the reflecting mirror (galvanometer mirror) 34 is matched with the detection signal pattern obtained from the detected point 30 for life activity stored in advance.

Even in a case where the objective lens 31 is largely displaced from a measurement location of the detected point 30 for life activity, if signal patterns of the objective lens 31 in case of large displacement are stored as described above, then it is possible to estimate a displacement direction and a displacement amount of the objective lens 31 by performing the pattern matching

with a current signal pattern (calculating an equivalent level between the patterns).

6.2.2) Method for estimating and setting position of detected point by detecting specific position on life-object surface

In the method described in section 6.2.1, a cross-sectional pattern including the detected point 30 for life activity is directly detected to find a position of the detected point. Another embodiment proposes a method in which when a depth from a life-object surface to the detected point is found in advance, a position of the life-object surface in three dimensions is detected and the position of the detected point is automatically estimated.

With reference to Fig. 16, the following will explain a method for detecting a relative position of a marked position 40 on a life-object surface from the detecting section for life activity, which is newly proposed as another exemplary embodiment (a second principle) related to the position monitoring section 46 regarding a detected point for life activity. It is assumed that a life-object surface is illuminated by an illumination lamp for general household use and light reflected diffusely on the life-object surface 41 is used for detection. However, another present exemplary embodiment is not limited to this, and may include a specific light source to illuminate the life-object surface 41.

The second principle to detect a position of a detected point, which is shown in this exemplary embodiment, uses a principle of the "trigonometry." That is, in the another exemplary embodiment shown in Fig. 16, the detecting section for life activity is provided with a plurality of camera lenses 42, and a plurality of two-dimensional photodetectors 43 (CCD sensors) disposed behind the plurality of camera lenses 42 and which can detect a two-dimensional image. Light emitted from the marked position 40 on the life-object surface (reflected diffusely from the marked position 40 of the life-object surface) is condensed at one point on a two-dimensional photodetector 43-1 due to the action of a camera lens 42-1. Similarly, light is condensed at one point on a two-dimensional photodetector 43-2 by the action of a camera lens 42-2. Accordingly, based on projected locations of the marked position 40 on the life-object surface, which are on the two-dimensional photodetectors 43-1 and 43-2 and on which images are formed, a distance 44 from surface points of an area where the detecting section for life activity is disposed to the life-object surface 41 and positions of the marked position 40 on the life-object

surface in a lateral direction and a depth direction are calculated by use of the trigonometry.

Further, an exemplary embodiment shown in Fig. 16 has a feature in that the position monitoring section 46 regarding a detected point for life activity and the detecting section 101 for life activity are provided in an integrated manner. As a result of such an integrated provision, if the depth of the detected point 30 for life activity from the life-object surface is found in advance, a distance from the surface points 45 of an area where the detecting section for life activity is disposed to the detected point 30 for life activity can be estimated.

6.3) Photoelectric conversion method for detection of life activity

The following describes a basic principle of the method (the second detection method) in (3) for extracting a life activity detection signal from a specified position in a life object by use of the second detection method described in section 6.1.3.

6.3.1) Utilization of confocal system

As a first exemplary embodiment, a method using the confocal system as well as the technical device described in section 6.2.1 is described. A basic principle of this exemplary embodiment has a feature in that an optical principle that 'light emitted from one point in a life object to every direction is condensed again on one point at a confocal position or an image forming position' is applied and 'only the light condensed on the one point at the confocal position or the image forming position is extracted so as to detect light emitted from a corresponding point in the life object.'

One exemplary embodiment of an optical system for life activity detection in a signal detecting section configured to detect a life activity detection signal from a specific position in a life object based on this basic principle is shown in Fig. 17. Further, a theory of the optical system for life activity detection of Fig. 17 is shown in Figs. 18 and 19.

The exemplary embodiment in Fig. 17 shows an optical system which can simultaneously measure life activities on three planar regions (δ, α, ε) having different depths in a life object. That is, in an optical system constituted by an objective lens 31 and a detection lens 32, a two-dimensional liquid crystal shutter 51-1 is disposed at a position of an image forming surface corresponding to a planar region including a detected point 30α for life activity in the life object. In the two-dimensional liquid crystal shutter 51-1, a pinhole-shaped light transmission section 56

can be set partially as shown in Fig. 19(a).

Accordingly, among light beams passing through the two-dimensional liquid crystal shutter 51-1, only a light beam passing through this light transmission section 56 is transmittable. As a result, only light emitted (reflected diffusely) from one point at the detected point 30α for life activity in a confocal relationship (image-forming relationship) with this light transmission section 56 can reach a lateral one-dimensional alignment photo detecting cell 54-1 and a longitudinal one-dimensional alignment photo detecting cell 55-2.

Accordingly, a life activity detection signal detected from the detected point 30α for life activity constituted by a two-dimensional plane including a point α is directly detected by the lateral one-dimensional alignment photo detecting cell 54-1 and the longitudinal one-dimensional alignment photo detecting cell 55-2 (the details thereof will be described later). On the other hand, a two-dimensional liquid crystal shutter 51-3 is disposed on an image forming surface corresponding to a detected point 30δ for life activity which is located deeper than the detected point 30α for life activity and which is constituted by a planar region including a point δ. Hereby, a life activity detection signal in two dimensions detected from the detected point 30δ is detected by a lateral one-dimensional alignment photo detecting cell 54-3 and a longitudinal one-dimensional alignment photo detecting cell 55-3.

Further, a two-dimensional liquid crystal shutter 51-2 is disposed on an image forming surface corresponding to a detected point 30ε for life activity which is located shallower than the detected point 30α for life activity and which is constituted by a planar region including a point ε. Hereby, a life activity detection signal in two dimensions detected from the detected point 30ε is detected by a lateral one-dimensional alignment photo detecting cell 54-2 and a longitudinal one-dimensional alignment photo detecting cell 55-2.

In Fig. 17, the two-dimensional liquid crystal shutter 51 capable of automatically opening and shutting a particular region is used for extraction of light (or an electromagnetic wave) obtained from the detected point 30 for life activity. However, the present exemplary embodiment is not limited to that, and a two-dimensional modulation element using EO (Electrical Optics) or AO (Acoustic Optics) may be used as the optical component capable of automatically opening and shutting a particular region. Still further, a fixed-type mechanical pinhole or slit incapable of

automatically opening and shutting a particular region, or a very small refractor or diffraction element may be also usable.

In the meantime, as the detection and position control methods of a location to obtain a life activity detection signal in a life object (the operations (1) and (2) described in section 6.1.3), which methods are used together with the detecting section for life activity (see section 6.1.3 for the definition of the term) including an optical system for life activity detection shown in Fig. 17, a method for "detecting a cross-sectional image in an life object" shown in Fig. 14 and Fig. 15 and described in section 6.2.1 is adopted.

If a two-dimensional changing pattern of diffused reflection light amount is detected from a specific cross section in this life object, then it is possible to find not only positions of a neuron cell body 1 and an axon 2 in a neuron and a position of a neuromuscular junction 5 on the specific cross section, but also an arrangement of a muscle cell 6 and a glial cell (Astrocyte).

In view of this, light (or an electromagnetic wave) emitted (reflected diffusely) from a location where a life activity is desired to be detected on a specific cross section as a measurement subject (e.g., a specific position in a neuron cell body or an axon) is condensed by the objective lens 31 and the detection lens 32, and the light is extracted at a condensed position (an image forming position or a confocal position for the detected point 30 for life activity).

A principle to detect a life activity detection signal from a specific position in the life object by use of the optical system for life activity detection as illustrated in Fig. 17 will be described here with reference to Fig. 18 in detail. In Fig. 18, light emitted (reflected diffusely) from the detected point 30α for life activity is condensed (imaged) at a spot μ on the two-dimensional liquid crystal shutter 51. Therefore, the liquid crystal shutter is locally opened only at this spot so as to form a light transmission section 56μ in the two-dimensional liquid crystal shutter. Similarly, a spot ζ on which light emitted (reflected diffusely) from the detected point 30β for life activity is condensed (imaged) is taken as a light transmission section 56ζ in the two-dimensional liquid crystal shutter.

In the meantime, light emitted (reflected diffusely) from a position η different from the above spots (see the optical paths 33 of detection light shown in a "wavy line" in Fig. 18) spreads out greatly over the two-dimensional liquid crystal shutter 51, and therefore, most of the light is

blocked by the two-dimensional liquid crystal shutter 51. Thus, only a very slight amount of the light passes through the light transmission section 56μ in the two-dimensional liquid crystal shutter, but the amount of the light passing therethrough is very small. As a result, the light is buried among noise components on the longitudinal one-dimensional alignment photo detecting cell 55.

As described above, by "selectively extracting light or an electromagnetic wave passing through a particular region" in an image forming surface or at a confocal position corresponding to a particular cross section in a life object, it is possible to selectively extract a life activity detection signal from a particular position in the life object. In view of this, by changing the arrangement of an optical element for selectively extracting light or an electromagnetic wave via the particular region, it is possible to simultaneously detect life activities in a plurality of regions at different positions along a depth direction in a life object.

In that case, the light or electromagnetic wave obtained from the life object is split into a plurality of light beams or electromagnetic waves by light amount, and optical elements for selectively extracting light or an electromagnetic wave passing through a particular region are placed on respective image forming surfaces (confocal positions) of the plurality of light beams (electromagnetic waves) thus split.

In Fig. 17, the two-dimensional liquid crystal shutter 51-1 is disposed on an image forming surface corresponding to the detected point 30α for life activity and the two-dimensional liquid crystal shutters 51-3 and 51-2 are disposed on respective image forming surfaces corresponding to the detected points 30δ and 30ε for life activity.

In the meantime, in Fig. 17, the light or electromagnetic wave obtained from the life object is split by a grating 37 into light beams (electromagnetic waves) traveling in three directions, but this is not limited in particular. The light or electromagnetic wave obtained from the life object can be split into light beams (electromagnetic waves) traveling in five directions or light beams (electromagnetic waves) traveling in seven directions by changing the design of the grating 37. Further, as light amount splitting means for splitting the light or electromagnetic wave obtained from the life object, a half mirror, a half prism, or a polarizing mirror or prism may be used.

The following describes a method for directly obtaining a life activity detection signal. As

shown in Fig. 18, after only the light or electromagnetic wave obtained from a particular detected point 30 for life activity in the life object is extracted by use of the two-dimensional liquid crystal shutter 51, a photodetector is disposed on a condensed plane (a re-imaging surface) constituted by a condensing lens 52, and a life activity detection signal is obtained by use of photoelectric conversion. Alternatively, a two-dimensional light detecting element (light sensing array) such as a CCD sensor may be disposed here.

However, in a case of attempting to detect a dynamical life activity rapidly changing in the life object (e.g., "to simultaneously trace respective action potential changes in a plurality of neurons through time") as the detection of membrane potential changing in a nervous system, for example, the CCD sensor cannot achieve a sufficient response speed.

In contrast, in exemplary embodiments shown in Figs. 17 to 19, one-dimensional alignment photo detecting cells 54 and 55 capable of tracing high-speed changes through time are combined in a matrix manner so that the high-speed changes on a two-dimensional surface can be detected at the same time and in real time. More specifically, light or an electromagnetic wave passing through the condensing lens 52 is split into pieces by light amount, and respective beams (electromagnetic waves) are directed toward the lateral one-dimensional alignment photo detecting cell 54 and toward the longitudinal one-dimensional alignment photo detecting cell 55. In Fig. 17, for splitting, by light amount, of the light passing through the condensing lens 52, a grating 53 for light distribution in which a 0th-order light transmittance is approximately 0% and a ratio of a +1st-order light transmittance to -1st-order light transmittance is approximately 1:1 is used. However, the present exemplary embodiment is not limited to this, and a half mirror, a half prism, or a polarizing mirror or prism may be used as the light amount splitting means.

The following explains about a method for obtaining a life activity detection signal by combining a lateral one-dimensional alignment photo detecting cell 54 and longitudinal one-dimensional alignment photo detecting cell 55 having alignment directions inclined to each other, with reference to Fig. 19.

Photo detecting cells a to j are arranged in a one-dimensional direction (lateral direction), and respective signal of the photo detection cells a to j can be detected independently at the same time. Although not illustrated here, respective preamps and signal processing circuits are connected to

the photo detecting cells a to j independently, so that respective high-speed changes of detection light amounts of the photo detecting cells a to j can be monitored in parallel through time. Since the changes of the detection light amounts of the respective photo detecting cells a to j can be detected in parallel, it is possible to detect a very rapid and slight change occurring at only one place without overlooking.

Further, in the lateral one-dimensional alignment photo detecting cells shown in Fig. 19(b), the parallel changes of the detection light amounts in the one-dimensional direction can be detected through time. Still further, a change of a detection light amount at one point in a two-dimensional plane can be extracted in combination with pieces of information on changes of detection light amounts obtained from longitudinal one-dimensional alignment photo detecting cells k to t, which are aligned in an alignment direction inclined toward that of the lateral one-dimensional alignment photo detecting cells (in a non-parallel relationship).

That is, "a plurality of photo detecting cell groups capable of independently detecting signals at the same time (the lateral one-dimensional alignment photo detecting cell 54 and the longitudinal one-dimensional alignment photo detecting cell 55) are disposed so that respective alignment directions of the photo detecting cells are inclined to each other (not in parallel), and a plurality of detection signals obtained from the respective photo detecting cell groups (detection signals obtained from the photo detecting cells a to j and the photo detecting cells k to t in the respective groups) are combined in a matrix manner." Accordingly, a high-speed change of a detection signal obtained only from a specific spot within the detected point 30 for life activity configured in two dimensions can be detected independently and continuously through time. This is a feature of the present exemplary embodiment shown in Fig. 19.

In the meantime, the alignment directions of the photo detecting cells in the respective photo detecting cell groups are set at right angles to each other in (b) and (c) of Fig. 19, but the present exemplary embodiment is not limited to this, and an angle of inclination between the alignment directions of the photo detecting cells may largely differ from 90 degree, as long as the arrangement directions of the photo detecting cells are not in parallel.

The following describes this more specifically, with reference to Fig. 19. At first, it is assumed that five neuron cell bodies are found in a detected point 30 for life activity as a result of

analysis of an internal structure as described in (1) of section 6.1.3 performed with the use of the optical system (see section 6.2.1 illustrated in Figs. 14 and 15. Then, the position control described in (2) of section 6.1.3 is performed, and even if a life object (e.g., an examinee) for measurement moves to some extent, the objective lens 31 is also moved in conjunction with the movement of the life object so that a location subjected to the detection of life activity is fixed relatively.

Subsequently, as the extract operation of a life activity signal shown in (3) of section 6.1.3, shutters are opened locally at image forming positions on the two-dimensional liquid crystal shutter 51 corresponding to the locations of the five neuron cell bodies in the detected point 30 for life activity, so as to form light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter.

Then, due to the operation of the condensing lens 52, respective light beams passing through the light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter are condensed at a point ζ' in the photo detecting cell b, a point θ' in the photo detecting cell d, a point λ' in the photo detecting cell f, a point μ' in the photo detecting cell h, and a point ξ' in the photo detecting cell j on the lateral one-dimensional alignment photo detecting cell 54. Similarly, respective light beams passing through the light transmission sections 56λ, ξ, θ, μ, and ζ in the two-dimensional liquid crystal shutter are condensed at a point λ' in the photo detecting cell l, a point ξ' in the photo detecting cell n, a point θ' in the photo detecting cell p, a point μ' in the photo detecting cell r, and a point ζ' in the photo detecting cell t on the longitudinal one-dimensional alignment photo detecting cell 55.

For example, when a neuron having an image-forming relationship with the light transmission section 56μ in the two-dimensional liquid crystal shutter fires an action potential, intensity of convergence light at the position μ' changes instantly in response to the action potential. As a result, detection signals are obtained from the photo detecting cells h and r. As such, by knowing from which photo detecting cells in the lateral one-dimensional alignment photo detecting cell 54 and in the longitudinal one-dimensional alignment photo detecting cell 55, detection signals can be obtained, it is found which neuron in the detected point 30 for life activity fires an action potential.

Then, as will be described later, pulse counting is performed in the life activity detection circuit and the number of action potentials in a specific time per neuron is calculated to detect an activation state.

The above explanation deals with the action potential of the neuron (corresponding to the "membrane potential changing in nervous system") as an example of the detection of life activity. However, the present exemplary embodiment is not limited to this, and if a path of the axon 2, the neuromuscular junction 5, or the muscle cell 6 is set so as to correspond to an image forming position on the light transmission section 56 in two-dimensional liquid crystal shutter, a signal transmission state in the axon 2 or a signal transmission state to the muscle can be measured.

