DESCRIPTION

BIOLOGICAL ACTIVITY CONTROL METHOD AND VARIOUS APPARATUSES UTILIZING THE METHOD

Technical Field

[0001] The present invention consists of first to fourth inventive groups that have a common basic concept.

The first inventive group relates to an antibacterial technique that prevents development of microorganisms (especially fungi) by using an ion.

The second inventive group relates to a method for controlling proliferative activity of cells by using an ion, and in particular, relates to a method for controlling proliferative activity of animal cells and a cell activity control apparatus utilizing the method.

The third inventive group relates to a refrigerator provided with an ice making apparatus with an antibacterial processing function to which the antibacterial concept of the first inventive group is applied.

The fourth inventive group relates to a rotating drum type washing machine with an antibacterial processing function to which the antibacterial concept of the first inventive group is applied.

The following description is classified into the inventive groups and presented in the above order.

Background Art

[0002]

(First Inventive Group)

Background Art of the First Inventive Group

In recent years, with growing demands for health, there have been growing demands for elimination of microorganisms (such as prokaryotes and eukaryotes) in various fields such as of daily commodities including home appliances, kitchen utensils, toiletries, stationeries, and furniture and decorative products, of industrial fields including paper and pulp-dedicated slime control agents and wood preservatives, and of medical fields including white coats, curtains, building materials, and medical appliances.

[0003] Antibacterial agents used for elimination of microorganisms including organic ones (synthetic compounds, natural compounds, and the like) and inorganic ones (metals such as silver, copper, and zinc, and photo-catalysts such as titanium oxide); conventionally, the organic compounds, which were developed as agricultural chemicals and medicines, have been mainly used. The conventionally used organic compounds have a wide range of antibacterial spectrum as well as superior immediate effectivity and bactericidality.

[0004] However, these organic compounds cause great burden on human body and environment and thus easily cause problems associated with safety. In view of this, in recent years, attention has been directed to inorganic antibacterial agents such as antibacterial metals including silver, copper, and zinc, or compounds containing these metals, and titanium oxide, which carries out germicide utilizing its photo-catalytic effect.

[0005] Attention is paid to the kinds of the metals for the inorganic

antibacterial agents. Silver ions and mercury ions are particularly superior in bacterial growth suppressive capability, followed by zinc ions, copper ions, and cadmium ions. Mercury and cadmium have great adverse affects on environment and thus are not suited for wide use as antibacterial materials, whereas silver ions, copper ions, and zinc ions have smaller adverse affects on environment and the like than do mercury and cadmium. The antibacterial activity of silver ions is 200 times greater than that of copper and 1000 times greater than that of zinc, and thus silver ions cause smaller adverse affects on environment and are particularly superior as antibacterial agents.

[0006] Thus, in recent years, antibacterial agents using silver are finding growing applications. However, if used in a wide range of applications, even the antibacterial agents using silver might find increased opportunity of leakage to natural environment, resulting in problems such as environmental pollution. Silver has particularly strong bactericidality, and thus even when it leaks to environment in a minute amount, the ecological system might be significantly affected.

[0007] Under such circumstances, there have been tightened restrictions on silver ion concentrations in drinking water. For example, in the United States, the concentration of silver ions in drinking water is restricted to 100 ppb or less, which is being even more severely tightened.

[0008] Thus, from the viewpoints of environmental preservation, maintenance of healthy lifestyles, and coping with statutory regulations, it is vital to reduce the metal content in the inorganic antibacterial agents and thereby to minimize unnecessary leakage of metal ions. This requires

a technique that allows for exhibition of a greater antibacterial effect at conventional metal ion concentrations.

[0009] Incidentally, prior art documents related to inorganic antibacterial agents include, for example, the following patent documents 1 to 3.

Patent document 1 proposes a bactericidal technique utilizing light. This technique carries out germicide utilizing flash pulses of a blue light emitting diode, instead of utilizing antibacterial metals. However, this technique, which involves intense light, causes prompted degradation of equipment, and additionally, the light itself might cause adverse affects on human body.

[0010] Patent documents 2 and 3 propose techniques that carry out germicide utilizing photo-catalysts. Patent document 2 is related to a technique that carries out germicide by irradiating a photo-catalyst such as titanium oxide with an electromagnetic wave having a wavelength in the range of 180 to 480 nm. Patent document 3 is related to a technique that utilizes antibacterial acrylonitrile fiber obtained by subjecting acrylonitrile fiber containing an antibacterial activity metal compound to heat treatment at pH 1 to 6. However, these techniques cannot allow for sufficient exhibition of antibacterial action with minute amounts of metal.

[0011]

[Patent document 1] Japanese Patent Application Publication No. 2004-275335.

[Patent document 2] Japanese Patent Application Publication No. 11-47738.

[Patent document 3] Japanese Patent Application Publication No.

2001-259012.

DISCLOSURE OF THE INVENTION

Problems that the Invention is to Solve

Means to Solve the Problems

[0012]

Disclosure of the First Inventive Group

Problems that the First Inventive Group is to Solve

The present inventors conducted an extensive study in order to solve the above-described problems. As a result it has been found that the amount of ions to be absorbed in a microorganism increases by irradiating the microorganism with a particular beam of light. It also has been found that irradiating the microorganism with the particular beam of light enables antibacterializing eukaryotes having thick cell walls at small ion concentrations, which was difficult to implement with conventional methods.

[0013] The first inventive group has been made in view of the above knowledge, and it is an object of the first inventive group to provide an antibacterial method capable of providing an equivalent or greater antibacterial effect against microorganisms compared with conventional methods at a smaller ion concentration and a smaller amount of ions, and provide an antibacterial apparatus capable of easily implementing this method.

[0014] The term "antibacterial," as used herein, is not only intended to prevent proliferation of microorganism instead of extinction thereof, but to

encompass all the following concepts: "sterilization (which means killing all the microorganisms)," "germicide (which means killing at least part of the microorganisms)," "disinfection," "fungus eradication," "bacteriostaticity (which means inhibiting proliferation of microorganisms)," "fungicide," "preservation," and the like.

Means of Realizing the Object

[0015]

Means of Realizing the Object of the First Inventive Group

A basic configuration of the first inventive group to realize the above-described object is characterized as follows. An antibacterial method for preventing growth of a microorganism using an ion includes: bringing the microorganism into contact with the ion after or while irradiating the microorganism with a particular beam of light; and irradiating the microorganism with a particular beam of light in a state where the microorganism is in contact with the ion.

[0016] With this configuration, the microorganism is irradiated with a particular beam of light before the microorganism is brought into contact with the ion or while the microorganism is being brought into contact with the ion, and in a state where the microorganism is in contact with the ion. The irradiation of the particular beam of light facilitates ion permeation through membrane. As a result, an antibacterial ion existing in the vicinity of the microorganism body is efficiently incorporated inside the microorganism body, where the ion exhibits its advantageous effects.