In the exemplary embodiment described above, respective sizes (aperture sizes) of the light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter are set relatively small, and a life activity per small region on the detected point 30 for life activity such as one neuron cell body 1 in the neuron or one muscle cell 8, axon 2 or neuromuscular junction 5 is detected. Other applied embodiments of this exemplary embodiment are as follows: (1) in Fig. 17, all two-dimensional liquid crystal shutters 51-1, 51-2, 51-3 may be disposed only at confocal positions or image forming positions corresponding to locations having the same depth (e.g., at the detected point 30α for life activity), so as to detect life activities in a two-dimensional direction corresponding to fixed locations having a specific depth; and (2) in Fig. 19, respective sizes (aperture sizes) of the light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter may be made larger, so that life activities in a relatively large range on the detected point 30α for life activity are detected. In this case, every one of the condensed spots ζ', θ', λ', μ', and ξ' in Fig. 19 (b) and (c) includes activity signals related to a plurality of neurons in the detected point 30α for life activity. Therefore, even if a pulsed signal corresponding to one action potential is detected at one of the condensed spots, a single neuron firing the action potential cannot be specified. However, by detecting the occurrence frequency of the pulsed signal corresponding to the action potential in the condensed spot, an activation state in a particular region constituted by a plurality of neurons in the detected point 30α for life activity can be detected.

This applied embodiment makes it possible to grasp life activities slightly in broad perspective

(as compared with an activity per neuron). An example of a specific purpose of this detection method is activity detection per column in the cerebral cortex.

When the respective sizes (aperture sizes) of the light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter are made larger, action potential signals from neurons at positions having different depths leak easily. Here, a thickness of the cerebral cortex in a human is slightly smaller than 2 mm, so that there is a low possibility that an action potential signal is obtained from a position at a shallower side or a deeper side than the cerebral cortex in a depth direction. Accordingly, if activities of neurons within 2 mm, which is a thickness of the cerebral cortex, are detected in a mass in this applied embodiment, the problem that action potential signals leak out from the positions having different depths beyond the range will be solved (because no action potential signal occur at the shallower side or the deeper side than that).

Further, the cerebral cortex is constituted by columns of about 0.5 to 1.0 mm in width, and it is said that there is relatively a little signal transmission between adjacent columns. Accordingly, when the respective sizes (aperture sizes) of the light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter are set according to one column size (about 0.5 to 1.0 mm), an activation state per column (e.g., an action-potential detection-frequency characteristic per column unit) can be detected.

On the other hand, in the cerebral cortex, there are many parts in which information processing is performed per column unit. In view of this, the present exemplary embodiment can effectively solve how the information processing is performed per column unit and find its details for the first time. In addition to the detection method as described above, the present exemplary embodiment has such a technical device that: (3) one two-dimensional liquid crystal shutter 51 blocks light at an image forming position of a column adjacent to a target column located at a light transmission section 56 in the two-dimensional liquid crystal shutter, so as to prevent detection of an action potential signal from the adjacent column, and "another light transmission section 56 in another two-dimensional liquid crystal shutter 51" is disposed at the image forming position of the adjacent column, so that an action potential signal from the adjacent column is detected by another photo detecting cells 54 and 55; and (4) by use of action potential signals obtained from columns adjacent to each other by different photo detecting cells 54 and 55 in (3),

cross talk (leak of a detection signal) from the adjacent column is removed by computing process of the signal. This yields an effect of improving signal detection accuracy per column unit by removing cross talk from an adjacent column.

The above explanation deals with the detection method in which a detection range of a measurement subject is about 10 to 1000 μm, which is relatively narrow area, at a corresponding image forming position of the light transmission section 56 in the two-dimensional liquid crystal shutter. In contrast, in a case where the oxygen concentration change in blood in surrounding areas is detected by use of the optical system for life activity detection as illustrated in Fig. 17, it is necessary to set the detection range more widely. In addition, it is necessary to further broaden the respective sizes (aperture sizes) of the light transmission sections 56ζ, θ, λ, μ and ξ in the two-dimensional liquid crystal shutter in conformity with the detection area thus set widely. In this case, although not illustrated in Fig. 17, a plurality of optical systems for life activity detection shown in Fig. 17 are provided, and color filters for selectively transmitting light having wavelengths of 780 nm, 805 nm, and 830 nm, respectively, are also disposed in the middle of the optical paths 33 of the detection light. Then, light beams having respective wavelengths of 780 nm, 805 nm, and 830 nm are detected separately, and a ratio between them in terms of detection light amount is calculated. A detection method of life activity in this case is performed (1) according to a time dependent variation of the ratio in terms of detection light amount between the detection light beams having respective wavelengths of 780 nm, 805 nm, and 830 nm, or (2) by comparing values obtained during the detection with preliminary measured values (reference values) of the ratio in detection light amount between the detection light beams having respective wavelengths of 780 nm, 805 nm, and 830 nm.

6.3.2) Extraction of spatial variations and time dependent variations by imaging optical system

As another applied embodiment with respect to the method described in section 6.3.1, the following describes an optical system for life activity detection which does not require such a high spatial resolution and which is suitable for a case of easily (generally) detecting a life activity at a low cost by use of a simplified optical system for life activity detection.

In the applied embodiment of the optical system for life activity detection described below, a photodetector 36 is disposed at an image forming position corresponding to a detected point 30

for life activity in a life object (at a location where a photo detecting cell corresponding to a detecting section thereof is placed), as shown in Fig. 20. An imaging lens 57 is automatically moved in an optical axial direction in accordance with movement of the life object (an examinee) so that the photodetector 36 always comes at the image forming position corresponding to the detected point 30 for life activity even if the life object (the examinee) moves.

More specifically, when the life object (the examinee) moves and the photodetector 36 comes off from the image forming position, a direction and a moving amount of the life object (the examinee) are estimated (the alignment operation corresponding to (1) and (2), partially) by use of the method described in section 6.2.2 and Fig. 16. If a necessary correction amount is found as a result of that, the imaging lens 57 is moved in the optical axial direction automatically to be corrected, as position control corresponding to the remaining operation of (2) in section 6.1.3.

In an exemplary embodiment shown in Fig. 20, the imaging lens 57 works in conjunction with a forwarding motor (not illustrated in the figure), and the imaging lens 57 moves along the optical axial direction in accordance with the drive operation of the forwarding motor.

Here, the position detection of a measurement subject as described in Fig. 16 uses general visible light. On the other hand, the optical system for life activity detection uses near infrared light (or infrared light). In view of this, a color filter 60 is disposed in the middle of the optical paths 33 of the detection light so that the visible light used for the position detection of the measurement subject is not mixed into the optical system for life activity detection as noise components.

Here, assume a case where a neuron fires an action potential at the detected point 30α for life activity. When the neuron fires an action potential to change the membrane potential 20, light absorption in the wavelengths of near infrared light (or infrared light) described in section 4.7 occurs for a short time. As a result, diffused reflection intensity (or transmitted light intensity) of light having the corresponding wavelength at the position α decreases. As shown in Fig. 20(a), when the photodetector 36 is disposed at an image forming position corresponding to the detected point 30 for life activity, a life activity detection signal 58 corresponding to the detected point 30 appears only at a photo detecting cell W located at the confocal (imaging forming) position corresponding to the position α in the photodetector 36.

If a neuron fires an action potential at a position δ away from the detected point 30 for life activity (e.g., a location deeper than the detected point 30 for life activity viewed from the life-object surface 41), the optical paths 33 of the detection light reflected diffusely at the position δ (or passing through the position δ) is once condensed at a position ahead of the photodetector 36, and then large-sized detection light having a cross-sectional spot size is projected over a wide area on the photodetector 36. As a result, not only life activity detection signals 58 are detected in a large range from photo detecting cells U to X in the photodetector 36, but also the detection signal amplitude of a life activity detection signal 58 detected from one photo detecting cell is largely reduced in comparison with Fig. 20(a).

In view of this, only when a large life activity detection signal 58 having a large detection signal amplitude is obtained only from one photo detecting cell, it is judged that a life activity on the detected point 30 for life activity is detected, and the life activity detection signal 58 is extracted.

On the other hand, if action potentials are fired at non-image forming positions like Fig. 20(b), the life activity detection signals 58 detected in the respective photo detecting cells U to X have a very small detection signal amplitude in most cases, so that they cannot be detected and are buried among noise components.

The above explanation deals with a case where the membrane potential changing in the nervous system is detected as the life activity detection signal 58. The present exemplary embodiment is not limited to this, and in a case where the oxygen concentration change in blood in surrounding areas is detected, it is necessary that a plurality of optical systems for life activity detection shown in Fig. 20 be disposed, and color filters 60 for selectively transmitting light having wavelengths of 780 nm, 805 nm, and 830 nm, respectively, be disposed in the middle of the optical paths 33 of the detection light. Then, light beams having respective wavelengths of 780 nm, 805 nm, and 830 nm are detected separately, and a ratio between them in detection light amount is calculated per photo detecting cell.

When a life activity detection signal 58 is obtained from the detected point 30 for life activity located at an image forming position corresponding to the photodetector 36 as shown in Fig. 20(a), a ratio of a detection light amount from a specific photo detecting cell changes prominently.

Therefore, only a detection signal having a prominent ratio in detection light amount, in comparison with the other photo detecting cells, is extracted as a life activity detection signal 58. Adversely, when respective ratios in detection light amount are not so different between adjacent photo detecting cells U, V, and W, they may be in the state of Fig. 20 (b). In view of this, signals of these cells are not extracted as the life activity detection signal 58.

Thus, (A) when detection light amounts obtained from neighboring photo detecting cells are compared with each other and a value (or a ratio) of a specific photo detecting cell is largely changed (has a high spatial resolution in the photodetector 36), only a signal component of the specific photo detecting cell is extracted as the life activity detection signal 58. Alternatively, the life activity detection signal 58 may be extracted (B) according to a time-dependent variation, in each photo detecting cell, of a ratio in detection light amount between the detection light beams having respective wavelengths of 780 nm, 805 nm, and 830 nm, or (C) by comparing values obtained during detection with preliminarily measured values (reference values) of the ratio in detection light amount of the detection light beams having respective wavelengths of 780 nm, 805 nm, and 830 nm.

Further, in addition to that, the optical system for life activity detection as illustrated in Fig. 20 may be applied to the temperature change measurement by the thermography. In this case, the optical system for position detection as illustrated in Fig. 16 may be also used together for alignment. That is, as shown in Fig. 20, when that part inside the life object which is deeper than the life-object surface 41 is activated, the bloodstream increases and the temperature of the life-object surface 41 increases locally. A temperature distribution of the life-object surface 41 at this time is measured, and an activation state at the detected point 30 for life activity is measured indirectly. In this case, the temperature distribution of the life-object surface 41 is extracted as a life activity detection signal 58.

In a case where at least one of the "membrane potential changing in the nervous system" and the "oxygen concentration change in blood in surrounding areas" is detected, a CCD sensor can be generally used as the photodetector 36 of Fig. 20. In a case where a local high-speed change in the detected point 30 for life activity is detected continuously (through time), a response speed of the CCD sensor is not enough for the detection. In this exemplary embodiment, preamps are

provided for respective photo detecting cells 38-01 to 38-15 disposed in a two-dimensional manner, so that detection light amounts of the photo detecting cells 38-01 to 38-15 are detected in parallel at the same time and a local high-speed change in the detected point 30 for life activity is detected continuously (through time).

A configuration on the photodetector 36 in such a case is shown in Fig. 21. A photo detecting cell group constituted by photo detecting cells 38-01 to photo detecting cells 38-05 is a one-dimensional alignment photo detecting cell, similarly to Fig. 19(b) and (c). The photo detecting cells 38-01 to 38-05 are individually and directly connected to respective front parts 85 of the life activity detection circuit.

The photo detecting cell 38 and its corresponding front part 85 of the life activity detection circuit are formed in a monolithic manner on a semiconductor chip of the photodetector 36 (by patterning together on the same semiconductor chip). Alternatively, the photo detecting cell 38 and its corresponding front part 85 of the life activity detection circuit may be formed in a hybrid manner in which they are constituted by separate semiconductor chips and disposed side by side on a surface of the photodetector 36.

The front part 85 of the life activity detection circuit corresponding to the photo detecting cell 38 includes a preamp and a simple signal processing circuit (a pulse counting circuit) incorporated therein, and its output is connected to a detection signal line 62 output from a front part and a rear part of the detecting circuit. Since the photo detecting cells 38 are connected to their corresponding front parts 85 of the life activity detection circuit in the photodetector 36, a life activity detection signal can be extracted stably and accurately without receiving any influence of disturbance noise even if the signal is very weak.

Adjacent to the photo detecting cell group constituted by the photo detecting cells 38-01 to the photo detecting cells 38-05, a photo detecting cell group constituted by photo detecting cells 38-11 to photo detecting cells 38-15 is disposed with some space, and each of the photo detecting cells 38 is connected to its corresponding front part 85 of the life activity detection circuit. With the use of the photo detecting cells 38-01 to the photo detecting cell 38-15 thus disposed in a two-dimensional manner, each life activity occurring in two dimensions of the detected point 30 for life activity can be detected independently at high speed and continuously.

On the photodetector 36 shown in Fig. 21, the front parts 85 of the life activity detection circuit corresponding to the photo detecting cells 38 are disposed in a large area. As a technical device to prevent detection light from the detected point 30 for life activity from being project on this area, as shown in Fig. 22, a lenticular lens 68 is disposed in the middles of the optical paths 33 of the detection light (between the imaging lens 57 and the photodetector 36). The lenticular lens 68 has a shape in which a plurality of cylindrical lens (in each of which a lens surface partially has a column shape) are provided in line, and has a function to locally change the optical paths 33 of the detection light.

Here, in order to simplify the explanation, Fig. 22 illustrates only optical paths of light rays passing through a center of the imaging lens 57 among the optical paths 33 of detection light rays emitted (reflected diffusely or transmitted) from respective spots on the detected point 30 for life activity. By use of optical refraction by the lenticular lens 68 in Fig. 22, the detection light rays emitted from the respective spots on the detected point 30 for life activity reach the photo detecting cells 38-2 to 38-4. However, the front parts 85 of the life activity detection circuit corresponding to the photo detecting cells 38 are configured not to be illuminated with these detection light rays.

In the meantime, the exemplary embodiment illustrated in Fig. 22 employs the lenticular lens 68, so that light (or an electromagnetic wave) from the detected point 30 for life activity is projected not on a region where the front parts 85 of the life activity detection circuit corresponding to the photo detecting cells 38 in the photodetector 36 are provided, but only on a region where the photo detecting cells 38 are provided.

However, the present exemplary embodiment is not limited to this, and other polarizing elements or partial light-blocking elements for projecting light only on a particular region in the photodetector 36 may be disposed on the way of the optical paths 33 of the detection light to the photodetector 36. As an example of the other polarizing elements mentioned above, a blazed diffraction element (having an inclination in a specific region) (e.g., a diffraction grating having a characteristic that the transmittances of 0th-order light and -1st-order light are almost 0%, and the transmittance of +1st-order light is almost 100%) can be used.

6.3.3) Method for detecting high-speed change of Nuclear Magnetic Resonance property

As another applied embodiment of this exemplary embodiment, a method for detecting a high-speed change of a Nuclear Magnetic Resonance property is described below with reference to Fig. 23 and Fig. 24.

When one neuron fires an action potential, its membrane potential changes temporarily, which causes absorption of electromagnetic waves in the range of chemical shift values described in section 5.2 due to Nuclear Magnetic Resonance (excitation by magnetic resonance in a hydrogen nucleus) and emission of an electromagnetic wave based on excitation relaxation occurring just after that.

On the other hand, when a specific region (a relatively wide region constituted by a plurality of neurons) in the nervous system is activated, the plurality of neurons in the specific region repeats firing of their action potentials in a short time. In view of this, an activation state in the specific area in the nervous system can be detected as a life activity detection signal by using MRI or fMRI not as a single action potential in one neuron, but as a signal averaged in a specific time range in a specific spatial region. Accordingly, in an alternative exemplary embodiment of the embodiment described in section 6.3.1 or 6.3.2, a local change of the Nuclear Magnetic Resonance property in the range of chemical shift values described in section 5.2 is detected by use of MRI (Magnetic Resonance Imaging) or fMRI (functional MRI) and thereby a life activity detection signal corresponding to the membrane potential changing of the neuron is detected.

However, in this alternative exemplary embodiment, a temporal resolution of the life activity detection signal which can be detected has only a level equal to that of the current MRI or fMRI. In this regard, since the temporal resolution and the spatial resolution are low in Conventional Technique 2, a single action potential of one neuron cannot be detected.

Fig. 23 shows another applied embodiment which can solve this problem and detect an internal high-speed change of the Nuclear Magnetic Resonance property. In Fig. 23(a), a plane where a (superconducting) magnet 73 and a coil 72 for magnetic field preparation are provided, a plane where an excitation coil 74 is provided, and a plane on which a two-dimensionally arranged cell array 71 for detecting a change of the Nuclear Magnetic Resonance property are arranged at right angles to each other. Herein, similarly to the conventional MRI or fMRI, the (superconducting) magnet 73 is used for application of a DC magnetic flux density from the outside. Furthermore,

a coil 72 for magnetic field preparation is disposed for spatial distribution correction of the magnetic flux density to form a uniform magnetic flux density in a part 75 of an organism to be detected (the head of an examinee) and for fine adjustment of a value of the DC magnetic flux density in accordance with the chemical shift values described in section 5.2. This coil 72 for magnetic field preparation may be used in the conventional MRI device or fMRI device in some cases.

Here, the head of a human body is mainly assumed a target for the detection of life activity as a target organism for the measurement in the applied embodiment shown in Fig. 23. However, the applied embodiment is not limited to this, and the detection of life activity may be performed on visceral organs such as the heart in the human body or an inside of limbs. Further, the organism is not limited to mammals such as dogs or cats, and any organisms including microorganisms may be set at the part 75 of the organism to be detected.

Further, this applied embodiment has a feature that "the part 75 of an organism to be detected (the head of an examinee) can be taken in or out through the excitation coil 74." Accordingly, by increasing the excitation coil 74 in size, the detection of life activity can be performed on an inside of a large organism like a human. This also yields such an advantage that a surface to detect a high-speed change of the Nuclear Magnetic Resonance property (a plane where the two-dimensionally arranged cell array 71 for detecting the change of the Nuclear Magnetic Resonance property is disposed) can be used freely. The following describes this situation more specifically. In order to detect the life activity, it is necessary to put a part 75 of the organism to be detected in or out of a region where respective DC magnetic flux densities formed by the (superconducting) magnet 73 and the coil 72 for magnetic field preparation are distributed over, and the following conditions are required: a) a space to provide the part 75 of the organism to be detected is secured in the area where the DC magnetic flux densities are distributed over; and b) a space where the part 75 of the organism to be detected can be put in and out is secured.

These conditions are also required even in the conventional MRI device or fMRI device. However, in these conventional devices, the space where the part 75 of the organism to be detected can be put in and out is often provided at a detecting-coil side (not illustrated in Fig. 23), which is provided for detection of a change of the Nuclear Magnetic Resonance property.

In the meantime, as shown in the applied embodiment of Fig. 23, there is no space where the part 75 of the organism to be detected can be put in and out, on a plane on a side of the (superconducting) magnet 73 for generating a DC magnetic flux density. If the space where the part 75 of the organism to be detected is put in and out is set at a side of a plane to detect a change of the Nuclear Magnetic Resonance property (the plane where the two-dimensionally arranged cell array 71 for detecting a change of the Nuclear Magnetic Resonance property is disposed) like in the conventional MRI device or fMRI device, the physical arrangement on this plane is largely restricted, thereby largely impairing the degree of freedom of the detection method of a change of the Nuclear Magnetic Resonance property. In contrast, the arrangement in Fig. 23 largely improves the degree of freedom of the detection method of a change of the Nuclear Magnetic Resonance property.

However, since a length (circumference) around the excitation coil 74 is longer in the arrangement of Fig. 23, a resistance value in the excitation coil 74 rises, thereby causing a problem that a frequency characteristic of the excitation coil 74 easily decreases. This applied embodiment has such a technical device that the cross section of a wire rod constituting the excitation coil 74 is widened so as to decrease the resistance value, thereby solving the above problem.

The applied embodiment illustrated in Fig. 23 has the following features: a plurality of detection cells 80 for detecting a change of the Nuclear Magnetic Resonance property, each including a detecting coil 84 for detection of life activity having a circumference shorter than that of the excitation coil 74, are disposed two-dimensionally in an array form (see Fig. 23(a)); and one detection cell 80 for detecting a change of the Nuclear Magnetic Resonance property is configured to include a front part 85 of the life activity detection circuit, so as to have an amplification function (a preamp function) of a detection signal obtained from the detecting coil 84 and a signal processing function equivalent to a front-part level (see Fig. 23(b)).

Here, when a single circumference of the detecting coil 84 is set to be shorter than the excitation coil 74, the resistance value in the detecting coil 84 is reduced and a frequency characteristic of the signal detection by the detecting coil 84 is improved. This makes it possible to detect a life activity detection signal changing at high speed more accurately.

In the meantime, since a preamp is provided outside a detecting coil (not illustrated in Fig. 23) in the conventional MRI device or fMRI device, disturbance noises are mixed in through a cable between the detecting coil and the preamp. On the other hand, in this applied embodiment, one detection cell 80 for detecting a change of the Nuclear Magnetic Resonance property is configured to have the preamp function to a detection signal obtained from each detecting coil 84 and the signal processing function equivalent to the front-part level, so that the mixture of disturbance noises is reduced and a life activity detection signal can be obtained stably and accurately.

This feature is described below, more specifically. As shown in Fig. 23(a), two-dimensionally arranged cell arrays 71 for detecting a change of the Nuclear Magnetic Resonance property, which is one type of a life activity detection signal, are disposed at both of a shallower side (not illustrated) and a deeper side of a part 75 of an organism to be detected (the head of an examinee), on the page space. In each of the two-dimensionally arranged cell arrays 71 for detecting a change of the Nuclear Magnetic Resonance property, detection cells 80 for detecting a change of the Nuclear Magnetic Resonance property, each having a configuration as illustrated in Fig. 23(b), are arranged two-dimensionally so as to form an array configuration.

Here, as shown in Fig. 23(b), a power line and ground line 81 to be provided in a front part 85 of the life activity detection circuit and a transmission line 82 for system clock + time stamp signal are disposed so as to be at right angles to the detecting coil 84. The reason is as follows: such an arrangement prevents not only transmission signals (a system clock and a time stamp signal) flowing through the transmission line 82 for system clock + time stamp signal from leaking to the detecting coil 84, but also the power line and ground line 81 from affecting the detecting coil 84 adversely. On the other hand, in this applied embodiment, a timing of detection of a change of the Nuclear Magnetic Resonance property (detection of life activity) is switched into an output timing of a life activity detection signal output from the front part 85 of the life activity detection circuit and vice versa, thereby improving detection accuracy of the detection of a change of the Nuclear Magnetic Resonance property (detection of life activity). Alternatively, as shown in Fig. 23(b), if the output line 83 for a life activity detection signal is disposed at right angles to the detecting coil 84, it is possible to prevent an output signal from the

output line 83 for a life activity detection signal from leaking to the detecting coil 84. This makes it possible to simultaneously perform the detection of a change of the Nuclear Magnetic Resonance property (detection of life activity) and the output of a life activity detection signal, so that the detection of a change of the Nuclear Magnetic Resonance property (detection of life activity) can be performs over a long period of time.

When one neuron fires an action potential, its membrane potential changes temporarily, which causes absorption and emission of an electromagnetic wave corresponding to the chemical shift value described in section 5.2. An absorption/emission characteristic of the electromagnetic wave changes in accordance with the action potential pattern, and its change signal appears in the detecting coil 84.

Although omitted in Fig. 23(b), an end part of this detection coil 84 is directly connected to a preamp in the front part 85 of the life activity detection circuit. Accordingly, when a life activity detection signal corresponding to the action potential pattern occurring in one neuron appears in the detecting coil 84, the life activity detection signal is amplified by the preamp. The signal thus amplified passes through a band-pass filter (or a detector circuit) tuned up with electromagnetic wave frequencies supplied from an excitation coil 74 in the front part 85 of the life activity detection circuit so that only an electromagnetic wave component corresponding to the chemical shift value is taken out, and the signal is converted into a digital signal by an A/D converter (Analog to Digital Converter) and temporarily stored in a memory section. The S/N ratio of the detection signal is largely improved due to the operation of the band-pass filter (or the detector circuit) as such. However, this detection signal is very weak, and therefore is subjected to signal processing (front-part processing) to increase the detection accuracy more in the front part 85 of the life activity detection circuit.

That is, since an action potential pattern to occur in a neuron is determined in advance, the action potential pattern corresponding to that is stored in the front part 85 of the life activity detection circuit. Then, a pattern matching calculation is performed between this detection pattern corresponding to the action potential stored in advance and a detection signal temporarily stored in the memory section (note that standardization processing of an amplitude value is performed at this time) at different checking timings. When a calculation result of the pattern

matching is larger than a specific value, it is considered that an action potential of the neuron has occurred, and a "detection time" and a "detection amplitude value" are temporarily stored in the memory.

As has been described in section 1.3, the term 24 of nerve impulse is about 0.5 to 4 ms. Accordingly, in order to perform the signal processing on this change accurately and efficiently during the term, it is desirable that a system clock frequency transmitted in the transmission line 82 for system clock + time stamp signal in Fig. 23(b) be in a range from 10 kHz to 1 MHz. A time stamp signal is given as a counter value incremented by 1 per each clock along this system clock frequency ("1" is added per each system clock). Further, this time stamp signal (this binary counter value is synchronized with the timing of the system clock and transferred along NRZI (Non Return to Zero Inverting)) and the system clock repeated specific number of times are arranged alternately through time and transferred. A time when a top bit of this time stamp signal has arrived at the front part 85 of the life activity detection circuit is taken as a "time indicated by the time stamp signal" and all the detection cells 80 for detecting a change of the Nuclear Magnetic Resonance property are synchronized with this time.

Initially, in the front part 85 of the life activity detection circuit, the "detection time" and the "detection amplitude value" of the action potential of the neuron are temporarily stored in the memory in response to a transmission signal from the transmission line 82 for system clock + time stamp signal. The information thus stored in the memory for a specific period of time is output to the output line 83 for a life activity detection signal at a timing designated from the outside.

Here, in the output line 83 for a life activity detection signal, an output timing is assigned to each detection cell 80 for detecting a change of the Nuclear Magnetic Resonance property, and the signal temporarily stored in the memory is transmitted over the output line 83 for a life activity detection signal at the timing thus designated in advance.

As such, signals from all the detection cells 80 for detecting a change of the Nuclear Magnetic Resonance property collected in the output line 83 for a life activity detection signal are used for: (a) achievement of high accuracy and high reliability of a detection signal based on a statistic process; and (b) calculation of an action-potential firing (or activated) area in a life object. The

above (a) and (b) are performed in a rear part (not illustrated in the figure) of the life activity detection circuit.

The following describes the former process at first. Every signal from all the detection cells 80 for detecting a change of the Nuclear Magnetic Resonance property includes a "detection time" of an action potential. Accordingly, when an action potential can be detected precisely, a detection signal of the action potential is obtained from a neighboring detection cell 80 for detecting a change of the Nuclear Magnetic Resonance property at the same timing.

Therefore, if no detection signal of the action potential is obtained from the neighboring detection cell 80 for detecting a change of the Nuclear Magnetic Resonance property at this timing, it is considered that there occurs "false detection" in a specific front part 85 of the life activity detection circuit, which is then removed from detection targets. By performing a comparison process on signals (detection times of action potentials) obtained from such a plurality of detection cells 80 for detecting a change of the Nuclear Magnetic Resonance property, higher accuracy and higher reliability of the detection signal can be achieved.

With reference to Fig. 24, the following describes a calculation method of an action-potential firing (or activated) area in a life object, which calculation method is performed by a rear part of the life activity detection circuit. When an action potential is fired by a neuron at a position α in a part 75 of an organism to be detected (the head of an examinee), a detection signal can be obtained from each spot within a two-dimensionally arranged cell array 71 for detecting a change of the Nuclear Magnetic Resonance property. According to the electromagnetics, a detected amplitude value of the detection signal obtained from each spot within the two-dimensionally arranged cell array 71 for detecting a change of the Nuclear Magnetic Resonance property can correspond to an intensity distribution of a magnetic field formed by a dipole moment (point magnetic charge) at the position α.

That is, the detected amplitude value of the signal obtained from each spot (π, ρ, σ, υ, ψ) within the two-dimensionally arranged cell array 71 for detecting a change of the Nuclear Magnetic Resonance property is inversely proportional to a square of a distance (r_π r_ρ, r_σ, r_υ, r_ψ) from each spot to the position α. In view of this, after smoothing "detected amplitude values" at the same "detection time" obtained from respective detection cells 80 for detecting a change of

the Nuclear Magnetic Resonance property so as to remove spike noise components, the relationship illustrated in Fig. 24 is used. As a result, it is possible to estimate an activated area in the part 75 of the organism to be detected (the head or the like of the examinee).

The estimation of an activated area corresponds to the extraction of a life activity detection signal in (3) of section 6.1.3. Accordingly, it is necessary to align an extraction location of a life activity detection signal or to identify the extraction location as described in (1) and (2) of section 6.1.3. For this operation, it is necessary to measure, in advance, an internal water concentration distribution pattern or an internal fat concentration distribution pattern according to the conventional MRI detection method by use of the signal detecting section described in Fig. 23 or the conventional MRI device. Subsequently, an image pattern obtained by the conventional MRI detection method and an extraction result of the life activity detection signal are combined, and alignment (identification of a location) of an activated area (or a region where action potentials are fired frequently) is performed.

Then, from the rear part of the life activity detection circuit provided in the signal detecting section (see section 6.1.3 about the definitions of the terms), "a signal of an internal activated area (a signal of a location and a range of an activated region)," "a signal of action-potential numbers per area during each setting term," "an internal signal transmission pathway based on a firing rate in an activated area," or the like is output as a life activity detection signal.

6.3.4) Method for reducing interference from other adjacent life activity detection systems

In the measuring method of life activity in the present exemplary embodiment, an amount of a life activity detection signal is very small, and in addition, it is necessary to illuminate a measurement subject with illuminating light for life activity detection. Therefore, in a case where a plurality of different detecting sections 101 for life activity are disposed at positions in proximity to each other, there is such a risk that a detecting section 101 for life activity may be affected (interfered) by illuminating light 115 for life activity detection from another detecting section 101 for life activity. In order to reduce this interference, in this exemplary embodiment, each illuminating light 115 for life activity detection has identification information, so that a degree of influence from other illuminating light 115 for life activity detection is measurable quantitatively. This makes it possible to offset interference by a computing process at a

detection side, thereby yielding an effect that high accuracy for the detection of life activity can be secured even if there are some physical interference to each other.

The following describes the method in which each illuminating light 115 for life activity detection is configured to have identification information. As has been described in the explanation in section 4.7 (about the detection of a weak signal), intensity modulation is performed on the illuminating light 115 for life activity detection with the use of the modulation signal generator 113 or 118 in advance. The present exemplary embodiment employs, as the modulation method, a modulation method called MSK (Maximum Shift Keying) using a (time-serial) combination of only two types of frequencies, i.e., a basic frequency and a frequency of 1.5 times the basic frequency. Fig. 27(a) shows the method in which each illuminating light 115 for life activity detection is configured to have identification information by use of MSK. An illuminating time of the illuminating light 115 for life activity detection is divided into a term 440 of detection of life activity and an inherent information expressing term 441 of a detecting section for life activity. Here, during the term 440 of detection of life activity, the illuminating light 115 for life activity detection 115 is subjected to intensity modulation with a single frequency of only a basic frequency and with constant amplitude, and life activities are detected during this term. Further, in a case where a life activity is controlled, a measurement subject is illuminated with strong and continuous illuminating light 115 for life activity detection (linear illuminating light without intensity modulation) only for a specific period within in this term 440 of detection of life activity. On the other hand, during the inherent information expressing term 441 of a detecting section for life activity, the illuminating light 115 for life activity detection is modulated based on MSK. Even in a case where a life activity is controlled, the intensity and the modulation method of the illuminating light 115 for life activity detection are maintained to be the same as during the term of detection. Hereby, the illuminating light 115 for life activity detection can be stably detected during the inherent information expressing term 441 of detecting section for life activity. Thus, the identification information of each illuminating light 115 for life activity detection can be recognized regardless of the detection term or the control term of life activity.

A modulation state of the illuminating light 115 for life activity detection during the inherent

information expressing term 441 of a detecting section for life activity is shown in Fig. 27(b). An intensity modulation period at a frequency of 1.5 times the basic frequency continues during a period of a synchronous signal 451. Accordingly, a start timing of the inherent information expressing term 441 of a detecting section for life activity can be easily found by detecting this synchronous signal 451. After that, illuminating light 115 for life activity detection is generated based on an originally combinatorial pattern of: the basic frequency, which is based on the MSK frequency and corresponds to ID information 452 for manufacturer identification of the detecting section for life activity; and a frequency of 1.5 times the basic frequency. By identifying the ID information 452 for manufacturer identification of the detecting section for life activity, the detecting section 101 for life activity can identify a manufacturer which manufactured a detecting section for life activity disposed at an adjacent position. Subsequently, an original combinational pattern of a basic frequency indicative of identification information 453 of a corresponding detecting section for life activity and a frequency of 1.5 times the basic frequency appears. In this exemplary embodiment, a production number of a corresponding detecting section for life activity is shown as the identification information 453, but alternatively, if all detecting sections for life activity have different patterns (information), the identification information 453 may have other information except the production number. Original information 454 related to a manufacture, which can be set by the manufacturer subsequently to the identification information 453, can be shown by the MSK modulation.