[0017] That is, with the above configuration, an increased number of ions are incorporated inside the microorganism body in a short period of time,

compared with conventional methods. Therefore, with a reduced number of ions to come into contact with the microorganism (one of the objects of this means is to reduce the concentration of the ions to exist around the microorganism), the obtained microorganism growth inhibitory effect is equivalent to or greater than the conventionally obtained effect.

[0018] Additionally, reducing the amount of ions makes the antibacterial free from adverse affects on environment.

[0019] Additionally, even for eukaryotes having thick cell walls, the above configuration makes ions permeate the cell walls, cell membranes, nuclear membranes, and the like to incorporate an increased number of ions in the eukaryote bodies, thereby efficiently antibacterializing the eukaryotes. It should be noted that the ion(s) refers to both an inorganic ion(s) and organic ion(s).

[0020] Here the basic concept of the present invention is to efficiently incorporate the ion in the microorganism body after increasing the ion permeability to the microorganism body by irradiating the microorganism with a particular beam of light. However, in actual circumstances of application, bringing the microorganism into contact with the ion before light irradiation substantially causes no inconveniences. This is because of the following reason. When the microorganism is brought into ion contact, such a state results that the ion exists on the surface of the microorganism, but the ion on the surface of the microorganism does not completely shield the particular beam of light. Therefore, even when the microorganism is irradiated with the particular beam of light in the state where the ion exists on the surface of the microorganism, part of the

particular beam of light reaching the microorganism changes an attribute of the microorganism, thereby improving the ion permeability. This makes ions existing in advance on the microorganism surface (ions brought in advance into contact) accelerate in their incorporation into the microorganism body.

[0021] In the above basic configuration, the ion may be a metal ion.

[0022] Metal ions have high antibacterial activity. It is therefore preferable to use a metal ion as the above ion.

[0023] In the above basic configuration, the particular beam of light may be a beam of light that acts on an ion-permeable channel of a biological membrane.

[0024] Employing this configuration causes the ion-permeable channel of the microorganism to open due to irradiation of the particular beam of light, thereby facilitating ion permeation through membrane. As a result, the ion that is in contact with the microorganism body is efficiently incorporated in the microorganism body, where the ion acts on the microorganism.

[0025] The "ion-permeable channel of a biological membrane" mainly refers to membrane transport protein membrane of the microorganism biological membrane, but this should not be construed to limit the ion-permeable channel; the term is intended as a concept that encompasses all mechanisms involved in ion incorporation into the microorganism.

[0026] In the above basic configuration, the metal ion may be a metal ion contained in a metal ion-containing solution. With this configuration, the microorganism is brought into contact with a metal ion-containing solution

that contains the metal ion. This method easily and reliably brings the metal ion into contact with the microorganism.

[0027] In the above basic configuration, the particular beam of light may have a peak wavelength of 300 to 600 nm.

[0028] If the peak wavelength of the particular beam of light is greater than 600 nm, the ion cannot be efficiently incorporated in the microorganism body. If the peak wavelength is less than 300 nm, this light itself breaks the DNA of the microorganism, which is not preferable because this greatly adversely affects human body and causes prompted degradation of equipment. In view of these circumstances, the peak wavelength is preferably restricted between the above range.

[0029] In the above configuration, the particular beam of light may have an irradiation intensity of 500 to 500000 $\mu W/cm^2$.

[0030] If the irradiation intensity of the particular beam is less than 500 $\mu W/cm^2$, the ion cannot be sufficiently incorporated in the microorganism body. If the irradiation intensity is greater than 500000 $\mu W/cm^2$, the effect of incorporating the ion in the microorganism body substantially reaches at its maximum to the detriment of cost performance. In view of these circumstances, the irradiation intensity is preferably restricted between the above range, more preferably between 1000 and 100000 $\mu W/cm^2$.

[0031] As the metal ion used in the first inventive group, from the viewpoints of the antibacterial effect and reducing adverse affects on environment, at least one ion selected from the group consisting of a silver ion, a copper ion, and a zinc ion is preferably used.

[0032] From the above-described viewpoints, the metal ion in the metal ion-containing solution has a concentration of 10 ppm or less and at the same time 1 ppb or more for securing a minimum degree of the advantageous effect. More preferably, the concentration is 5 ppb to 1 ppm, still more preferably 10 ppb to 900 ppb.

[0033] Examples of the microorganism to which the first inventive group can be applied include prokaryotes such as Escherichia coli, photosynthetic bacteria, lactic acid bacteria, actinomycete, and Staphylococcus aureus, yeasts such as Candida bacteria, and eukaryotes such as Cladosporium cladosporioides and trichophyton.

[0034] An invention directed to an antibacterial apparatus that is capable of implementing the antibacterial method according to the first inventive group is an antibacterial apparatus including: ion generating means of generating an ion; contact means of bringing the ion generated at the ion generating means into contact with a microorganism; and irradiating means of irradiating the microorganism with a particular beam of light in a state where the microorganism is in contact with the ion by the contact means.

[0035] According to an invention directed to another embodiment, an antibacterial apparatus includes: ion generating means of generating an ion; irradiating means of irradiating the microorganism with a particular beam of light; and contact means of bringing the microorganism irradiated with the particular beam of light into contact with the ion generated at the ion generating means.

[0036] Here the particular beam of light may be configured to have a peak

wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

[0037] Additionally, the ion may be a metal ion.

Additionally, the metal ion may be a silver ion.

Use of an antibacterial apparatus of these configurations enables efficient antibacterialization of microorganisms by simple operations, and additionally, the antibacterial action involves ions of extremely low concentrations. Thus, the present invention accomplishes the antibacterial object substantially without environmental contamination.

Effects of the Invention

[0038] The present invention significantly enhances the antibacterial effect against microorganisms without increasing the amount of antibacterial ions to be contained in the antibacterial agent.

[0039]

Brief Description of the Drawings of the First Inventive Group

Fig. 1 is a diagram for illustrating an antibacterial method according to the first inventive group.

Fig. 2 shows antibacterial test results in the case of using *Cladosporium cladosporioides* (NBRC 6348).

Fig. 3 shows antibacterial test results in the case of using *Escherichia coli* (NBRC-3972).

Fig. 4 shows antibacterial test results for describing a relation between the wavelength of the particular beam of light and the antibacterial effect.

Fig. 5 is a graph showing antibacterial test results in a fifth test

group.

Fig. 6 is a graph showing the antibacterial potency of groups of identical light irradiation intensities.

Fig. 7 is a graph showing a relation between the wavelength of the irradiation light and the antibacterial effect.

Fig. 8 is a graph showing antibacterial results of samples A to D in an eighth test group.

Fig. 9 is a graph showing that silver-ion incorporating portions in the microorganism body change depending on a particular beam of light.

[0040]

[Description of Reference Numeral]

1 Metal plate (silver plate)

2 Metal ion storage vessel

3 Bacterial solution

4 Light irradiating portion (LED)

5 Black box

6 Agar

7 Test vessel

8 Test vessel

9 Current source

10 Metal ion elution solution

11 Metal ion generating apparatus

12 Test solution

13 Metal ion application apparatus (contact portion and irradiating portion)

[0041]

Best Mode for Carrying out the First Inventive Group

[First]

As the ion having the antibacterial effect against microorganisms, a metal ion is exemplified, specific examples including a silver ion, a copper ion, a zinc ion, a cadmium ion, and a mercury ion. Among these metal ions, silver and/or copper are preferable for their superior safety for human body. Still, the present invention will not be limited to particular ions and various ions having an antibacterial effect are applicable.

[0042] The microorganism targeted for application of the present invention will not be limited to particular kinds. Still, particularly significant advantageous effects are expected with microorganisms having unique membrane binding protein that passes metal ions therethrough.

[0043] Examples of the microorganism targeted for application of the present invention include prokaryotes such as Escherichia coli, photosynthetic bacteria, lactic acid bacteria, actinomycete, and Staphylococcus aureus, yeasts such as candida bacteria, and eukaryotes such as Cladosporium cladosporioides and trichophyton. The present invention is also applicable to pathogenic viruses.

It is of course possible that the present invention is applicable to a target that contains a plurality of kinds of the foregoing.

[0044] The above-described membrane binding protein refers to a biological membrane that has the property of selectively passing therethrough ions utilizing a concentration gradient of the ions or a potential gradient between inside and outside of the membrane.

Examples of such biological membrane include membrane transport protein. Membrane transport protein is usually closed to atmosphere in terms of functionality. Upon receipt of a predetermined level of stimulation, the protein opens to allow particular molecules and ions to pass therethrough. Because of the potential selectivity of the membrane transport protein, the kinds of ions that can be incorporated (transported) therein are fixed. It is believed that depending on the kind of the membrane transport protein, some ions can pass through the membrane while others cannot (that is, selectivity occurs). The rate at which an ion passes through the membrane varies depending on the kind of the ion.

[0045] The present invention is characterized in significantly enhancing the ion antibacterial effect by incorporating ions in the microorganism body in a short period of time, and examples of a light source used in the present invention include solid lights such as an LED (light emitting diode) and an LD (laser diode), and bulb-type lights such as a black light and a halogen light source. Preferably, an LED or an LD is used. This is because the LED and LD are advantageous in that they are capable of controlling light wavelength, are easy to mount in the antibacterial apparatus, and are advantageous in terms of cost.

[0046] The period of time for which the ion is brought into contact with the microorganism may be suitably selected depending on the kind of the ion to be used, the kind of the microorganism, the concentration of the ion, and the amount of the microorganism. For example, in the case of antibacterializing Escherichia coli using a silver ion, the contact time is usually 1 minute to 24 hours, preferably 1 minute to 3 hours.

[0047]

[Embodiments]

Embodiments of the first inventive group will be described below.

Fig. 1 schematically shows a test procedure in the following test groups. In Fig. 1, reference numeral 1 denotes a metal plate, reference numeral 2 denotes a metal ion storage vessel, reference numeral 3 denotes a bacterial solution in which bacteria are dispersed, reference numeral 4 denotes a light irradiating portion, reference numeral 5 denotes a black box made of a light-shielding material, reference numeral 6 denotes an agar for cultivating microorganisms, reference numeral 7 denotes a test vessel, reference numeral 8 denotes a test vessel on a side without irradiation, reference numeral 9 denotes a current source, and reference numeral 10 denotes a metal ion elution solution. For convenience of description, the metal plate 1, the metal ion storage vessel 2, the current source 9, and the metal ion elution solution 10 will be collectively referred to as a metal ion generating apparatus 10, and the black box 5, the light irradiating portion 4, the test vessel 7, and a test solution 12, which are located inside the black box 5, will be collectively referred to as a metal ion application apparatus 13.

[0048] The light irradiating portion 4 has such a structure of one LED (available from Nichia Corporation, Cree, Inc., or the like) or a combination of a plurality of LEDs. The metal ion application apparatus 13 functions as an apparatus that acts as means (contact portion) of bringing an ion into contact with a microorganism and at the same time as means (irradiating portion) of irradiating the microorganism with light.

[0049]

(First Test Group)

As the metal plate 1, a silver plate was prepared. Silver is characterized in that it is small in its tendency for ionization, hardly emits electrons, and is difficult to oxidize. Silver has a standard single electrode potential of +0.8V and hardly becomes a cation. Therefore, when silver in a metal state is put into water, the silver does not easily elute. In view of this, as the method by which to prepare the silver ion solution, it is preferable to use the metal ion generating apparatus 11 shown in Fig. 1, where silver is applied with an electric field. Specifically, two pure-silver plates were placed in the metal ion storage vessel 2 shown in Fig.1, and a voltage (up to approximately 50V) was controlled in order to apply a current of 10 to 50 mA between the silver plates, thus allowing silver ions to elute in the solution. With this method, an electrical current of, for example, 30 seconds at 12.5 mA results in a silver ion solution of 900 ppb.

Controlling the current applied between the silver plates and the period of time of application enables it to prepare a silver ion solution of a 1 to 2000 ppb concentration using the metal ion generating apparatus 11. When a silver ion solution of a higher concentration than the above is prepared, it is possible to use, for example, silver ion zeolite (available from NFG) and hold 1 g of the silver ion zeolite (available from NFG) in an aqueous solution of 10 mL to effect an ion exchange, thereby preparing silver ion water of 106.2 ppm.

[0050] As the metal ion storage vessel 2, a material that is inactive with respect to the silver ion-containing solution is preferable, and examples of

such material include glass, Teflon (registered trademark), and stainless.

[0051] As the antibacterial target microorganism, a *Cladosporium cladosporioides* (NBRC 6348) standard strain (eukaryote) having an initial bacterial count of approximately 1×10^7 to 1×10^8 was prepared. This bacterial body was dispersed in a phosphate buffer (50 mM concentration), thus preparing a spore suspension 3. As the vessel for preparing the spore suspension, a vessel such as of glass, Teflon (registered trademark), and stainless is used.

[0052] The metal ion generating apparatus 11 was used as the apparatus acting as the contact portion for bringing a metal ion into contact with the microorganism and at the same time as the light irradiating portion for irradiating the microorganism with light output from the light source.

[0053] A mixture solution (referred to as test solution A) of 9 mL of the 900 ppb silver ion solution and a 1 mL bacterial solution of the spore suspension 3 was put into one of the test vessels (7 and 8) shown in Fig. 1, and a mixture solution (referred to as test solution B) of 9 mL pure water, in place of the silver ion solution, and a 1 mL bacterial solution of the spore suspension 3 was put into the other test vessel 8. These test vessels were immediately placed in the black box 5 in order to completely eliminate influences of light such as natural light and a fluorescent light, and after some period of time, the test solutions were irradiated with ultraviolet light having a peak wavelength of 365 nm and an irradiation intensity of 1800 $\mu W/cm^2$. The test solutions were sampled 15 minutes, 30 minutes, and 60 minutes after the ultraviolet light irradiation.