Next will be explained a method to remove influence in terms of signal processing in case where interference occurs between different detecting sections for life activity. Light emissions are not synchronized between the different detecting sections for life activity, and therefore inherent information expressing terms 441 of the detecting sections for life activity come at different timings. In a term 440 of detection of life activity during which one detecting section for life activity emits light, an inherent information expressing term 441 of another detecting section for life activity in another device may also occur at the same time. In this case, during the term 440 of detection of life activity during which the one detecting section for life activity emits light, modulated light with a frequency of 1.5 times the basic frequency leaks therein, so that interference of the light can be found immediately. Further, during a period of a

synchronous signal 451, intensity modulation is continued with the frequency of 1.5 times the basic frequency, so that a leakage level (interference level) can be detected accurately by comparing amplitude values at respective frequencies after the spectrum analysis. A computing process is performed based on the detection result, thereby largely removing the influence from other detecting sections 101 for life activity. Thus, when each illuminating light 115 for life activity detection is configured to have identification information as illustrated in Fig. 27, the life activity can be detected stably and highly accurately even if interference occurs from other detecting sections 101 for life activity.

6.5) Measuring method of life activity

6.5.4) Other measuring methods of life activity

The nervous system of a mammalian animal including a human has a hierarchical structure. In a central nervous system layer 7 such as the cerebral cortex layer, very complicated neural circuits are formed, and therefore, it is very difficult to generate personal information or even life activity information from a life activity detection signal detected therefrom.

However, the neural circuits between layers are connected with each other, so that activities are performed in cooperation with the respective layers.

In view of this, another exemplary embodiment has a feature in that "life activity information is generated from a life activity detection signal of a lower layer and thereby life activity information of a higher layer is estimated" as measures to the difficulty in acquiring life activity information related to the central nervous system layer 7 including the cerebral cortex layer or the limbic system.

It is said that an amygdala takes a central role in regard to the emotional reaction in the brain of a human or an animal, and the emotional reaction is expressed in a central amygdaloid nucleus (Hideho Arita: Nounai busshitsu no sisutemu shinkei seirigaku (Chugai-igakusha, 2006) p. 105). An output signal from the central amygdaloid nucleus is directly input into a facial motor nucleus (Masahiko Watanabe: Nou Shinkei Kagaku Nyumon Koza (Ge) (Yodosha, 2002), p. 222).

Here, this facial motor nucleus works on a facial muscle to control a facial expression. Accordingly, the emotional reaction expressed in the central amygdaloid nucleus appears on the facial expression directly.

On the other hand, a neural circuit directly output from the central amygdaloid nucleus to the cerebral cortex does not exist remarkably, and an output signal from this central amygdaloid nucleus reaches a prefrontal area via a medial nucleus in the amygdala, for example. In addition to that, this medial nucleus receives signal inputs from other areas in the amygdala, the thalamus, or the hypothalamus (Masahiko Watanabe: Nou Shinkei Kagaku Nyumon Koza Gekan (Yodosha, 2002), p. 221).

When an output signal from the central amygdaloid nucleus reaches the prefrontal area with some change affected by these signals, a feeling recognized in the prefrontal area becomes slightly different from the emotion under subconsciousness occurring in the central amygdaloid nucleus. This indicates such a possibility that "a facial expression exhibits an emotion more accurately than a person is aware of."

In view of this, another embodiment explained herein has a feature in that instead of obtaining a life activity detection signal from the central nervous system layer 7 including the cerebral cortex layer, movement of a facial muscle formed by an action from the facial motor nucleus is detected, and life activity information is generated from the detection signal. Accordingly, without a need to obtain life activity information from the central nervous system layer 7 (including the cerebral cortex layer or the limbic system) for which interpretation of life activity is very complicated and difficult, information about the emotional reaction related to the limbic system or the cerebral cortex can be obtained accurately from a result of "interpretation of the movement of the facial muscle" for which the interpretation is relatively easy.

In this case, the marked position 40 on the life-object surface as shown in Fig. 16 corresponds to a facial position of the examinee (or user). In the meantime, there have been digital cameras with a function to automatically detect a facial position of a subject by use of an image recognition technique in these days. In view of this, in this another embodiment explained herein, the position monitoring section regarding a detected point for life activity (a section for performing the first detection) is configured to have the image recognition technique, and a detection signal from the facial position of the examinee (or user) is assumed as a life activity detection signal.

Further, in a case where the another exemplary embodiment described herein is performed, an

imaging pattern size is standardized to a size to show a whole face of the examinee (or user) and stored in the memory section 142 of the rear part, at a stage of the process of "A] changing of an imaging pattern size (standardization of the size)". If the face size of the examinee is standardized to a predetermined size as such regardless of how small/large the face of the examinee is or how far a distance between the examinee and the signal detecting section 103 is, easiness and accuracy of position detection of eyes or a mouth in the face are improved, thereby making it easy to generate the life activity information from the life activity detection signal.

Fig. 25 shows relationships between a facial expression and an emotional reaction. Fig. 25(a) shows a facial expression during rest, Fig. 25(b) shows a facial expression at the time of smiling, Fig. 25(c) shows a facial expression at the time of getting angry, and Fig. 25(d) shows a facial expression at a loss (they may be difficult to be distinguished from each other due to poor drawings, but intend to show the respective facial expressions). An expression shows a feeling of the examinee (or user). Muscular movements on the face at this time are shown with arrows in Fig. 26. At the time of smiling as in Fig. 25(b), outside muscles of eyebrows and eyes contract downward. Further, outside muscles of a mouth contract upward and outward. At the time of getting angry as in Fig. 25(c), outside muscles of eyebrows and upper eyelids contract upward, and muscles of lower eyelids contract downward. At the same time, outside muscles of a mouth contract downward and outward. On the other hand, at the time of being at a loss as shown in Fig. 25(d), inside muscles under eyebrows contract toward the inside. Further, at the same time, muscles around lower eyelids contract to raise lower eyelids upward. As such, the detection result of contraction and relaxation states of facial muscles is correlated with life activity information corresponding to the emotional reaction or the like.

When the facial muscle contracts, activation of the neuromuscular junction 5 (a change of a membrane potential) and subsequent potential changing 27 of a muscle fiber membrane occur. Accordingly, the change of the membrane potentials can be detected by use of the near infrared light/infrared light as shown in section 4.7 sections or the Nuclear Magnetic Resonance as shown in section 5.2.

Further, when the facial muscle contracts, an oxygen concentration change occurs in capillaries around the facial muscle, so that the "detection of oxygen concentration change in blood in

surrounding areas" is enabled by use of near infrared light.

Moreover, when the facial muscle contracts or repeats contraction and relaxation, heat generated from the inside of the muscle reaches a surface of the face, thereby locally increasing the temperature on the skin surface of the face. Accordingly, even if the distribution of temperature on the skin surface of the face is measured using a thermography, the detection of life activity can be performed in regard to activities of the facial muscle.

11) Other Applied Embodiments regarding Detection/Control of Life Activity

11.1) Other life activity phenomena of which contracted and relaxed states of skeletal muscle are to be detected/controlled

As examples of dynamical life activities occurring in a life object, chapters 1 to 5 mainly dealt with methods for detecting an action potential state and a signal transmission state of the nervous system. However, the present exemplary embodiment is not limited to them, and every "detection, measurement, or control of dynamical life activities in a life object by a non-contact method" will be included in the present exemplary embodiment or the applied embodiments. In the explanation of section 6.5.4 with reference to Figs. 25 and 26, the detection of a signal transmission state to the neuromuscular junction (an activation of the neuromuscular junction 5) is used for the detection of contraction and relaxation states of a skeletal muscle. As an applied embodiment of the above exemplary embodiment, chapter 11 explains a method for directly detecting an actual contraction state and an actual relaxation state of a skeletal muscle, and a principle thereof. Further, a method for controlling contraction/relaxation of a skeletal muscle by use of the detection principle is also explained herein.

According to B. Alberts et. al.: Molecular Biology of the Cell, 4th Edi. (Garland Science, 2002) Chap. 16, a process of contraction of a skeletal muscle is mainly constituted by the following two steps:

a] control to enable contraction of the skeletal muscle by release of calcium ions into a muscle cell; and

b] contraction of the skeletal muscle by migration of Myosin to actin filaments in the muscle cell.

Meanwhile, the "signal transmission to the neuromuscular junction (the activation of the neuromuscular junction 5)" explained in section 6.5.4 occurs as a front step right before the

above step [a].

In the contraction step of the skeletal muscle in [b], "deformation of Myosin," "attachment of a Myosin head to actin filaments," "restoration of a Myosinshape in a contact state," and "detachment of the Myosin head from the actin filaments" are repeated. Here, the "deformation of Myosin" occurs by using hydrolysis of ATP (Adenosine triphosphate). That is, a part of the Myosin includes a specific enzyme called Myosin ATPase, and when ATP in which three phosphoryls are connected in series bonds thereto, one neighboring water molecule is incorporated therein and one of the phosphoryls is removed from the bond.

Thus, the contraction of the skeletal muscle requires "attachment of a Myosin head to actin filaments." However, in relaxation of the skeletal muscle, Tropomyosin occupies this bonding site, and obstructs the "attachment of a Myosin head to actin filaments." Meanwhile, when the "signal transmission to the neuromuscular junction (the activation of the neuromuscular junction 5)" explained in section 6.5.4 occurs, a large quantity of calcium ions flow into this site as the step [a]. When the calcium ion thus flowing in at this time bonds to Troponin, Tropomyosin connected to the Troponin is displaced, and the "attachment of a Myosin head to actin filaments" is enabled. When this calcium ion bonds to the Troponin, it is estimated that an ionic bond is formed between a residue of Aspartate included in the Troponin or a carboxyl group constituting a part of a residue of Glutamate, and the calcium ion Ca^{2+}.

11.3) Movement mechanism of Myosin ATPase

A partial molecular structure where ATP bonds to an active site having a function of Myosin ATPase in Myosin is described on p. 15850 in I. Rayment: Journal of Biological Chemistry vol. 271 (1996), and an extract of its principal part is shown in Fig. 29. In Fig. 29, a bold solid line indicates a covalent bond, a bold wavy line indicates an ionic bond, and a vertical line made up of lateral continuous lines indicates a hydrogen bond. Further, an arrow of a fine solid line indicates a biased direction of an electron probability distribution of a bonding orbital (an electron cloud density distribution). Here, ATP has a molecular structure in which three phosphoryls are connected to adenosine in series, but in Fig. 29, a state where one phosphoryl is connected to the adenosine is collectively described as AMP (Adenosine monophosphate). It is said that a magnesium ion Mg^{2+} plays an important part in hydrolysis of ATP, and a water

molecule activated by the action of the magnesium ion Mg^{2+} directly works on a bonding site between two phosphoryls to cleave the bonding. Further, an active site having a function of Myosin ATPase in Myosin includes Lysine Lys185 and Asparagine Asn235. Here, the number in Fig. 29 indicates a sequential identification number of amino acid in Myosin, which is a protein.

When ATP bonds to the active site having a function of Myosin ATPase, oxygen atoms $O5^-$ and O2 therein are hydrogen-bonded to a part of a residue of Lysine Lys185 and a part of a residue of Asparagine Asn235. Further, a hydrogen atom H1 in a water molecule around ATP is hydrogen-bonded to an oxygen atom O2 in ATP. On the other hand, a magnesium ion Mg^{2+} forms a weak ionic bond to an oxygen atom O1 in the water molecule, thereby activating the water molecule.

In addition, it is also considered that the magnesium ion Mg^{2+} also forms a weak ionic bond to an oxygen atom O9 in another water molecule, as well as forming weak ionic bonds to two oxygen atoms $O3^-$ and $O8^-$ in ATP. It is said that in a water environment in a life object (about pH 7), ATP is charged with negative electricity, and a γ phosphoryl and a β phosphoryl therein correspond to two negative electric charges and one negative electric charge, respectively.

In Fig. 29, for the convenience of explanation, it is assumed that $O3^-$, $O5^-$ and $O8^-$ are each charged with one negative electric charge. When a residue of Lysine Lys185 and a divalent magnesium ion Mg^{2+},which are charged with positive electric charge in the waters environment in a life object (about pH 7), bond to them, an electrically neutralized state is formed as a whole. When each molecule is placed three-dimensionally to form various bonds as such, an electron existence probability (a density distribution of an electron cloud) around the oxygen atom $O5^-$ in ATP makes a movement α toward a nitrogen atom $N1^+$ charged with positive electricity, via a hydrogen atom H2 in the residue of Lysine Lys185, as has been described in Fig. 57(b). Then, in order to make up for the decrease of the electron cloud density around the oxygen atom $O5^-$, a part of the electron probability of a bonding orbital between a phosphorus atom P1 and an oxygen atom O2 moves in a direction β.

On the other hand, since the oxygen atom O2 bonding two phosphoryls in ATP forms is hydrogen-bonded to a hydrogen atom H6 in a residue of Asparagine Asn235, a part of the electron cloud density distribution located around the oxygen atom O2 slightly moves toward a

nitrogen atom N2 via the hydrogen atom H6 as shown by an arrow γ. Further, in order to make up for an overwhelming lack of the electron cloud density around the magnesium ion Mg^{2+} having two positive electric charges, the electron cloud density distribution makes a movement δ from the vicinity of the oxygen atom O2 via a phosphorus atom P2 and an oxygen atom $O8^-$.

As a result, the electron cloud density around the oxygen atom O2 largely decreases, but since this oxygen atom O2 forms a hydrogen bond to a hydrogen atom H1 in the water molecule, the decrease of the electron cloud density is prevented by use of this hydrogen bonding path. More specifically, the electron probability of a bonding orbital between the oxygen atom O1 and the hydrogen atom H1 in the water molecule decreases as shown by an arrow ε, and the electron existence probability of the hydrogen bond increases. The electrons thus increased work as a bonding orbital between the hydrogen atom H1 and the oxygen atom O2, thereby forming a covalent bond between the hydrogen atom H1 and the oxygen atom O2. Further, the magnesium ion Mg^{2+} draws a peripheral electron cloud density toward its circumference, so that the electron cloud flows in a direction of an arrow ζ.

As a result of this, the electron existence probability of the bonding orbital between the oxygen atom O1 and the hydrogen atom H1 in the water molecule decreases and the covalent bond is changed into a hydrogen bond. In accordance with this change, a distance between the oxygen atom O1 and the hydrogen atom H1 is broadened, but the description about the distance change is omitted in Fig. 29. When the bias of the electron cloud density occurs in the directions shown by the arrows ε and ζ as such, the electron cloud density around the oxygen atom O1 largely decreases, and the water molecule is activated. This causes the oxygen atom O1 to take the electron cloud density around the phosphorus atom P1 adjacent to the oxygen atom O1 so as to make up for the depressed electron cloud density around the oxygen atom O1 (η).

This results in that the electron cloud density increases between the phosphorus atom P1 and the oxygen atom O1, and the electron existence probability works as a bonding orbital between the phosphorus atom P1 and the oxygen atom O1. This forms a covalent bond between the phosphorus atom P1 and the oxygen atom O1. On the other hand, the magnesium ion Mg^{2+} draws a peripheral electron cloud density thereof toward its circumference, so that the electron cloud further flows in a direction shown by an arrow θ. Then, the electron cloud density moves

in the directions shown by the arrows β, γ, δ, η, and θ, which largely reduces the electron existence probability of the bonding orbital between the phosphorus atom P1 and the oxygen atom O2. When an area having an electron existence probability of "0" occurs between the phosphorus atom P1 and the oxygen atom O2 as shown in Fig. 57(c) as a result thereof, the bonding orbital between the phosphorus atom P1 and the oxygen atom O2 changes into an antibonding orbital and the bonding between the phosphorus atom P1 and the oxygen atom O2 is cleaved.

When the hydrolysis mechanism of ATP is summarized, the following things can be said as shown in Fig. 29 (b).

>> The covalent bond between the oxygen atom O1 and the hydrogen atom H1 in the water molecule changes into a hydrogen bond, and the hydrogen bond between the oxygen atom O2 and the hydrogen atom H1 in ATP changes into a covalent bond.

>> In Fig. 29(b), a γ phosphoryl and a β phosphoryl having a phosphorus atom P1 and a phosphorus atom P2 in a center each have a hydroxyl group -OH just after hydrolysis of the ATP in an area where a bond between the phosphorus atom P1 and the oxygen atom O2 changes into a bond between the phosphorus atom P1 and the oxygen atom O1, but a bond between OH is cleaved immediately in the water environment (pH 7) in the body.

The hydrolysis reaction of ATP has a large feature that "a γ phosphoryl (an oxygen atom O5 therein)/a β phosphoryl (oxygen atoms O2 and O6 therein) are respectively hydrogen-bonded to a residue of Lysine Lys185/a residue of Asparagine Asn235" over the reaction.

11.4) Characteristics of detection/control of life activity

Section 11.4 relates to an appropriate wavelength range of an electromagnetic wave (light) to be used at the time of optically detecting/measuring or controlling contracted and relaxed states of a skeletal muscle and performs examination from a wide viewpoint. The appropriate wavelength range at the time of detecting or measuring an action potential state of a neuron has been already explained in section 4.7. This section first discusses the explanation in section 4.7 more specifically, and then discusses a suitable wavelength range of an electromagnetic wave (light) to be used for the detection/measurement or control by a non-contact method with respect to more general dynamical activities occurring "in a life object," as well as the action potential

state of a neuron and the contracted and relaxed states of a skeletal muscle. Subsequently, based on general results of the consideration, an appropriate wavelength range of an electromagnetic wave (light) to be used at the time of detecting or controlling the contracted and relaxed states of a skeletal muscle is discussed.

The present exemplary embodiment or its applied embodiment has a large feature in that:

[1] detection/measurement or control is performed on dynamical life activities occurring "in a life object." A more specific feature thereof is such that: in order to embody the detection/measurement or control,

[2] detection/measurement or control is performed by use of a transition of a vibration mode according to an interaction of an external electromagnetic field (an electromagnetic wave) with a vibration mode which occurs during an activity in the life object or when the activity changes and which is caused by two or more specific atoms in a molecule at that time.

Further, near infrared light is suitable for the electromagnetic wave which can pass through the "life object," and particularly, has a feature that:

[3] a transition between vibration modes which a hydrogen atom (forming a hydrogen bond) involves is easy to interact with near infrared light. This is because a hydrogen atom is the most lightweight among other atoms and therefore is easy to oscillate at high speed (at high frequencies) (in view of classical physics). Accordingly, in an exemplary embodiment or its applied embodiment having the feature [3], absorption changes of near infrared light at a shorter wavelength (high frequency) which is less absorbed by water molecules can be easily detected/measured, which allows detection/measurement or control of life activity in a relatively deep area in the life object.

With regard to the wavelengths which meet the above features in the present exemplary embodiment or the applied embodiment, the following first discusses [1] a range in which detection/measurement or control can be easily performed "in a life object." Visible light does not pass through a human skin and therefore an inside of the human body cannot be observed. In general, visible light having a wavelength of 0.8 μm or less can hardly pass through the life object. In the meantime, when a palm is held against sunlight while fingers are closed, red light can be seen from the gap between the fingers. From such a phenomenon, it can be understood

that light having a wevelength longer than red light passes through a life object to some extent. More specifically, it is demonstrated by experiments that light having a wavelength of 0.84 μm or more passes through skin on a life-object surface to enter the life object easily. On the other hand, as has been described in section 4.7, since infrared light having a wavelength of more than 2.5 μm is easily absorbed by water molecules in a life object (as excitation energy of a symmetrically telescopic vibration, an anti-symmetrically telescopic vibration, and a rotation of water molecules), it is difficult to transmit electromagnetic waves therethrough due to light attenuation. As has been described in section 4.7, water molecules occupy 70% (by weight) of chemical compounds constituting an animal cell, so that a wavelength light beam with a little light attenuation due to absorption by water molecules can pass through a life object. Accordingly, in a case where detection/measurement or control of life activity is performed using an electromagnetic wave which "passes through a life object," it is desirable to use near infrared light having a wavelength in a range from 0.84 μm (or 0.875 μm) to 2.5 μm.

The following discusses [1] a range in which detection/measurement or control can be easily performed "in a life object," more specifically. As has been already described in section 4.7, there are absorption bands corresponding to combinations of a water molecule around center wavelengths of 1.91 μm and 1.43 μm. Further, there is another absorption band around a center wavelength of 0.97 μm, though light absorption is small. Here, the following discusses in detail near infrared absorption spectra of water which is shown in Fig. 2.1.1 on page 12 and Fig. 4.6.1 on page 180 of Yukihiro Ozaki/Satoshi Kawata: Kinsekigai bunkouhou (Gakkai Shuppan Center, 1996), which is referred to for the above absorption bands. As a result, it is found that wavelength ranges indicative of half values of absorbances at the largest absorption wavelengths of 0.97 μm, 1.43 μm, and 1.91 μm are given in ranges from 0.943 to 1.028 μm, from 1.394 to 1.523 μm, and from 1.894 to 2.061 μm, as shown in Fig. 28. That is, light absorption by water is large in these wavelength regions. Accordingly, in the wavelength ranges from 0.84 μm to 2.5 μm, a wavelength region except for the above ranges corresponds to a region where the light absorption by water is small. That is, in the present exemplary embodiment or the applied embodiment, when light absorption is considered to be small in the absorption band around a center wavelength of 0.97 μm (there is little influence of the light absorption), it is desirable to

use, for detection/measurement or control of life activity, electromagnetic waves including an electromagnetic wave having a wavelength within any of a first applicable wavelength range I from 2.061 μm to 2.5 μm, a second applicable wavelength range II from 1.523 μm to 1.894 μm, and a third applicable wavelength range III from 0.84 μm to 1.394 μm, as shown in Fig. 28. In the meantime, in a case where the influence (light absorption) by an oxygen concentration indicator in a living tissue is desired to be removed at the time of detection or control of life activity (see section 4.7), the third applicable wavelength range III will be from 0.875 μm to 1.394 μm. By setting the third applicable wavelength range III as such, even if the oxygen concentration indicator exists in the middle of a detection light path, the detection light is not absorbed, so that the S/N ratio of a life activity detection signal can be secured. Further, in order to prevent light absorption in the absorption band having a center wavelength of 0.97 μm, it is desirable to use electromagnetic waves including an electromagnetic wave having a wavelength within any of a fourth applicable wavelength range IV from 1.028 μm to 1.394 μm and a fifth applicable wavelength range V from 0.84 μm to 0.943 μm (or from 0.875 μm to 0.943 μm) in addition to the above ranges.

Naturally, the desirable wavelength range of the electromagnetic wave for the detection/measurement or control of life activity is applied to the detection or measurement of an action potential state of a neuron explained in section 4.7. Subsequently, in regard to a result of the above consideration,

[2] the detection or measurement of an action potential state of a neuron is discussed in consideration of the feature of the present exemplary embodiment or the applied embodiment that detection/measurement or control is performed by use of an interaction of an external electromagnetic field with a transition between vibration modes occurring between two or more specific atoms in a molecule during activity in a life object or when the activity changes. At the time of detection/measurement of an action potential state of a neuron, a using wavelength corresponding to the 1st overtone for transition between anti-symmetrically telescopic vibration modes mainly caused by C-H-Cl^- is in a range from 2.05 to 2.48 μm, according to section 4.7. However, this wavelength range overlaps with the wavelength region of 2.05 to 2.061 μm where water absorbs light greatly. Accordingly, it is desired that the electromagnetic waves

corresponding to the 1st overtone and used for the detection/measurement include an electromagnetic wavelength within a wavelength range of 2.061 to 2.48 μm so that the above overlapping range can be avoided. In the meantime, in a case where the light absorption by water in the absorption band having a center wavelength of 0.97 μm causes any problem, it is desirable that the electromagnetic waves corresponding to the 3rd overtone of the transition between anti-symmetrically telescopic vibration modes and used for the detection/measurement include an electromagnetic wavelength within a wavelength range of 0.840 to 1.37 μm according to section 4.7. Further, in order to remove the influence by the oxygen concentration indicator as described above, it is desirable that the electromagnetic waves corresponding to the 3rd overtone and used for the detection/measurement include an electromagnetic wavelength within a wavelength range of 0.875 to 1.37 μm. However, in order to avoid the influence of light absorption by water in the absorption band having a center wavelength of 0.97 μm so as to obtain highly accurate detection/measurement, it is preferable to use electromagnetic waves including an electromagnetic wave having a wavelength in either range from 0.840 μm to 0.943 μm (or 0.875 μm to 0.943 μm) or from 1.028 μm to 1.37 μm for the detection/measurement of an action potential state of a neuron.

In consideration of the feature of [1] detection/measurement or control in a life object and the feature of [2] interaction of a transition between vibration modes with an external electromagnetic field (an electromagnetic wave) as well, the following describes a case of performing detection/measure or control of contracted and relaxed states of a skeletal muscle. As has been described in section 11.1, a contraction/relaxation motion of a skeletal muscle is constituted by two steps:

a] control to enable contraction of the skeletal muscle by release of calcium ions into a muscle cell; and

b] contractile function of the skeletal muscle.

Accordingly, the detection/measurement or control can be performed on each of the two steps, independently.

Initially explained is a detection/measurement method or a control method related to the step [a]. As described in section 11.1, in the step (a), it is expected that an ionic bond between a

carboxyl group and a calcium ion Ca^{2+} occurs. In this case, as described in section 3.5, it is considered that a relative light absorbance of the absorption band corresponding to a symmetrically telescopic vibration mode of a single carboxyl group largely decreases. Accordingly, in this exemplary embodiment,

>> the change (rapid decrease) of the relative light absorbance of the absorption band corresponding to the symmetrically telescopic vibration mode of the carboxyl group is detected so as to detect/measure whether or not the skeletal muscle is in a contractable state,

or alternatively,

>> excitation light in a vibration mode is projected to increase an energy level of the symmetrically telescopic vibration mode of the carboxyl group, so that a bond of a calcium ion Ca^{2+} to the carboxyl group is prevented and the contraction/relaxation action of the skeletal muscle is controlled. The symmetrically telescopic vibration mode of the carboxyl group is generally a ground state (a vibration state in which the energy level is the lowest). When it is illuminated with excitation light corresponding to the nth overtone, the energy level of the symmetrically telescopic vibration mode of the carboxyl group rises. In a case where a vibration of the carboxyl group is small (the energy level is low), a calcium ion Ca^{2+} easily bonds to the carboxyl group. On the other hand, in a case where the energy level of the vibration mode rises, even if the calcium ion Ca^{2+} bond thereto temporarily, it is highly probable that the calcium ion Ca^{2+} is thrown off (separated) due to the high energy. That is, by illumination with excitation light corresponding to the nth overtone, the calcium ion Ca^{2+} is hard to bond to the carboxyl group, so that contraction control of the skeletal muscle is obstructed and a relaxed state of the skeletal muscle continues.

Since section 3.5 only shows a wavenumber value of a reference tone exciting the symmetrically telescopic vibration mode of the carboxyl group, the following explains a wavelength corresponding to excitation light of the nth overtone. The following explanation is not limited to the control of contraction/relaxation of the skeletal muscle, but can be applied commonly to every exemplary embodiment or applied embodiment described in section 11.4, in which [2] detection/measurement or control is performed by use of a transition of a vibration mode according to an interaction of an external electromagnetic field (an electromagnetic wave)

with a vibration mode which occurs during activity in the life object or when the activity changes and which is caused by two or more specific atoms in a molecule at that time.

Initially, by use of the following formula (A 38) as described in section 4.5:

[Math. 38]

$$\varepsilon_m \cong \underline{\varepsilon_m} + <\underline{m}\,|\,\kappa_3 x^3 + \kappa_4 x^4\,|\,\underline{m}> = \frac{2\kappa_2}{\beta}\left(m+\frac{1}{2}\right) + \frac{3\kappa_4}{4\beta^2}\left(2m^2+2m+1\right)\cdots(A\cdot 38),$$

a necessary amount $h\nu_m$ of energy at the time when an energy level ε_0 is shifted to ε_m is expressed by:

[Math. 60]

$$h\nu_m = \varepsilon_m - \varepsilon_0 = \frac{2\kappa_2}{\beta}m + \frac{3\kappa_4}{2\beta^2}\left(m^2+m\right)\cdots(A\cdot 60).$$

Accordingly, from formula (A 60), where frequencies of the reference tone, the 1st overtone, and the 2nd overtone are assumed ν_1, ν_2 and ν_3, the following relations are established:

[Math. 61]

$$\frac{2\kappa_2}{\beta h} = 2\nu_2 - \nu_3 = 2\nu_1 - \frac{\nu_3}{3}\cdots(A\cdot 61);\ \text{and}$$

[Math. 62]

$$\frac{3\kappa_4}{2\beta^2 h} = \frac{\nu_3}{3} - \frac{\nu_2}{2} = \frac{\nu_3}{6} - \frac{\nu_1}{2}\cdots(A\cdot 62).$$

With the use of formulae (A 60) to (A 62) thus obtained, a value of a wavelength λm (a frequency ν_m) of a (m-1)th overtone can be estimated from the frequencies ν_1, ν_2, and ν_3 of the reference tone, the 1st overtone, and the 2nd overtone based on the anharmonic vibration.

Based on the reference documents, wavelengths λm of the reference tone and the (m-1)th overtones estimated by calculation using formulae (A 60) to (A 62) are shown in Table 7. Among the values shown in Table 7, a value to which (1) is attached is referred from Yukihiro Ozaki/Satoshi Kawata: Kinsekigai bunkouhou (Gakkai Shuppan Center, 1996) P. 218 to P. 219. On the other hand, a value to which (2) is attached is obtained by combining the calculation result in section 3.5 with a reference from R. M. Silverstein and F. X. Webster: Spectrometric Identification of Organic Compounds 6th Edit. (John Wiley & Sons, Inc., 1998) Chapter 3, Section 3·6. Further, a wavelength of the (m-1)th overtone of a symmetrically telescopic

vibration of an ionic carboxylic acid group -COO^- is calculated by extrapolation of a calculated value of a vibration of C = O of carboxylic acid -COOH by use of a value of the wavelength of the reference tone.

[Table 7]

	Reference tone (μm)	1st overtone (μm)	2nd overtone (μm)	3rd overtone (μm)	4th overtone (μm)
Intermolecular hydrogen bonding in primary amide -$CONH_2$	3.19-3.21 (calculation result)	1.60-1.62 Reference (1)	1.07-1.09 Reference (1)	0.81-0.83 (calculation result)	0.65-0.67 (calculation result)
Vibration of hydrogen bonding part in secondary amide -$CONH^-$	3.02-3.32 (calculation result)	1.53-1.67 Reference (1)	1.04-1.12 Reference (1)	0.79-0.85 (calculation result)	0.64-0.68 (calculation result)
Vibration between C = O of carboxylic acid -COOH	5.68 Reference (2)	2.84-2.86 (calculation result)	1.89-1.92 Reference (1)	1.42-1.45 (calculation result)	1.13-1.17 (calculation result)
Symmetrically telescopic vibration of ionic carboxylic acid group -COO^-	6.25-6.37 Reference (2)	3.12-3.21 (calculation result)	2.08-2.15 (calculation result)	1.56-1.63 (calculation result)	1.24-1.31 (calculation result)
Intermolecular hydrogen bonding in associated -OH alcohol	2.90-3.25 (calculation result)	1.50-1.60 Reference (1)	1.04-1.05 Reference (1)	0.80-0.77 (calculation result)	0.67-0.61 (calculation result)

Most carboxyl groups are in a state of an ionic carboxylic acid group -COO^- in a water environment (pH = around 7) in a life object. Accordingly, the excitation light of the nth overtone with respect to a symmetrically telescopic vibration mode of the carboxyl group in the present exemplary embodiment basically corresponds to a row of "Symmetrically telescopic vibration of ionic carboxylic acid group -COO^-" in Table 7. However, even under this water environment, there is a probability that some carboxyl groups keep a state of a carboxylic acid -COOH, and a calcium ion Ca^{2+} bonds to this C = O site. Accordingly, in a] control to enable contraction of the skeletal muscle by release of calcium ions into a muscle cell, in the present exemplary embodiment, both wavelengths are combined and assumed as follows:

- a wavelength range corresponding to the 2nd overtone is assumed 1.89 to 2.15 μm,
- a wavelength range corresponding to the 3rd overtone is assumed 1.42 to 1.63 μm, and

- a wavelength range corresponding to the 4th overtone is assumed 1.13 to 1.31 μm.

Further, similarly to section 4.7, measurement errors to these values are expected by about 10%. In view of this, respective lower limits of the above ranges are $1.89 \times (1 - 0.05) = 1.80$, $1.42 \times (1 - 0.05) = 1.35$, and $1.13 \times (1 - 0.05) = 1.07$. Similarly, respective upper limits thereof are $2.15 \times (1 + 0.05) = 2.26$, $1.63 \times (1 + 0.05) = 1.71$, and $1.31 \times (1 + 0.05) = 1.38$. Thus, the wavelength ranges including measurement errors of ±5% are as follows:

- the wavelength corresponding to the 2nd overtone is assumed 1.80 to 2.26 μm,
- the wavelength corresponding to the 3rd overtone is assumed 1.35 to 1.71 μm, and
- the wavelength range corresponding to the 4th overtone is assumed 1.07 to 1.38 μm.

In consideration of overlapping parts, it is concluded that "a wavelength range suitable for detection/measurement or control is in a range from 1.07 to 1.71 μm and in a range from 1.80 μm to 2.26 μm." Further, by excluding, from this range, the wavelength range in which light is largely absorbed by water molecules, as shown in Fig. 28, the wavelength range suitable for [a] detection/measurement or control to a bond between Ca^{+} and a carboxyl group $-COO^{-}$ is 1.07 to 1.39 μm, 1.52 to 1.71 μm, and 2.06 to 2.26 μm. This wavelength range is shown in Fig. 28.