In Fig. 1, reference numeral 4 denotes the light irradiating portion,

and the light source of this light irradiating portion has a structure of 14 ultraviolet LEDs 4 (available from Nitride Semiconductors Co., Ltd.) combined together. The LEDs 4 were applied with a voltage of 3.8V and a total current of 21 mA in order to cause the LEDs 4 to output the ultraviolet light.

[0054] In addition to the test solutions A and B, a mixture solution (referred to as test solution C) of 9 mL of the 900 ppb silver ion solution and a 1 mL bacterial solution of the spore suspension 3, and a mixture solution (referred to as test solution D) of 9 mL pure water (without silver ions) and a 1 mL bacterial solution of the spore suspension 3 were prepared. The test vessels with these test solutions were immediately placed in the black box 5 in order to completely eliminate influences of light such as natural light and a fluorescent light, and allowed to stand without light irradiation. The test solutions were sampled 15 minutes, 30 minutes, and 60 minutes after.

[0055] Among the above-described test solutions, the test solution A, which meets all the three requirements <bacterial body + silver ions + particular light irradiation>, is the test solution according to the antibacterial method of the present invention.

[0056] The test solution B, which meets only two requirements <bacterial body + particular light irradiation>, the test solution C, which meets only two requirements <bacterial body + silver ions>, and the test solution D, which involves neither silver ion contact nor particular light irradiation with respect to the <bacterial body>, are comparative examples.

It should be noted that in the preparation of the above-described

test solutions, the ultraviolet LEDs 4 function as the light irradiating portion for outputting a particular beam of light that facilitates the membrane permeation of the ion through the biological membrane, and the metal ion application apparatus functions as the contact portion for bringing the ion into contact with the microorganism and the irradiating portion for irradiating the microorganism with light.

[0057] A sample solution of 100 μL was sampled from each of the above-prepared test solutions A to D and applied onto the potato agar 6 shown in Fig. 1, where the sample solution was cultivated for seven days at 25°C. Then the number of colonies on the agar was counted. By this method, the antibacterial effect of each sample solution was examined. The results is shown in Fig. 2.

[0058] Fig. 2 confirms that the test solution A (indicated as ○ in the figure), which results from irradiating ultraviolet light to *Cladosporium cladosporioides* in a silver-ion contacted state, exhibits a single-digit higher germiciding effect than that of the test solution C (indicated as ● in the figure), which results from silver ion contact without ultraviolet light irradiation.

[0059] It also has been found from a comparison between the test solution B (indicated as ▲ in the figure) and the test solution D (indicated as Δ in the figure) that the irradiation of ultraviolet light alone provides no antibacterial effects.

[0060] From these results, the following conclusion can be made. The irradiation intensity of the ultraviolet light used in the above tests is sufficiently lower than the intensity with which fungi can be

antibacterialized. Thus, the difference in antibacterial potency between the test solution A (○) and the test solution C (●) is not caused by the germiciding effect of the ultraviolet light itself, but this difference is possibly a result of promoted metal ion incorporation into the bacterium body by the ultraviolet light irradiation. That is, as a result of facilitated silver ion incorporation into the *Cladosporium cladosporioides* body by irradiation of the beam of light having a peak wavelength of 365 nm and an irradiation intensity of 1800 μW/cm^2, the antibacterial potency of the silver ion possibly increased.

[0061] As clearly seen from the above results, for the particular beam of light irradiated to the bacterial body, it is sufficient to use a light intensity that is low enough to cause no antibacterial effects on fungi. Thus, the antibacterial method according to the present invention can be used as a method for antibacterializing fungi that grow on human or animal skin. Additionally, from the viewpoint of enhancing safety in applying the antibacterial method according to the present invention, the particular beam of light preferably has such a degree of irradiation intensity and/or irradiation period of time that the light itself will not have an antibacterial effect on the bacterial body

[0062]

(Second Test Group)

Four kinds of test solutions were prepared in the same manner as in the first test group except that *Escherichia coli* (NBRC-3972, E. coli) was used in place of *Cladosporium cladosporioides* (NBRC 6348), and each of the test solutions were subjected to an antibacterial test. The test

solutions prepared in the second test group are denoted as 2A to 2D, respectively corresponding to the above-described test solutions A to D.

[0063] The results of the antibacterial tests are shown in Fig. 3. In Fig. 3, "▲–▲" (test solution 2A) meets all the three requirements <bacterial body + silver ions + particular light irradiation> and is an example of the present invention. In Fig. 3, "●–●" (test solution 2C) meets only two requirements <bacterial body + silver ions>, "Δ–Δ" (test solution 2B) meets only two requirements <bacterial body + particular light irradiation>, and "○–○"(test solution 2D) involves neither silver ion contact nor particular light irradiation with respect to the <bacterial body>. These constitute a comparative example group in relation to the inventive example.

[0064] As clearly seen from the results shown in Fig. 3, combining particular light irradiation with silver ion contact provides an approximately three-digit higher E. coli antibacterial effect compared with the case of silver ion contact without particular light irradiation (see ▲–▲ and ●–●). It also has been found that in the case of particular light irradiation without silver ion contact (Δ–Δ), and in the case of involving neither particular light irradiation nor silver ion contact (○–○), the antibacterial tendency was the same as in the case of the above-described fungi (test solutions B to D).

[0065]

(Third Test Group)

Here the relation between the kind of the particular beam of light and the antibacterial effect was examined using three kinds of particular beams of light having peak wavelengths of 365 nm, 525 nm, and 660 nm.

Specifically, as the bacterial body, *Cladosporium cladosporioides* (NBRC 6348) was used as in the first test group. As the light source, a LED unit available from Ships Inc. was used to output the beams of light (at a peak wavelength of 365 nm and an irradiation intensity of 1800 μW/cm^2, a peak wavelength of 525 nm and an irradiation intensity of 2800 μW/cm^2, and a peak wavelength of 660 nm and an irradiation intensity of 4000 μW/cm^2). The silver ion concentration was set at 600 ppb. For the case of the 525 nm irradiation intensity, the bacterial body was allowed to stand in a nutrient-free phosphate buffer solution for one day (one day starved state). The other matters were the same as in the first test group.

[0066] The results of the antibacterial tests are shown in Fig. 4. It has been confirmed from Fig. 4 that the cases of the 365 nm wavelength (○) and the 525 nm wavelength (Δ) each exhibited a high reinforcing effect of antibacterial potency. The case of the 660 nm wavelength (◊) exhibited substantially no reinforcing effect of antibacterial potency.

The reason for the result that no reinforcing effect of antibacterial potency was observed in case of the 660 nm wavelength is possibly that with this wavelength, silver ions cannot be efficiently incorporated in the microorganism body.

[0067] From the above-described results, 660 nm or higher is not preferable for the particular beam of light. In view of this, a beam of light having a peak wavelength of lower than 660 nm is preferably used, and more preferably, a beam of light having a peak wavelength of 600 nm or lower is used. It should be noted, however, that a beam of light having a peak wavelength of lower than 300 nm is not preferable in that it might

cause damage to DNA of a biological cell and cause harm to human and animals. Additionally, a beam of light having a peak wavelength of lower than 300 nm is not preferable in that it causes early degradation of the antibacterial apparatus (such as the housing). In view of this, as the light used to enhance the antibacterial potency, a beam of light having a peak wavelength of 300 to 600 nm is preferably used.

[0068]

(Fourth Test Group)

Sixty minutes after the light irradiation, sample solutions were sampled from the test solution A (*Cladosporium cladosporioides*, particular light irradiation + silver ions) and the test solution C (no light irradiation + silver ions) of the first test group and from the test solution 2A (*Escherichia coli*, particular light irradiation + silver ions) and the test solution 2C (no light irradiation + silver ions) of the second test group, and bacterial bodies were collected from the sample solutions by the centrifugal separation method. These bacterial bodies were pre-fixed in a 4°C environment using a 0.1 M cacodylate buffer solution and 2% glutaraldehyde and then washed three times in a 0.1 M cacodylate buffer solution at 4°C, and additionally, subjected to post-fixation processing by a method involving three hours of immersion in a 2% osmium tetraoxide aqueous solution at 4°C.

[0069] Next, the bacterial bodies were processed for 10 to 15 minutes with series of alcohol bath of increasing concentration and then processed with propylene oxide for 10 minutes three times. Further, the bacterial bodies were substituted using propylene oxide + epoxy resin for one hour, and subjected to embedding processing (in which the bacterial bodies were

allowed to stand in the epoxy resin for two days (processing temperature: 60°C) in order to make the resin infiltrate the bio-samples) using epoxy resin (main agent: Epon 812, curing agent: DDSA and NMA, speed enhancing agent: DMP-30) for two days at 60°C.

[0070] The samples thus obtained were turned into thin pieces using ultramicrotome and reinforced with carbon films for charge-up prevention, thus preparing samples for energy filter-type transmission electron microscope (EF-TEM) observation. The samples were subjected to electron microscope observation and energy dispersive X-ray analysis using R-TEM Super UTM available from EDAX.

[0071] As a result, in a sample A related to *Cladosporium cladosporioides*, no silver crystals were confirmed by the electron microscope observation, but the X-ray analysis confirmed local existence of silver at particular locations inside the bacterial body, not in the vicinity of the cell membrane. In a sample 2A related to *Escherichia coli*, it was confirmed that silver existed not around the cell membrane but in a center portion of the cell. In samples C and 2C, for which light irradiation was not carried out, no silver was detected inside the cell by both electron microscope observation and X-ray analysis.

[0072] These results lead to speculation that the silver ion exhibits its antibacterial effect when incorporated in the bacterial body by irradiation of a particular beam of light, and that the irradiation of a particular beam of light significantly promotes incorporation of the silver ion, thereby realizing a more potent antibacterial effect.

[0073]

(Fifth Test Group)

In a fifth test group, the same apparatus and method as those described in the first test group (see Fig. 1) were used to examine the relation between the silver ion concentration and the light irradiation intensity that influences the antibacterial potency and the relation between antibacterial potency and light wavelength.

[0074] As the antibacterial target microorganism, a *Candida albicans* NBRC-1060 standard strain (eukaryote) having an initial bacterial count of approximately 1×10^7 was prepared, and this bacterial body was dispersed in a phosphate buffer (50 mM concentration) using sterilization water, thus preparing a bacterial solution of a bacterial count of 1×10^6/1mL.

[0075] Silver ion concentration solutions with four different kinds of concentrations, namely, 60 ppb, 100 ppb, 300 ppb, and 1100 ppb, were prepared. Then, three test solutions were prepared for each of the four silver ion concentrations (4 kinds × 3 = 12 test solutions) by adding 1 mL of the above-described bacterial solution to 9 mL of the four different kinds of silver ion solutions. Additionally, two test solutions (reference test solutions) of zero silver ion concentrations were prepared containing only 1 mL of the bacterial solution added to 9 mL of the phosphate buffer solution. As the vessel for housing each test solution, the same vessel as the test vessel 7 shown in Fig. 1 was used.

[0076] Next, the test solutions of the identical silver ion concentration were grouped into a test unit. One of the three test solutions was placed in the test vessel 8 side without irradiation of ultraviolet light, and the other two test solutions were placed in the test vessel 7 side with one of the

test solutions irradiated with ultraviolet light having a peak wavelength of 365 nm and an irradiation intensity of 1 mW/cm^2 (1000 μW/cm^2) for 30 minutes and the other test solution irradiated with ultraviolet light having an irradiation intensity of 50 mW/cm^2 (50000 μW/cm^2) for 30 minutes.

[0077] For the reference test solutions, one of them was not irradiated with ultraviolet light (placed in the test vessel 8 side) and the other was irradiated with ultraviolet light having an irradiation intensity of 50 mW/cm^2 (placed in the test vessel 7 side).

From each test solution, a sample was extracted 30 minutes after the ultraviolet light irradiation. The sampled test solutions will be denoted as samples A to N. Table 1 lists test conditions for the samples A to N.

Similarly to the first test group, each test solution was housed in the black box 5 immediately after preparation in order to eliminate influences of light such as natural light and a fluorescent light in the laboratory.

[0078]

[Table 1]

Silver ion concentration of test solution	No light irradiation	365 nm light irradiation intensity: 1 mW/cm^2	365 nm light irradiation intensity: 50 mW/cm^2
0	Sample A		Sample B
1100 ppb	Sample C	Sample D	Sample E
300 ppb	Sample F	Sample G	Sample H
100 ppb	Sample I	Sample J	Sample K
60 ppb	Sample L	Sample M	Sample N

The samples A to N were subjected to an antibacterial test. The antibacterial test method was such that 100 μL of each sampled test solution was applied onto the agar 6 (potato agar) shown in Fig. 1, where the test solution was cultivated for three days at 25°C followed by counting the number of colonies on the agar.

[0079] The test results are shown in Fig. 5. Fig. 6 shows the results in Fig. 5 collectively on a light irradiation intensity basis. In Fig. 5, which is a graph showing the relation between the silver ion concentration and the light irradiation intensity that influences the antibacterial effect, a comparison between the sample A (silver ion concentration 0 + no light irradiation) and the sample B (silver ion concentration 0 + 50 mW/cm^2 light irradiation) shows that no antibacterial effects occur from 30-minute irradiation of the 365 nm ultraviolet light having an irradiation intensity of 50 mW/cm^2.

[0080] From the C to E group, the F to H group, the I to K group, and the L to N group, in which the silver ion concentrations are identical but the light irradiation intensities differ, the following knowledge can be seen.

(i) At any of the silver ion concentrations, light irradiation intensity enhances the antibacterial effect.

(ii) At any of the silver ion concentrations, the antibacterial effect improves as the light irradiation intensity increases.

(iii) The antibacterial potency reinforcing effect by light irradiation is notable at a silver ion concentration of 1100 ppb.