In a case where a life object is illuminated with electromagnetic waves including an electromagnetic wave having a wavelength in the range explained as above, in the present exemplary embodiment or the applied embodiment, measurement/control is performed as follows:

>> A signal related to a life activity is detected by an absorption amount or an absorption change of the electromagnetic wave having a wavelength in the above range in a life object, and the detection signal is processed to measure a life activity state; and

>> An illumination amount of the electromagnetic wave having a wavelength in the above range is increased in the life object (temporarily) so as to control the life activity. That is, a light amount of the electromagnetic wave projected to the body for detection of life activity is very small, so that a ratio of carboxyl groups in which a vibration mode is excited in a skeletal muscle is small and the life activity itself is not affected. However, when the light amount of the electromagnetic wave thus projected is increased, most of the carboxyl groups in the skeletal muscle are excited to cause vibrations, thereby resulting in that bonding of calcium ions Ca^{2+}

thereto is obstructed and contraction of the skeletal muscle becomes impossible.

Further, in the present exemplary embodiment or the applied embodiment, detection/measurement and control related to life activity may be performed at the same time. In this case, while an illumination amount of the electromagnetic wave having a wavelength in the above range is decreased to detect/measure a life activity and check an active state thereof, the control of life activity is performed (by increasing the illuminating light amount sometimes).

Next will be explained a feature of an activity at a molecular level to be used for detection/measurement or control in the present exemplary embodiment or the applied embodiment, that is,

[3] a case where the transition between vibration modes which a hydrogen atom (forming a hydrogen bond) involves (which has been already explained in this section) is used.

As shown in Fig. 29, in a hydrolysis reaction of ATP in a skeletal muscle, hydrogen bonds to a part of a residue of Lysine Lys185 and a part of a residue of Asparagine Asn235 are formed. In order to cause a hydrolysis reaction stably by a neutralization effect of local charges, "a hydrogen bond between a residue of amino acid having positive electric charge and ATP having negative electric charge" is required. Therefore, in the hydrolysis of ATP, hydrogen bonds to residues of Lysine Lys185 are also formed in other areas in addition to the skeletal muscle very often. That is, as described in section 11.3, since ATP has negative electric charge in the water environment of pH 7, local bonds to a magnesium ion Mg^{2+} and a residue of amino acid having positive electric charge is necessary for electrical neutralization. A residue of amino acid having positive electric charge is included in only the residue of Arginine except for the residue of Lysine Lys185, and in either case, a hydrogen atom is placed outside the positively charged part. Accordingly, in an electrically neutralized state, it is highly probable that a hydrogen bond is formed between this hydrogen atom and an oxygen atom in the ATP. Further, since the hydrogen atom itself, which is involved with this hydrogen bond, is more lightweight than other atoms, the use of this transition between vibration modes makes it easy to perform detection/ measurement or control of life activity in a relatively deep region in a life object, as described earlier.

Only small part of a residue of Lysine and a residue of Arginine is hydrogen-bonded to a water molecule (an oxygen atom thereof), but an absorption band occurring in ATP hydrolysis and an

absorption band deriving from the hydrogen bond to the water molecule have different values of center wavelengths for the following reason. Fig. 30(a) shows a case where a part of the residue of Lysine Lys185 is hydrogen-bonded to an oxygen atom in ATP, and Fig. 30(b) shows a case where a part of the residue of Lysine Lys185 is hydrogen-bonded to an oxygen atom in a water molecule. When a distance between a hydrogen atom H2 involved with hydrogen bonding and an oxygen atom O5 or O10 becomes smaller than an optimal value, the water molecule is fixed not lightly and therefore relative arrangements between the oxygen atom O10 and hydrogen atoms H9/H10 do not change. In contrast, when the distance between the hydrogen atom H2 and the oxygen atom O5 becomes smaller than the optimal value, distortion occurs in ATP and intramolecular energy in ATP and the whole Lysine Lys185 forming a hydrogen bond increases, as shown in Fig. 30(b).

As a result, an increasing amount of the energy of the whole molecule at the time when the distance between the hydrogen atom H2 and the oxygen atom O5/O10 becomes smaller than the optimal value is larger in the case of hydrogen bonding to a part in ATP than in the case of hydrogen bonding to a water molecule.

Fig. 31 shows an influence to an anharmonic vibration potential property due to a difference in a molecular structure involved with a hydrogen bond. A distance between two atoms forming an electric dipole moment, indicated by a lateral axis in Fig. 31, represents a distance between the hydrogen atom H2 in the residue of Lysine Lys185 and the oxygen atom O5/O10 of a hydrogen-bonding partner in the example of Fig. 30. The property of Fig. 30(a) corresponds to an alternating long and short dash line in Fig. 31, while the property of Fig. 30(b) corresponds to a broken line in Fig. 31. It is considered that a potential property in a direction in which two hydrogen-bonded atoms are distanced away from each other (a direction in which the distance between the hydrogen atom H2 and the oxygen atom O5/O10 becomes larger than the optimal value) is not affected by a molecular structure involved with the hydrogen bond that much. On the other hand, when the two hydrogen-bonded atoms come closer (the distance between the hydrogen atom H2 and the oxygen atom O5/O10 becomes smaller than the optimal magnitude), distortion occurs in a molecular structure in ATP in a direction in which the distance between the two atoms increases as shown in Fig. 30(a), thereby resulting in that a difference value of total

energy increases (which is indicated by the property of the dash line of Fig. 31).

Further, as the difference value of total energy increases when the two hydrogen-bonded atoms come closer, coefficient values of κ2 and κ4 both increase as shown in Fig. 31. Consequently, as shown in formula (A 60), the frequency of the absorption band increases (the wavelength decreases). For this reason, depending on whether a hydrogen-bonding partner to which a part of the residue of Lysine Lys185 is hydrogen-bonded is ATP or a water molecule, the wavelength of the absorption band varies. Further, as shown in the explanation above, depending on a difference in a residue of amino acid involved with a hydrogen bond (e.g., whether the residue of amino acid is a residue of Lysine Lys185, a residue of Arginine, or a residue of Asparagine Asn235), a wavelength value of the absorption band varies.

In this way, the present exemplary embodiment or the applied embodiment has such an effect that a difference of molecules involved with bonding is estimated from a wavelength value of the absorption band which varies (temporarily) during life activities, so that a difference between detailed life activities (internal reactions) can be identified. Further, this feature and effect are not limited to the contraction/relaxation in a skeletal muscle and hydrogen bonding, but also applicable to any life activities (internal reactions) accompanied with (temporal) variations in a vibration mode of a specific atom. Further, when this wavelength selectivity by the molecular difference involved with bonding is used for life activity control to be explained in chapter 12, it is possible to perform control according to the difference of an appropriate wavelength so that other life activities are less affected. This yields such an effect that side effects caused unnecessarily due to the life activity control can be reduced.

On the other hand, from a combination of the explanations in chapters 4 and 5, when an anharmonic vibration potential property changes as shown in Fig. 31, a distribution characteristic of electrons located around a hydrogen atom involved with a hydrogen bond changes. In view of this, the detection or measurement of any life activities (internal reactions) accompanied with (temporal) variations in a vibration mode of a specific atom may be performed by use of not only the difference in the wavelength value of the absorption band, but also the difference in the chemical shift value at the time of Nuclear Magnetic Resonance (see chapter 5).

A detailed correspondence between a wavelength value of the absorption band corresponding

to hydrogen bonding occurring in a life activity (internal reaction) and a combination of molecules involved with the hydrogen bond requires data filing of theoretical calculation and experimental values. In the present specification, instead of explaining strict values, an outline of the wavelength range of the absorption band which takes into account measurement errors and differences of detection values caused due to a measurement environment is explained. The transition between vibration modes corresponding to hydrogen bonding occurring in hydrolysis of ATP structurally has a characteristic close to the row of "Intermolecular hydrogen bonding of primary amide -$CONH_2$" in Table 7. The hydrogen bonding in the ATP hydrolysis corresponding to the contraction of a skeletal muscle is related to a residue of Lysine Lys185 and a residue of Asparagine Asn235 (Fig. 29), but a variation of the center wavelength of the absorption band depending on the difference of the residue of amino acid is considered to be relatively small. The wavelength ranges of respective absorption bands are explained below together. As described in section 4.7, when a variation range considering the difference in a detection value caused by measurement errors or measurement environments is estimated as ±15%, the variation ranges are as follows: $1.60 \times (1 - 0.15) = 1.36$, $1.62 \times (1 + 0.15) = 1.86$, $1.07 \times (1 - 0.15) = 0.91$, and $1.09 \times (1 + 0.15) = 1.25$. Accordingly, when the values are summarized, the following ranges can be obtained:

- a wavelength range of an absorption band corresponding to the 1st overtone is from 1.36 μm to 1.86 μm; and
- a wavelength range of an absorption band corresponding to the 2nd overtone is from 0.91 μm to 1.25 μm.

With respect to the ranges thus obtained, remaining ranges obtained by excluding the wavelength ranges greatly absorbed by the water molecule shown in Fig. 28 are as follows:

- the wavelength range of the absorption band corresponding to the 2nd overtone is from 1.03 μm to 1.25 μm; and
- the wavelength range of the absorption band corresponding to the 1st overtone is from 1.52 μm to 1.86 μm, as shown in Fig. 28.

However, the ranges show only a detection range of the nth overtone to the last. Further, an absorption band corresponding to combinations is also included in the near-infrared

region. In view of this, when the wavelength range to detect combinations is also taken into account, the first, second, third, fourth, and fifth wavelength ranges I to V with less absorption by water shown in Fig. 28 can be taken as target ranges. Alternatively, if an absorption amount in the absorption band for the combinations is large and is not affected by the absorption by water very much, a desirable wavelength range will be in a range from 0.84 μm (or 0.875 μm) to 2.50 μm as shown in section 4.7. Further, similarly to the above as for the hydrolysis of ATP, the following can be performed:

- Detection of a signal related to a life activity based on an absorption amount or an absorption change of the electromagnetic wave having a wavelength in the above range in a life object, and measurement of a life activity state by processing the detection signal; and

- Control of the life activity by increasing (temporarily) an illumination amount of the electromagnetic wave having a wavelength in the above range in the life object (note that detection/measurement and control may be performed in parallel). That is, in order to contract a skeletal muscle, oxygen atoms O2, O6, and $O5^{-}$ in ATP are hydrogen-bonded to a part of a residue of Lysine Lys185 and a part of a residue of Asparagine Asn235 just before a hydrolysis reaction of ATP (Fig. 29). At this time, a high-intensity electromagnetic wave is projected so that vibration modes of most of the hydrogen atoms H6, H5, and H2 related to hydrogen bonding are excited. This causes the hydrogen atoms H6, H5 and H2 to vibrate in an excited state, thereby cleaving the hydrogen bonds by the energy. This causes ATP not to have a molecular arrangement in which hydrolysis can be performed as shown in Fig. 29, thereby resulting in that the hydrolysis reaction of ATP is obstructed, so that the skeletal muscle does not contract and its relaxed state continues.

The above explanation mainly deals with detection/measurement or control for contraction/relaxation of a skeletal muscle as an example, but the present exemplary embodiment is also applicable to detection/measurement or control for any activities in a life object related to the "hydrolysis of ATP" as an applied embodiment. For example, the detection/measurement or control by the aforementioned method is applicable to an ion pump function to pump a specific ion out of a cell to the outside or carbon fixation during photosynthesis as an operation using the hydrolysis of ATP. Further, according to B. Alberts et. al.: Molecular Biology of the Cell, 4th

Edi. (Garland Science, 2002) Chap. 16, motor protein is used for substance transport in a cell including substance transport in a neuronal axon, but the hydrolysis of ATP is also used for movement of this motor protein. Accordingly, the detection/measurement or control by the aforementioned method is applicable to this substance transport in a cell as one example of life activities.

11.5) Features of detection method of life activity

This section explains characteristics of a life activity detection signal obtained by using a hydrolysis reaction of ATP for muscular contraction detection and a measurement method related to it. However, the present exemplary embodiment is not limited to the above, and a phenomenon of a] control to enable contraction of a skeletal muscle by release of calcium ions into a muscle cell, as described in the above section, may be used for detection of muscle. Initially, as premise for the detection of life activity, a muscle portion is illuminated with an electromagnetic wave (light) including a center wavelength of the absorption band which occurs when a part of a residue of Lysine Lys185 is hydrogen-bonded to an oxygen atom in ATP, as described in the previous section (section 11.4), so as to detect an absorbing state of the electromagnetic wave (light). Fig. 32 shows a difference in absorption change of an electromagnetic wave (light) before initiation of a muscular contraction activity 511 and during a muscular contraction activity 512. Before initiation of the muscular contraction activity 511, no hydrogen bonding occurs between a part of a residue of Lysine Lys185 and an oxygen atom in ATP, so that an absorption band corresponding to that is not caused and a light absorption amount at a center wavelength thereof is small. After that, during the muscular contraction activity 512, a hydrolysis reaction of ATP occurs asynchronously, so that an absorption amount of the electromagnetic wave fluctuates greatly along a detection time. That is, a very large number of Myosins exist in a muscle cell, and timings to cause the hydrolysis reaction of ATP are different between individual Myosins. At the moment when many Myosins cause the hydrolysis reaction of ATP at the same time, the absorption amount of the electromagnetic wave (light) increases, but on the other hand, at the moment when only a few Myosins cause the hydrolysis reaction of ATP, the absorption amount of the electromagnetic wave (light) decreases. Accordingly, in the present exemplary embodiment, as for the detection signal characteristic shown in Fig. 32,

muscle contractile activity is evaluated based on an amplitude value 513 of the absorption change amount of the electromagnetic wave (light). Alternatively, an amount of muscle contractile activity may be evaluated using a maximum value of the absorption change amount of the electromagnetic wave (light) within a specific time.

In the present exemplary embodiment, a "contraction state of facial muscles of a human" is detected so as to measure an emotional reaction of an examinee as described in section 6.5.4, as a method for measuring a life activity by detecting the "muscular contractile activity" as a detection subject of life activity. J. H. Warfel: The Extremities 6th edition (Lea & Febiger, 1993) describes a relationship between contraction of an expression muscle on a face and an expression, and an extract therefrom is shown in Fig. 33. When a person is surprised, an epicranius 501 contracts, and when a person feels pain, a corrugator 502 contracts. This corresponds to phenomena that the eyebrows are raised when a person is surprised and that the forehead is wrinkled when a person feels pain. Further, cheeks rise with the smile, which indicates a state where a zygomaticus 503 contracts when smiling. On the other hand, when a person feels sorrow, a depressor anguli oris 505 contracts, so that the mouth stretches and the outside of the mouth turns down. In the meantime, when a person wants to say something or to express feelings such as dissatisfaction, the person sometimes shoots out the lips. When a person wants to represent facial expression, an orbicularis oris 504 contracts. On the other hand, when a person is expressionless, a depressor labii inferioris 506 tends to contract. When a person has some doubt and shows disdain, a mentalis 507 contracts and a center of the mouth turns down.

A relationship between a location of a mimetic muscle which contracts on a face and a facial expression suggests that "what emotional reaction is expressed can be found according to which mimetic muscle contracts." The present exemplary embodiment has such a feature that an emotional reaction or a feeling of an examinee is measured in real time to find which muscle contracts and how strong the contraction is by use of this phenomenon. There has been conventionally known a technique in which a feeling of the examinee is estimated from geometric information such as a placement, a shape, or a time dependent variation of constituent parts (eyes and a mouth) on the face. However, this method has such a problem that an original facial structure of the examinee and a facial angle in measurement largely affect the measurement,

so that measurement accuracy is poor and the measurement takes time. In contrast, in this exemplary embodiment, since the emotional reaction or the feeling is measured according to a location or strength of a mimetic muscle to contract, highly accurate measurement can be performed instantly. Further, since the measurement is a non-contact method, the measurement can be advantageously performed on the examinee in a natural state without imposing a burden on the examinee.

Further, not only the present exemplary embodiment can perform measurement in a non-contact manner, but also the present exemplary embodiment has such a device that the measurement can be performed stably even if the examinee moves around freely. In a case where the examinee moves around freely during the measurement, a position 522 of a detection subject of life activity (that is, the examinee) may move toward a corner of a detectable range 521 in the detecting section for life activity in some cases, as shown in Fig. 34, for example. In such a case, the present exemplary embodiment utilizes a signal obtained from the position monitoring section 46 regarding a detected point for life activity so as to detect a life activity. As has been already described in section 6.1.3,

♦ the present exemplary embodiment has a large feature that the second detection is performed based on the first detection. The "first detection" as used herein indicates "position detection of a detected point for life activity" as defined in section 6.1.3, and the "position monitoring section 46 regarding a detected point for life activity" shown in Fig. 16, for example, performs the detection. Further, the "second detection" indicates "detection of life activity" and the "detecting section 47 for life activity" shown in Fig. 16, for example, performs the detection.

In the meantime, the present exemplary embodiment also has such a feature that in order to attain the feature, an operation check (S101) of the detecting section 101 for life activity and the position monitoring section 46 regarding a detected point for life activity is performed in advance, as shown in Fig. 35 or 36, and

♦ when at least either one of position detection (the first detection) of a detected point for life activity and detection of life activity (the second detection) is not performable (S102), such a process is performed that a life activity detection signal is not output (S103).