[0081] A comparison between the sample C (silver ion 1100 ppb + no light irradiation) and the sample H (silver ion 300 ppb + 50 mW/cm^2 light

irradiation) shows that light irradiation provides for equivalent or greater antibacterial effects at 1/3 to 1/4 silver ion concentrations.

[0082] Fig. 6 shows the results in Fig. 5 collectively on a light irradiation intensity basis. The above-described matters can be more clearly seen from Fig. 6. Specifically, it can be seen that with only ultraviolet light having an irradiation intensity of 50 mW/cm^2, no germiciding effects are observed, that when the silver ion concentration is set at 1100 ppb, a sufficient antibacterial effect is obtained at an irradiation intensity of 1 mW/cm^2, and that rather than the case of 1100 ppb silver ion concentration without light irradiation, the case of 300 ppb silver ion concentration with 50 mW/cm^2 light irradiation intensity exhibits a high antibacterial effect.

[0083] These results confirm that by using a small intensity of light that does not exhibit an antibacterial effect directly to the bacterial body, the antibacterial effect of the silver ion can be significantly enhanced.

While in this test group the light irradiation was carried out in the state where the bacterial body was immersed in the silver ion solution, the light irradiation may be carried out after spraying silver ion water over the bacterial body (microorganism). Additionally, the silver ion may be brought into contact with the bacterial body by attaching the bacterial body (microorganism) with silver, a silver compound, or a silver ion-containing substance (e.g., zeolite, ceramics, silica gel, silicate salt, calcium phosphate, and the like that contain silver ions) followed by spraying of water.

[0084] Additionally, an antibacterial reinforcing effect by light irradiation can be obtained also by irradiating in advance the bacterial body with light and bringing the silver ion into contact with this bacterial body within 20

minutes, preferably 5 minutes, more preferably 2 minutes after the light irradiation.

[0085]

(Sixth Test Group)

In a sixth test group, beams of light of different wavelengths were used in order to examine the relation between the wavelength of the irradiating light and the antibacterial effect.

Similarly to the above test group, *Candida albicans* NBRC-1060 was used as the bacterial body, and six test solutions of 1100 ppb silver ion concentration were prepared at a bacterial count of 7×10^6/mL. One of them was not irradiated with light while the others were irradiated with beams of light having any of the peak wavelengths of 365 nm, 400 nm, 525 nm, 600 nm, and 660 nm for 30 minutes. Then, an antibacterial test was carried out similarly to the fifth test group. As the light source of the beams of light, an LED (light emitting diode) was used.

[0086] The results are shown on a bar graph in Fig. 7. As clearly seen from the results shown in Fig. 7, at a wavelength in excess of 600 nm, no light irradiation effects were observed. At 365 nm, 400 nm, and 525 nm, notable effects were observed, and at 525 nm, a particularly notable effect was observed.

[0087] These results show that bringing the silver ion into contact with the bacterial body and irradiating it with a beam of light of 600 nm or less wavelength reinforces the antibacterial potency of the silver ion. Thus, the "particular beam of light" defined by this conclusion is a beam of light having a wavelength of 600 nm or less (preferably, less than 600 nm).

The tendency shown in Fig. 7 indicates that with a beam of light of less than 365 nm wavelength, an antibacterial potency reinforcing effect is also obtained. Note, however, that a beam of light of less than 300 nm peak wavelength is not preferable in that the light damages the DNA of the biological cell and thus does harm to an operator who implements the method of the present invention. In view of this, as the beam of light used to reinforce the antibacterial potency, a beam of light having a wavelength of equal to or more than 300 nm and less than 600 nm is preferably used.

[0088]

(Seventh Test Group)

In a seventh test group, *Escherichia coli* IFO3972 was used as the bacterial body, and whether or not the antibacterial potency reinforcing effect was present was examined with respect to silver ion, copper ion, and zinc ion. Specific conditions are as follows:

The bacterial count was 4.7×10^7.

The irradiation conditions were such that a beam of light having a peak wavelength of 365 nm was used to carry out a 30-minute irradiation at a light irradiation intensity of 50 mW/cm^2. As the metal ion concentration, the silver ion was 110 ppb, the copper ion was 2500 ppb, and the zinc ion was 6500 ppb.

As the reference (reference test solution), a metal ion-free phosphate buffer solution (50 mM concentration) was used.

[0089] The method by which to prepare the copper ion aqueous solution and the zinc ion aqueous solution was such that: 1 g of copper zeolite or zinc zeolite was put into and stirred in 5 mL of pure water; after being

allowed to stand for one hour, the resulting aqueous solution was centrifuged for 10 minutes at 5000G; a supernatant of the centrifuged solution was sampled and diluted suitably in order to determine the metal ion concentration of this aqueous solution by atomic absorption analysis.

[0090] The results in the seventh test group are listed on Table 2.

[Table 2]

Kind of ion and its concentration	30-minute irradiation of 365 nm light and 50 mW/cm^2 light	Remaining bacterial count (CFU/mL)
Reference test solution 1	–	2.0×10^6
Reference test solution 2	○	1.2×10^6
Silver ion 110 ppb	–	1.7×10^5
Silver ion 110 ppb	○	2.2×10^3
Copper ion 2500 ppb	–	1.4×10^6
Copper ion 2500 ppb	○	5.6×10^5
Zinc ion 6500 ppb	–	9.6×10^5
Zinc ion 6500 ppb	○	5.3×10^5

The results shown on Table 2 clearly confirm that also with the metal ions (copper ion and zinc ion) other than the silver ion, the antibacterial effect improves by light irradiation. It is speculated that the improvement of the antibacterial effect by irradiation of a particular beam of light is because the ion-permeable channel of the bacterial body (microorganism) is opened by the irradiation of the particular beam of light, and as a result, the metal ion existing on the surface of the bacterial body is rapidly incorporated inside the bacterial body, where the metal ion exhibits a physiological effect (anti-proliferative effect).

[0091]

(Eighth Test Group)

In the first to seventh test groups, it has been recited that irradiating the microorganism with particular light reinforces the antibacterial potency, and that the reinforcement is possibly because the metal ion existing on the surface of the bacterial body is rapidly incorporated inside the bacterial body. In the eighth test group, this was examined in further detail. Specifically, the eighth test group proves the incorporation of the silver ion inside the bacterial body and reveals the location and the existence proportion of the silver ion after incorporation inside the bacterial body by using inductively coupled plasma emission analysis.

[0092] The ICP emission analysis is such an analysis method that crates a plasma flame at high temperature of approximately 9000K by allowing argon gas to flow through a high frequency coil through which a high degree of current flows, and introduces an atomize solution sample to the flame in order to use the resulting product as an emission light source.

[0093] As the sample, *Candida albicans* NBRC-1060 was used as the bacterial body, and two test solutions were prepared at a bacterial count of 9.5×10^6/mL for each of the cases bacterial body/water (A and B) and bacterial body/1100 ppb silver ion water (C and D). In each of the two different kinds of test solutions, one of the test solutions was not irradiated with light, while the other was irradiated with a beam of light having a peak wavelength of 365 nm and an irradiation intensity of 50 mW/cm^2 for 30 minutes. As the light source, an LED (light emitting diode) was used.

[0094] The above-prepared samples A to D were subjected to confirmation of a silver ion-light composite effect using the same apparatus and method as those described in the first test group. Table 3 shows test conditions for each sample.

[Table 3]

	Silver ion concentration	Light irradiation (365 nm -50 mW/cm^2-30 minutes)
Sample A	0	Not Performed
Sample B	0	Performed
Sample C	1100 ppb	Not Performed
Sample D	1100 ppb	Performed

Fig. 8 shows the antibacterial test results of the conditions in Table 3. The results shown in Fig. 8 confirm that bringing the silver ion into contact with the bacterial body (microorganism) while irradiating it with light significantly enhances the antibacterial potency compared with carrying out silver ion contact without light irradiation.

Next, the samples A to D were subjected to the following test in order to reveal the location of the silver incorporated inside the bacterial body.

[0095]

[Test Method]

After each sample was centrifuged for 10 minutes at 15000 rotations/minute using a centrifugal separator cooled to 4°C, a sediment (bacterial body) was collected. Then, with the use of Mitochondria Isolation Kit available from Pierce Biotechnology, Inc., the sample bacterium was separated into a mitochondria fraction, a nuclear fraction,

and a cytosol fraction. Cytosol refers to a part of cytoplasm with cell organelles removed.

[0096] After the fractions of the sample bacterium were accurately weighed using a micro-balance, 5 mL of concentrated nitric acid (61%; EL: for high purity chemicals for electronics industry) and approximately 25 mL of ion exchanged water were added to the sample bacterium, thus obtaining a total weighing of 30 mL. Then 5 mL of the total was put into a sonicator and subjected to ultrasonic vibration processing for approximately five minutes.

[0097] The fraction samples of each sample bacterium thus prepared were subjected to ICP emission analysis to examine the amount of silver. The method by which to examine the amount of silver was such a method that subjected in advance an external standard sample of silver to ICP emission analysis to obtain a calibration curve, and applied values at the fraction samples to the calibration curve.

[0098] Fig. 9 shows the results of the ICP emission analysis. In Fig. 9, the distribution ratio on the vertical axis indicates the ratio (existence percentage) of amount of silver existing in each of the fractions relative to the total amount of silver, which is assumed to be 1, detected in the mitochondria, nuclear, and cytosol fractions. It should be noted that in the case with water/no light and the case with water/light, no silver was detected from any of the fractions, and thus are denoted as zero distribution ratios.

[0099]

[Test Results]

As shown in Fig. 9, both in the cases with silver ion/no light and with silver ion/light, substantially no silver was observed to exist in cytosol.

In the case with silver ion/no light, a larger amount of silver was observed in the mitochondria fraction than in the nuclear fraction.

[0100] In the case with silver ion/light, a larger amount of silver was observed in the nuclear fraction than in the mitochondria fraction.

That is, a comparison between the case with silver ion/no light and the case with silver ion/light in the mitochondria fraction confirms that the incorporation amount of the silver ion to the nucleus is approximately 2.8 times larger in the "with light" condition. The result reveals that irradiation of the light having a peak wavelength of 365 nm (particular beam of light) significantly increases the incorporation amount of the silver ion to the nucleus.

[0101] This fact leads to the conclusion that the significantly high antibacterial effect indicated by • (Ag + 365 nm) in Fig. 8 is because of incorporation of a large amount of silver ions to the nucleus by irradiation of light having a peak wavelength of 365 nm. The above-described fact also leads to the speculation that the antibacterial mechanism varies between the case of the silver ion alone and the case of bringing the silver ion into contact with the microorganism while irradiating it with particular light.

[0102] That is, it is speculated that in the case of the silver ion alone, the generation of the antibacterial potency is due to an energy metabolism disturbance caused by selective accumulation of silver on the mitochondria,

while in the case of bringing the silver ion into contact with the microorganism while irradiating it with particular light, the silver incorporation is promoted not to the mitochondria but to the nucleus, resulting in an enhanced proliferative disturbance to the microorganism.

[0103]

Industrial Applicability of the First Inventive Group

With the antibacterial method according to the present invention, the antibacterial potency of metal ions is reinforced, thereby making it possible to prevent growth of microorganisms with lower metal ion concentrations. Thus, use of this antibacterial method according to the present invention realizes a human friendly antibacterialization with reduced environmental contamination. Therefore, the industrial applicability of the inventive antibacterial method is considerable.

(Second Inventive Group)

[0104]

Background Art of the Second Inventive Group

Malignant tumors are serious diseases harmful for human life. In view of this, various methods are being developed to cure malignant tumors. The methods for curing malignant tumors are roughly classified into surgical therapy, chemotherapy, radiation therapy, photodynamic therapy (PDT), and the like.

[0105] Surgical therapy is a treatment that directly removes a malignant tumor by a surgery, and chemotherapy is a treatment that administers an antitumor agent in the body to kill tumor cells or inhibit proliferation of the tumor cells. Since surgical therapy removes the target tumor by surgery, the tumor is certainly removed.

[0106] However, it is difficult to surgically remove a tumor that is too minute to macroscopically recognize. Additionally, in the case of a malignant tumor, it is possible that the tumor cell (e.g., cancer cell) metastasizes to some other place, and it is therefore difficult to completely remove the malignant tumor cell only by surgical therapy. In view of this, generally, surgical therapy is used in combination with chemotherapy, which affects the whole body.

[0107] Radiation therapy is a treatment that kills tumor cells by irradiating an affected part with a high energy beam. The high energy beam has no selectivity and thus is destructive to every cell, irrespective of tumor cells or normal cells. Therefore, the irradiation must be carried out with pinpoint precision to a limited area. It is thus impossible to apply

radiation therapy to non-solid cancers and minute tumor cells that are difficult to detect the existence. In view of this, radiation therapy is in many cases used in combination with another treatment, especially with chemotherapy.

[0108] Photodynamic therapy (PDT) is a treatment that laser-irradiates an affected part after administration of a light-sensitive chemical substance, such as a porphyrin derivative, that is absorbed in a body cell. The light-sensitive chemical substance such as the porphyrin derivative has the property of producing a chemical reaction upon exposure to laser light and generating active oxygen. When administered to human, the porphyrin derivative rapidly disappears from normal cells but stays in tumor cells for a long period of time. Utilizing this property, when the light-sensitive chemical substance is administered and the affected part is laser-irradiated within a predetermined period of time after the administration, the tumor cells can be selectively killed.

[0109] As described above, in various treatments against malignant tumors, chemical substances that exhibit unique effects in the living body are used, and as a chemical substance that has a unique effect against malignant tumors, there is known a platinum compound-based nucleic acid metabolic antagonist agent.