For example, as shown in Fig. 34, if the position 522 of the detection subject of life activity

(for example, the examinee) is within the detectable range 521 in the detecting section for life activity, the detection of life activity (the second detection) can be performed. However, if the position 522 of the detection subject of life activity (for example, the examinee) is out of the detectable range 521 in the detecting section for life activity, the detection of life activity (the second detection) cannot be performed. Further, reflection light obtained by illuminating the detection subject of life activity (e.g., the examinee) with the illuminating light for life activity detection is detected, but if light is blocked on a part of the optical path, the detection of life activity (the second detection) cannot be performed. Similarly, a case where position detection by the position monitoring section 46 regarding a detected point for life activity shown in S102 of Fig. 35 or 36 cannot be performed corresponds to a case where the detection subject of life activity (e.g., the examinee) moves outside the range where the position detection by the position monitoring section 46 regarding a detected point for life activity is performable or a case where light is blocked on a part of the detection light path.

Further, as described above, in a case where at least either of the first and second detections is not performable, a specific value such as "0" may be output, for example, as shown in S103 of Fig. 35 or 36, instead of stopping the output of the life activity detection signal 106. At the same time, the user may be notified of the state where the detection of life activity is not performable, by means of a "screen display" or "audio" (S103).

On the other hand, section 6.1.3 describes that a position of a measurement subject in three dimensions is calculated by position detection of a detected point for life activity (the first detection) and a signal of detection (the second detection) related to the life activity is obtained from the calculated position in a life object. This specific content thereof will be explained, more specifically. The meaning of "based on the first detection" in the above feature is that:

♦ a position in a depth direction of the detected point 30 for life activity is detected based on the position detection (the first detection) of the detected point for life activity. This corresponds to the step of S104 in Fig. 35 or 36 (detection by the position monitoring section 46 regarding a detected point for life activity). The principle of "trigonometry" is used as a specific method thereof as described in section 6.2.2 with reference to Fig. 16. Subsequently, based on "positional information in the depth direction of the detected point 30 for life activity" obtained

as a result of the detection in S104 (corresponding to the distance 44 surface points of an area where the detecting section for life activity is disposed in Fig. 16), the objective lens 31 (Fig. 17 or 18) provided in the detecting section 101 for life activity is displaced in the optical axial direction so as to be moved to a position optimum for detection of life activity. This corresponds to controlling of an operation of the detecting section 101 for life activity as described in S105. In the meantime, the camera lens 42 is also provided in the position monitoring section 46 regarding a detected point for life activity as shown in Fig. 16, and the camera lens 42 is optimized in accordance with the position in the depth direction of the detected point 30 for life activity obtained in S104. As a result, a clear imaging pattern of the life-object surface 41 is obtained on the two-dimensional photodetector 43 provided in the position monitoring section 46 regarding a detected point for life activity. Thus, only after the clear imaging pattern is obtained in the position monitoring section 46 regarding a detected point for life activity, an efficient life activity detection signal 106 specialized in the measurement of life activity (described later) is obtained.

The explanation with reference to Fig. 33 has described that "when a location of a muscle to contract in mimetic muscles is found, it is easy to find a corresponding emotional reaction." That is, all life activity detection signals indicative of muscular contraction amounts over the region in the detectable range 521 in the detecting section for life activity as shown in Fig. 34 are not output, but "a location of a muscle related to the emotional reaction" (or expression) is extracted from the detectable range 521 in the detecting section for life activity and only a contraction state of the muscle is output as the life activity detection signal. This makes it easy to perform interpretation using the life activity detection signal 106 (that is, life activity measurement). Accordingly, the present exemplary embodiment has a large feature in that:

♦ a life activity detection signal 106 is output based on position detection (the first detection) of a detected point for life activity. Then, if a relationship between the position 522 of the detection subject of life activity (a relative position of the detected point 30 for life activity in Fig. 17, 18, or 20 to the position monitoring section 46 regarding a detected point for life activity shown in Fig. 16) and the life activity detection signal 106 is examined, it can be easily determined whether or not this feature is performed. That is, even in a case where the examinee keeping the

same feeling (emotion) moves, if the life activity detection signal 106 is output continuously and stably, it can be determined that a position of a specific muscle is followed and a contraction state of the muscle is output as the life activity detection signal 106, based on the position detection (the first detection) of the detected points for life activity (the feature is performed). On the other hand, in a case where light is blocked on a part of the detection light path of the position monitoring section 46 regarding a detected point for life activity, and even after a while (in consideration of a buffer process in the life activity detection signal 106), a reliable life activity detection signal 106 is still kept output, it is estimated that the feature is not performed.

Before "a location of a muscle related to an emotional reaction (or expression)" is extracted from the detectable range 521 in the detecting section for life activity, it is necessary to extract a position 522 of a detection subject of life activity in the detectable range 521 in the detecting section for life activity in the position monitoring section 46 regarding a detected point for life activity. This position extraction process uses, for example, a "face recognition technique" and a "facial angle extraction technique" used in digital cameras or the like. In this face recognition technique, positions of eyes, a mouth, a nose, and ears having shapes peculiar to a human face are extracted by a pattern matching so as to find a "place thought to be a face." After the "place thought to be a face" is found as such, positions of eyes, a mouth, a nose, and ears in the place are searched, and a facial angle is estimated.

Here, "positions of various mimetic muscles related to an emotional reaction (expression)" can be deduced from the positions of the eyes and the mouth as shown in Fig. 33. An operation to deduce the "positions of various mimetic muscles related to the emotional reaction (or expressiveness)" from the imaging pattern in two dimensions on the two-dimensional photodetector 43 corresponds to the method for detecting a position in two dimensions on a planer orientation of the detected point 30 for life activity by the position monitoring section 46 regarding a detected point for life activity, in step 106 described in Fig. 35 or 36. Meanwhile, this section 11.5 explains the detection of contracted states of various mimetic muscles as exemplary detection of life activity. However, the exemplary embodiment shown in Fig. 35 or 36 is not limited to that, and is applicable to detection or measurement of any life activities, for example, extraction of a place where a neuron fires an action potential as described in chapter 4,

extraction of a position of an activated cell based on a phosphorylation activity as will be described later in chapter 13, and the like.

There are two methods as a method for leading a detection result obtained in step 106 in Fig. 35 or 36 to a life activity detection signal 106. First of all, in the present exemplary embodiment shown in Fig. 35, a detection location in the detecting section 101 for life activity is controlled based on the detection result of step 106 (S107). In this step, the control is performed so as to obtain a life activity detection signal only from the "positions of various mimetic muscles related to an emotional reaction (expression)" in the detectable range 521 in the detecting section for life activity. That is, locations corresponding to the "positions of various mimetic muscles related to an emotional reaction (expression)" obtained in step 106 are set as light transmission sections 56 in the two-dimensional liquid crystal shutter of Figs. 18 and 19 (see section 6.3.1).

As a result, in the longitudinal one-dimensional alignment photo detecting cell 55 in Fig. 18, only a life activity detection signal 106 associated with muscular contraction (an ATP hydrolysis reaction) of a corresponding mimetic muscle is obtained. Then, the life activity detection signal obtained here is output as it is (S108). In this exemplary embodiment, since the extracting method of the life activity detection signal 106 is very simple, it is advantageously possible to manufacture the detecting section 101 for life activity at low cost and to obtain a highly precise detection signal.

On the other hand, in the applied embodiment shown in Fig. 36, life activities are detected in the whole detection region (all regions in the detectable range 521 in the detecting section for life activity shown in Fig. 34) in the detecting section 101 for life activity, as shown in S111. Further, in this case, as the detecting section for life activity, the method explained in section 6.3.2 with reference to Fig. 20 to Fig. 22 is used. In the signal processing operation section of the rear part in the rear part 86 of the life activity detection circuit, a necessary detection signal is extracted from the life activity detection signals obtained in S111 by use of detection information of S106 (S112), and is output as a necessary life activity detection signal (S113). In a case where this method is adopted, contraction information of other face muscles except the "mimetic muscles related to the emotional reaction (or expression)" illustrated in Fig. 33 is also obtained as a detection signal, thereby making it possible to perform advanced signal processing with the use

of those detection signals in the signal processing operation section of the rear part. Accordingly, with the use of the method shown in this applied embodiment, it is possible to more highly precisely measure life activities.

The above exemplary embodiment in which a location of a mimetic muscle contracting on a face and its contraction amount are detected to measure an emotional reaction (or emotional movement) of an examinee can be applied to prevention of depression, or early detection or diagnosis thereof. The following explains this applied embodiment. Most people do not laugh when feeling depressed, and the number of active expressions tends to decrease. Accordingly, as described above with reference to Fig. 33, when even a physically unimpaired person feels depressed, it is estimated that the number of contractions of the zygomaticus 503 and the orbicularis oris 504 decreases. When the person feels further depressed or feels sad triggered by the depression, it is considered that the frequency of slight contraction of the depressor anguli oris 505 increases. When the depression further progresses, the person laughs less and grows expressionless. In this case, it is very likely that the zygomaticus 503 and the orbicularis oris 504 are relaxed while the depressor labii inferioris 506 is kept strained. In view of this, by detecting a location of a mimetic muscle to contract and an amount of the contraction, how deep the depressed feeling is at that point can be estimated (measured). Further, the frequency of a depressed feeling through time (e.g., how long the depressed feeling continues or how often the depressed feeling occurs in a day or week) or a time dependent variation of the occurrence frequency of the depressed feeling (whether or not the person forget the feeling and gets well soon, or whether or not the depressed state progresses as time passes) will also be a problem. As such,

1] if the progress of the depression of the examinee can be measured over time, it will be useful for early detection or medical examination of the depression.

In addition to that, the use of this applied embodiment enables

2] prevention of the depression according to mental inclination of the examinee.

That is, people who are apt to think relatively seriously and sober people tend to develop depression more easily. Accordingly, by monitoring a facial expression and grasping mental inclination of the examinee, precautionary measures to depression can be performed according to

the mental inclination of the examinee. Concrete methods are explained below. As described above, a location of a mimetic muscle contracting on a face and its contraction amount are detected, and how deep the depressed feeling of the examinee is (progress in view of depression) at that point is expressed with a value. Then, if the measurement can be performed continuously over time by means of the life detecting division 218 described in section 7.2.2.3, a time dependent variation of the level of the depressed feeling thus expressed with a value is examined. This allows easy judgment on which level the examinee is at, for example, "healthy," "feeling blue," "caution needed for mental health," "brief depression (= continuous examination required)," "treatment required," or "very serious," and timely treatment by a psychiatrist is enabled.

Conventionally, such an attempt has been made that oxygen analyzing in blood with a brain wave or near infrared light is used for diagnosis of depression. However, it is necessary that a measuring apparatus be made contact with a patient in the above method, thereby causing such a problem that a large burden is imposed on a patient and continuous measurement for a long period is difficult. In contrast, this applied embodiment is measurement in a completely non-contact manner, so that continuous measurement for a long period can be performed easily without imposing a burden on the examinee.

The following describes prophylaxis and a diagnosis method for depression by use of the life detecting division 218 explained in chapter 7.

<Method in which life detecting division is provided in consulting room of psychiatrist>

This is a method to utilize the life detecting division 218 as a diagnosis device and corresponds to the packaged device. When an ambulatory patient sits down before this life activity control device, a progression level of depression appears in the form of a numerical value sequentially. By use of this value, a psychiatrist can grasp therapeutic effects numerically.

<Method in which life detecting division is provided around body of patient and time dependent change of feeling of patient is grasped through time>

Assume a case where the life detecting division 218 is provided on a desk or adjacent to a television or a personal computer. In this applied embodiment, the life detecting division 218 can be provided in a non-contact manner to an examinee. Further, in a case where the method

explained with reference to Fig. 35 or 36 is used, even if the examinee moves, the movement can be followed automatically. Accordingly, this makes it possible to grab a change of the feeling of the patient for an extended period through time. Then, a life activity detection signal 248 or life activity information 249 obtained by the life detecting division 218 is transferred to a psychiatrist or an administrator of a company via the network in real time. This allows the psychiatrist or the administrator of the company to perform early preventive treatment or early detection to depression.

If such early detection to depression is enabled based on the above technique, a corresponding early treatment is also performable. Further, an applied embodiment can contribute to this treatment of depression.

12] Control Method of Life Activity

This exemplary embodiment has a feature in that:

[1] an inside of a life object is illuminated with an electromagnetic wave from its outside;

[2] a state in the life object is locally changed; and

[3] a life activity is controlled in a non-contact manner.

The following describes a configuration of a life activity control device for performing the control, a basic principle used for the control of life activity, and the like.

12.1) Outline of basic control method of life activity

Fig. 37 shows an example of the life activity control device to be used in the present exemplary embodiment. The life activity control device to be used in the present exemplary embodiment has the following features:

>> An electromagnetic wave having a relatively high intensity is projected to an inside of a life object from its outside so as to be used as control light;

>> An electromagnetic wave having a wavelength in a range of not less than 0.84 μm but not more than 2.5 μm is used as the control light;

>> The control light is condensed on a specific location in the life object;

>> The control of life activity and the detection of life activity may be performed in parallel

... The control is performed after an active state is detected at the location to be controlled in the life object, or the control is performed while the detection is performed; and

>> A specific voltage from the exterior can be applied at the same time as irradiation of the control light.

In the measuring method of life activity in the present exemplary embodiment, it is necessary to set a location to be a control object in a life object at first. A part 600 of an organism to be detected/controlled, which is taken as the control object, is assumed the head of an examinee in Fig. 37 for convenience sake, and the present exemplary embodiment takes, as an example, an action potential control in a neuron. However, the present exemplary embodiment is not limited to that, and any location in the life object including a hand, a foot, and a waist may be taken as the part 600 of an organism to be detected/controlled, and the organism herein may be plants, bacteria, and microorganisms besides animals.

This life activity control device is provided with a position detecting monitor section 432 of a detected point for life activity to monitor the location of the part 600 of an organism to be detected/controlled. This position detecting monitor section 432 of the detected point for life activity performs monitoring according to the method explained in section 6.2 with reference to Figs. 14 and 16. Further, in a case where the examinee is an animal, it may move slightly during detection or control. In case of such slight movement, the objective lens 31 is moved in three axial directions to follow the detected point 30 for life activity.

More specifically, when the part 600 of an organism to be detected/controlled moves after the position detecting monitor section 432 of the detected point for life activity initially sets a position of the detected point 30 for life activity, the position detecting monitor section 432 of detected point for life activity automatically detects a displacement amount thereof, and the objective lens 31 is moved by an operation of an objective lens driving circuit 605 according to the displacement amount thus detected, thereby mechanically correcting the displacement amount. In the exemplary embodiment shown in Fig. 37, a position detecting light source 431 of the detected point for life activity is provided as a different member from a light source for light (electromagnetic wave) to be used for detection or control of life activity, and projects light to the same location as the detected point 30 for life activity where the detection or control of life activity is performed or to its neighboring region (a slightly wide region including the detected point 30 for life activity). Alternatively, the position detection of a detected point for life

activity may be performed using the same light source as the light source to be used for the detection or control of life activity.

An electromagnetic wave (light) 608 for detection/control of life activity emitted from a light emitting component 111 is converted into parallel light by a collimating lens 606, and then condensed by the objective lens 31 on a detected point 30 for life activity in the part 600 of an organism to be detected/controlled. By condensing the electromagnetic wave (light) 608 for detection/control of life activity as such, the following effects are yielded: (1) a life activity only at a local specific location in a life object can be controlled; and (2) the energy of the electromagnetic wave (light) 608 for detection/control of life activity can be used effectively.

Fig. 37 shows a configuration having only one light emitting component 111, but alternatively, a plurality of light emitting components 111 may be provided. If the electromagnetic wave (light) 608 for detection/control of life activity emitted from the plurality of emitting components 111 is passed through the same objective lens 31, light can be condensed at a plurality of spots in the part 600 of an organism to be detected/controlled at the same time, so that life activities in a plurality of different detected points 30 for life activity can be controlled at the same time. Further, by independently controlling respective light emissions from the plurality of light emitting components 111, respective timings of the control of life activity in a plurality of different detected points 30 for life activity can be changed, independently.

Further, the detecting section 101 for life activity is provided in the life activity control device shown in Fig. 37, and detection of life activity can be performed in parallel with the control of life activity. This yields the following effects of the present exemplary embodiment: (1) the control of life activity can be performed after checking a necessity of the control at the detected point 30 for life activity by detecting a life activity state thereof, so that efficiency of the control of life activity increases; and (2) the detection of life activity can be performed while the life activity is controlled, so that effects of the control of life activity can be checked in real time and effectiveness of the control of life activity is increased. Note that the detecting section 101 for life activity in Fig. 37 uses the principle explained in section 6.3 with reference to Figs. 17 to 22 and has the configuration explained.

Meanwhile, in the life activity control device shown in Fig. 37, a single light source (the light

emitting section 111) is used for the detection and the control of life activity. This yields the following effects: (1) the number of necessary components can be reduced, so that downsizing and cost reduction of the life activity control device can be achieved; and (2) it is not necessary to align the optical systems (optical adjustment) separately for the detection and the control of life activity and assembling of the life activity control device is simplified, so that cost reduction and high reliability of the life activity control device can be achieved. In the case of this method, the light amount of the electromagnetic wave (light) emitted from the light emitting component 111 is changed through time, so as to switch between the detection and the control to the life activity through time. That is, the light amount of the electromagnetic wave (light) emitted from the light emitting component 111 is reduced at the time of the detection of life activity, and in the meantime, the light amount of the electromagnetic wave (light) emitted from the light emitting component 111 is increased at the time of the control of life activity performed intermittently. The changing of the light emission amount at this time is controlled by a modulation signal generator 118 based on an instruction from a control section 603. Then, a light emitting component driver 114 changes the amount of a current to be supplied to the light emitting component 111 in accordance with an output signal from this modulation signal generator 118.

Alternatively, different light sources may be provided for the detection and the control of life activity. In that case, there is such an advantage that (1) the control and the detection of life activity can be performed at the same time zone, so that accuracy of the detection of life activity is improved and the effectiveness of the control of life activity is more improved. As shown in Fig. 28, appropriate wavelengths for the detection and the control of life activity are separated in a plurality of regions (ranges), in general. Accordingly, in a case where different light sources are used for the detection and the control of life activity, it is desirable to select light sources for emitting respective electromagnetic waves (light) having wavelengths included in different wavelength ranges (regions) from each other.

Further, the life activity control device shown in Fig. 37 has feature in that irradiation of the electromagnetic wave (light) 608 for detection/control of life activity to the detected point 30 for life activity and application of a specific voltage from the outside can be performed at the same time. When the application of a specific voltage is performed at the same time as such, the

control of life activity can be performed more effectively. Here, a control section 603 performs a synchronous control of a timing to increase a light emission amount of the light emitting component 111 and a timing to apply a specific voltage at the time of the control of life activity. That is, when a command signal is output from the control section 603, the modulation signal generator 604 operates a power supply 602 for high voltage and high frequency generation so as to generate a high voltage temporarily. This high voltage is applied to electrode terminals (plates) 601-1 and 601-2, so that a strong electric field occurs between the electrode terminal (plate) 601-1 and the electrode terminal (plate) 601-2. An effect of this strong electric field occurring between the electrode terminal (plate) 601-1 and the electrode terminal (plate) 601-2 is similar to AED (Automated External Defibrillator) used for heart resuscitation.

Meanwhile, an arrangement of the two electrode terminals (plates) 601-1 and 601-2 is fixed in the life activity control device shown in Fig. 37, and the part 600 of an organism to be detected/controlled (the head or the like of the examinee) is to be inserted therebetween. However, the arrangement is not limited to that, and the electrode terminal (plate) 601-1 and the electrode terminal (plate) 601-2 may be directly attached (or temporarily adhere) to a surface of the part 600 of an organism to be detected/controlled (the head or the like of the examinee).

Further, Fig. 38 shows an applied embodiment of the life activity control device shown in Fig. 37. Fig. 38 has a feature in that an electromagnetic wave 608 for detection/control of life activity is led to an optical waveguide 609, so that an inside of a life object is illuminated with the electromagnetic wave 608 for detection/control of life activity like an endoscope and a catheter. Further, in this case, a signal obtained from the position detecting monitor section 432 of a detected point for life activity is transmitted to an optical waveguide driving circuit 610 so as to control a position of the objective lens 31 provided at a tip of the optical waveguide 609. As shown in Fig. 38, when the optical waveguide 609 is used, the control of life activity can be performed even at a location deep in an organism to be a detection/control object by illuminating the location with the electromagnetic wave 608 for detection/control of life activity, thereby drastically improving a controllable range.

Further, the present exemplary embodiment is not limited to the configuration, and the light emitting component driver 114, the light emitting component 111, and the detecting section 101

for life activity may be housed in one small capsule. In this case, the capsule is introduced into a body in such a manner that an examinee shallows the capsule, for example, and a position of the capsule is controlled from the outside by wirelessly communicating with a control section provided outside the body. In the applied embodiment in Fig. 38, the examinee has a burden at the time of introducing the optical waveguide 609 into the body. In contrast, if the capsule is used, not only the burden on the examinee can be largely reduced, but also the electromagnetic wave 608 for detection/control of life activity can be continuously projected for a long time, so that the efficiency of the control of life activity (e.g., treatment efficiency) can be largely improved.

12.3) Molecular structure of ion channel and gating control method

It is said that the voltage-gated Na^+ ion channels exist in the neuron cell body 1, and many of them are distributed near the root of the axon 2 in the neuron cell body 1, in particular. In B. Hille: Ion Channels of Excitable Membranes 3rd Edition (Sinauer Associates, Inc., 2001) p. 110, Plate 7, a model of the voltage-gated ion channel is described, and a simplified conformation of an extract of the model is shown in Fig. 39(a). Here, the "cover (gate)" and the "positively charged part" of the voltage-gated Na^+ ion channel 11 correspond to a gate 615 and a charged part 616 in Fig. 39(a), respectively.

Meanwhile, as shown in Fig. 39(a), an ion channel is embedded in a cell membrane 613 which separates an inside layer 612 facing the cytoplasm in a neuron and an outside layer 611 of the cell membrane located outside the neuron. This ion channel is made from a protein constituted by amino acids connected to each other. As shown in Fig. 39(b), in the protein, an atomic arrangement constituted by two carbon atoms C and one nitrogen atom is repeated to form a principal chain 623 of the amino acid. Particularly, a hydrogen bonding part 621 is formed between an oxygen atom double-bonded to a carbon atom C on one principal chain 623 of the amino acid and a hydrogen atom covalently bonded to a nitrogen atom on an adjacent principal chain 623 of the amino acid, which may result in that a part of the protein has an α helix conformation in which the principal chain 623 of the amino acid has a spiral tertiary structure.

Here, a residue of amino acid is expressed with "R" in Fig. 39 (b). In Fig. 39(a), (c), and (d), a part in the protein which has this α helix conformation is expressed with a shape of a

"cylinder," and respective cylindrical parts are expressed with α, β, γ, and δ. In the meantime, the bonding strength of one hydrogen bonding part 621 itself is not so strong, but there are many hydrogen bonding parts 621 in the α helix conformation, so that the overall bonding strength becomes strong. Accordingly, a cylindrical part having an α helix conformation has a very strong mechanical strength (bending stress).

As shown in Fig. 39(a), ends of the cylindrical parts α and β are closed during a resting term, so that a gate 615 is closed. Even during this resting term, ions having positive electric charge is going to enter the inside layer 612 facing the cytoplasm, because [1] the outside layer 611 of the cell membrane is much higher in ion concentration than the inside layer 612 facing the cytoplasm, and [2] there occurs a potential gradient (an arrow in wavy line) in the cell membrane 613. However, the mechanical strengths of the cylindrical parts α and β prevent incoming forces of the positive ions. Further, inside each of the cylindrical parts γ and δ respectively connected to the cylindrical parts α and β, a residue having "positive electric charge" is bonded to a residue 622 of amino acid, thereby forming a charged part 616. This residue having positive electric charge is presumably a residue of Lysine or a residue of Arginine. Since an amount of positive electric charges in a residue of Histidine is very small in a water environment (about pH 7) in a life object, it is not assumed that the residue of Histidine contributes to that.

Further, during the resting term, due to an electrostatic force from an electric field occurring by the potential gradient indicated by the arrow in wavy line in the cell membrane 613, this charged part 616 moves to a location closest to the inside layer 612 facing the cytoplasm most. The movement of the charged part 616 causes the cylindrical parts γ and δ to be twisted, so that a space of a crack 614 is expanded. It is considered that an expanding force of this crack 614 reaches the cylindrical parts α and β and works as a force closing the gate 615. Here, a state in which positive electric charges gather on a surface of the outside layer 611 of the cell membrane 613 and negative electric charges gather on the inside layer 612 facing the cytoplasm, thereby causing a potential gradient called a "polarized state."

On the other hand, when a depolarized state is caused as shown in Fig. 39(c) and the potential gradient decreases, a force to bring the charged part 616 closer to the inside layer 612 facing the cytoplasm by the electrostatic force weakens. This weakens a twisting force of the cylindrical

parts γ and δ, so that the charged part 616 is brought back to a regular position and the space in the crack 614 is shortened. Accordingly, the cylindrical parts α and β open the gate 615 in conjunction with each other. When the gate 615 is opened, Na^+ ions flow into the inside layer 612 facing the cytoplasm from the outside layer 611 of the cell membrane and a "neuronal action potential" or "impulse propagation along axon fiber" occurs. The explanation so far has been known conventionally.

In this regard, this exemplary embodiment has a feature in that during the resting term, "this ion channel is illuminated with electromagnetic waves (light) including an electromagnetic wave (light) having a specific wavelength, so that the mechanical strengths of the cylindrical parts α and β are changed so as to control opening and closing of the gate 615." The present exemplary embodiment has the following effects: [1] since the life activity control device is inexpensive, anyone can easily perform detection/measurement and control of life activity; [2] because of a high spatial resolution, adverse effects hardly occur in places other than a target part to be a controlled; and [3] because of selectivity of wavelength, adverse effects hardly occur in other life activities.

As described above, the mechanical strengths of the cylindrical parts α and β, which are indispensable to surely perform the opening and closing of the gate 615, are maintained by the bonding strength of the hydrogen bond shown in Fig. 39(b). The present exemplary embodiment has a feature in that an electromagnetic wave (light) exciting a vibration mode occurring in this hydrogen bond of C = O ... H-N is projected. Due to a very high vibrational energy of the excited state, in the hydrogen bonding part 621 in the excited state, [1] a hydrogen bonding strength is largely weakened, or [2] a phenomenon that the hydrogen bond is cleaved occurs. As a result, the mechanical strengths of the cylindrical parts α and β largely decrease and the incoming force of positive ions toward the inside layer 612 facing the cytoplasm cannot be restrained, thereby resulting in that the gate 615 is opened as shown in Fig. 39(d).

The explanation so far dealt with a method in which a neuronal action potential is accelerated only by illumination of an electromagnetic field (light) without a combination of an external electric field. As another applied embodiment, the neuronal action potential and the impulse propagation along an axon fiber can be controlled finely with higher accuracy by support of the

external electric field application to be used together with the illumination of the electromagnetic field (light). That is, the gate 615 of the ion channel is closed in a polarized state of Fig. 39(a), while the gate 615 of the ion channel is opened in a depolarized state of Fig. 39 (c). In this regard, a specific ion channel is set to be in an intermediate state between the polarization and the depolarization (a field strength caused just before the gate 615 is opened) by applying a strong electric field thereto from the outside. Accordingly, in an ion channel in this intermediate state, its gate 615 is opened due to slight changes in the mechanical strengths (deterioration of strength) of the cylindrical parts α and β.

A method to give a strong electric field from the outside is such that a high voltage is temporarily applied between the electrode terminals (plates) 601-1 and 601-2 by driving the power supply 602 for high voltage and high frequency generation in the life activity control device shown in Fig. 37. Since a light amount of an electromagnetic field (light) to be projected can be largely decreased by the support of the external electric field application, not only occurrences of side effects caused due to the control of life activity can be further reduced, but also a destruction risk of ion channels due to the illumination of a strong electromagnetic field (light) can be reduced. This yields such an effect that the support of the external electric field application can largely improve safety during the control of life activity.

12.4) Characteristic of control of life activity

A wavelength suitable for the electromagnetic field (light) to be projected for neuronal action potential control by opening and closing of the gate 615 of the ion channel or impulse propagation along axon fiber control will be explained below. As described in section 12.3, it is necessary to excite a vibration mode caused in the hydrogen bond of C = O ... H-N, in this case. The excitation of the vibration mode of this type has a feature relatively near to the row of the "Vibration of hydrogen bonding part of secondary amide -CONH-" in Table 7. Thus, as shown in section 4.7 or 11.4, when a variation range considering the difference in a detection value caused by measurement errors or measurement environments is estimated as ±15%, the variation ranges are as follows:

$1.53 \times (1 - 0.15) = 1.30$, $1.67 \times (1 + 0.15) = 1.92$, and

$1.04 \times (1 - 0.15) = 0.88$, $1.12 \times (1 + 0.15) = 1.29$.

Accordingly, when these values are summarized, the following ranges can be obtained:

- a wavelength range of an absorption band corresponding to the 1st overtone is from 1.30 μm to 1.92 μm; and

- a wavelength range of an absorption band corresponding to the 2nd overtone is from 0.88 μm to 1.29 μm.

With respect to the ranges thus obtained, remaining ranges obtained by excluding the wavelength ranges greatly absorbed by the water molecule shown in Fig. 28 are as follows:

- the wavelength range of an absorption band corresponding to the 2nd overtone is from 0.88 μm to 0.94 μm and 1.03 μm to 1.29 μm,

- the wavelength range of an absorption band corresponding to the 1st overtone is from 1.52 μm to 1.89 μm, as shown in Fig. 28.

However, the ranges show only a detection range of the nth overtone to the last. An absorption band corresponding to the combinations is also included in the near-infrared region. In view of this, when the wavelength range to detect combinations is also taken into account, the first, second, third, fourth, and fifth wavelength ranges I to V with less absorption by water shown in Fig. 28 can be taken as target ranges. Alternatively, if an absorption amount in the absorption band for the combinations is large and is not affected by the absorption by water very much, a desirable wavelength range will be in a range from 0.84 μm (or 0.875 μm) to 2.50 μm as shown in section 4.7.

As a concrete example to control a life activity by decreasing the mechanical strength of an α helix, section 12.3 has described the gating control in the ion channel. Alternatively, a life activity may be controlled by decreasing a mechanical strength of other α helices, as another exemplary embodiment. For example, as described in section 11.1, Myosin is included in a skeletal muscle. An α helix is included in a tertiary structure of this Myosin so as to secure a mechanical strength at the time the skeletal muscle contracts. In view of this, when the skeletal muscle contracts, the skeletal muscle may be illuminated with light having a wavelength within the above range to decrease the mechanical strength of the α helix, so that a muscular contractive force is weakened.

CLAIMS

[Claim 1]

A detecting method of life activity, comprising:

illuminating the life object with an electromagnetic wave of which a wavelength is included in a designated waveband or the wavelength relates to a designated peak; and

detecting the activity at least in a local area in the life object.

[Claim 2]

A controlling method of life activity, comprising:

illuminating the life object with an electromagnetic wave of which a wavelength is included in a designated waveband or the wavelength relates to a designated peak; and

controlling the activity at least in a local area in the life object.

[Claim 3]

A transmission method of information related to life activity, comprising:

illuminating the life object with an electromagnetic wave of which a wavelength is included in a designated waveband or the wavelength relates to a designated peak; and

transmitting information obtained on the basis of detection of the activity at least in a local area in the life object.

[Claim 4]

The detecting method of life activity, the controlling method of life activity, or the transmission method of information related to life activity in any one of claims 1 through 3, wherein:

the designated waveband relates to a wavelength of not less than 0.84 μm but not more than 110 μm.

[Claim 5]

The detecting method of life activity, the controlling method of life activity, or the transmission method of information related to life activity in any one of claims 1 through 3, wherein

the designated peak relates to a chemical shift value in a range of not less than δ1.7 ppm but not more than δ4.5 ppm.

[Claim 6]

A sensor configured to detect life activity at least in a local area in a life object.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A non-invasive method applied to life object comprising:

irradiating the life object with a first electromagnetic wave having a prescribed wavelength, the prescribed wavelength being included in a range from 1.028 μm to 2.50 μm; and

detecting a signal relating to a second electromagnetic wave, the second electromagnetic wave having a wavelength same as the prescribed wavelength, the second electromagnetic wave being obtained from the life object and at least a part of the second electromagnetic wave being condensed out of the life object to generate the signal; and

detecting neural activity, muscular activity, or cellular activity based on the detected signal,

2. A method according to claim 1, wherein:

a photodetector is located at a confocal position or an image forming position of a local area in the life object,

the photodetector comprises one or more photo detecting cells,

the part of the second electromagnetic wave is condensed at one photo detecting cell, and

the signal from the photodetecting cell is extracted.

3. The method according to claim 2, comprising:

obtaining position information on the local area, wherein

a signal detection relating to the second electromagnetic wave is based on the position information.

4. The method according to claim 2 or 3, wherein:

one photo detecting cell is located at the confocal position or the image forming position of the local area in the life object,

another photo detecting cell is located at a confocal position or an image forming position of another local area in the life object,

a third electromagnetic wave has a wavelength same as the prescribed wavelength,

at least a part of the third electromagnetic wave is condensed at the another photo detecting cell, and

another signal from the another photo detecting cell is extracted simultaneously.

5. The method according to claim 4, wherein the signal and the another signal are simultaneously processed.

6. The method according to any one of claims 2 to 5, wherein a colour filter is disposed in front of the photodetector.

7. The method according to any one of claims 2 to 6, wherein position information of the confocal position and the image forming position corresponds to depth information.