[0110] Specifically, platinum complexes are known such as cisplatin (cis-dichloroamineplatinum), platinum carboxylate, and platinum silicon. All of these platinum complexes have such a structure that has tetravalent platinum as a structural center that is surrounded by a bond of ions of chlorine, ammonium, carboxylic acid, silicon, and so forth. It is believed

that these platinum complexes bond to DNA in a cancer cell to hinder DNA synthesis and a cancer cell division that follows, thereby killing the cancer cell. Thus, these platinum complexes in many cases provide prominent effects against solid cancers against which other medicines are not effective.

[0111] Thus, the platinum compound-based antitumor agents are effective antitumor agents. However, the platinum compound-based antitumor agents cause violent vomiting when orally administered or intravenously injected, and cause side effects such as kidney disorder. Additionally, the platinum compound-based antitumor agents might not be sufficiently effective depending on the occurrence location of cancer. Moreover, a long period of use might cause drug resistance (such as occurrence of a cisplatin-resistant cancer) to the detriment of the effectiveness of the platinum compound-based antitumor agents.

[0112] In view of these circumstances, such treatments are being conducted that combine together different kinds of platinum compound-based antitumor agents or combine a platinum compound-based antitumor agent with some other antitumor agent, but the above-described problems have not been solved yet. Thus, there is a need for development of a medicine that selectively acts on a tumor cell and not on a normal cell or a technique that implements a selective action on a tumor cell and not on a normal cell.

[0113] As the technique to selectively kill a tumor cell, the following patent documents 2-1 and 2-2 are exemplified.

[Patent document 2-1] Japanese Patent Application Publication No.

2004-223175 (e.g., claim 1).

[Patent document 2-2] Japanese Patent Application Publication No. 2002-543164 (e.g., claim 1).

Patent document 2-1 relates to a tumor curing apparatus that breaks air bubbles that exist in a tumor or on the surface thereof in order to kill at least a part of the tumor cells constituting the tumor.

[0114] Patent document 2-2 relates to the following technique. A method for making a tissue of a subject vertebrate an active agent transport target, including: (a) exposing the tissue to an ionizing radiation before, after, while, or during a combined period of these times when the subject vertebrate is administered a transport vehicle containing the active agent; and (b) making the tissue a target of the transport vehicle by the exposure of the tissue.

However, these techniques are still not satisfactory.

[0115]

Disclosure of the Second Inventive Group

Problems that the Second Inventive Group is to Solve

The second inventive group has been made in view of the above circumstances, and it is a main object of the second inventive group to provide a technique that implements a selective action on a tumor cell. With this object in mind, the present inventors conducted an extensive study on the basis of a unique viewpoint. As a result, the following pieces of knowledge have been found.

(1) Irradiating a cell with a particular beam of light incorporates a larger amount of ions inside the cell compared with the case without light

irradiation.

(2) When the cell is not irradiated with a particular beam of light, metal ions outside the cell cannot be sufficiently incorporated inside cell.

(3) The effect of irradiating the cell with a particular beam of light becomes particularly notable with a malignant tumor cell.

[0116] The second inventive group has been made in view of the above knowledge, and it is a first object of the second inventive group to provide a method capable of controlling a cell activity. More specifically, the first object is to provide a method for efficiently and selectively incorporating ions in a target living cell, thereby providing a cell activity control method for inhibiting the cell activity of the target cell or reinforcing the cell activity of the target cell. It is a second object of the second inventive group to provide a cell activity control apparatus capable of easily implementing this method.

[0117] The cell activity control method and the apparatus according to the second inventive group can be applied to, for example, cancer patients. Applying the present invention enables it to efficiently incorporate metal ion species having an antitumor effect only in a malignant tumor cell. This selectively kills the malignant tumor, thereby reducing side effects.

[0118]

Means of Realizing the Objects of the Second Inventive Group

The second inventive group directed to a cell activity control method to realize the above-described objects is characterized as follows. A cell activity control method for controlling a cell activity by using an ion includes: bringing the ion into contact with a cell after irradiating the cell

with a particular beam of light or while irradiating the cell with the particular beam of light; or irradiating the cell with a particular beam of light in a state where the cell is in contact with the ion.

[0119] With this configuration (hereinafter referred to as a basic configuration), a cell is irradiated with a particular beam of light while bringing an ion into contact with the cell or after bringing the ion into contact with the cell, or the cell is irradiated with a particular beam of light in a state where the cell is in contact with the ion. Irradiating the cell with the particular beam of light facilitates ion permeation through cell membrane. Thus, contacted ions are effectively incorporated inside the cell.

[0120] That is, with the above-described configuration, a larger amount of ions are incorporated only in a cell that exists in a light-irradiated site. The ions incorporated inside the cell directly affect cellular metabolism, and therefore, selecting the kind of ions to be incorporated enables it to reinforce cell proliferation or inhibit cell proliferation. That is, with the above-described configuration, the cell activity can be controlled.

[0121] In the basic configuration of the method according to the second inventive group, the cell may be an animal cell. Additionally, the cell activity control in the basic configuration may be such control that inhibits cell proliferation by, after or while irradiating an animal cell with the particular beam of light, bringing the animal cell into contact with an ion for reducing activity of the animal cell so as to increase an incorporation amount of the ion inside the animal cell.

[0122] The operative effects of the second inventive group are more

effectively exhibited with animal cells. The technical significance of this will be described with a tumor cell taken as an example.

[0123] Generally, tumor cells, especially malignant tumor cells, are active in proliferative activity (a high state of cell activity), and thus when the tumor cells are irradiated with a particular beam of light, the ion incorporation is accelerated, and at the same time the effects of the incorporated ions on the living body are notably exhibited. That is, applying antitumor ions after or while irradiating a tumoral affected part with a particular beam of light causes incorporation of a high concentration of the antitumor ions in the tumor cell, where the antitumor ions operate to inhibit cell proliferation. In the meantime, cells existing in regions that are not directly irradiated with the particular beam of light incorporate no antitumor ions or few antitumor ions, if any, and thus cell proliferation is not prevented. Additionally, even in the region irradiated with the particular beam of light, normal cells are small in the incorporation amount of antitumor ions compared with malignant tumor cells, and therefore will not be killed.

[0124] That is, this configuration enables selective incorporation of antitumor ions only in light-irradiated tumor cells. This realizes such a significant effect that the killing effect against tumor cells is high and normal cells are not damaged (side effects are reduced). Additionally, this configuration enables it to effectively incorporate antitumor ions in the tumor cells by irradiation of the particular beam of light, thereby reducing the amount of application of medicine onto the affected part. This also reduces side effects.

[0125] As used herein, "inhibition of proliferation" is used as a term that encompasses, in addition to inhibition of cell division, inhibition of growth of a cell itself, weakening immune effects, and death and killing of the cell as a result of inhibition of cell division and growth.

[0126] In the above configurations, a metal ion may used as the ion. As the metal ion, at least one ion selected from the group consisting of a silver ion, a copper ion, and a zinc ion may be used.

[0127] Metal ions are preferably used for their stability, and in particular, a metal ion selected from the group consisting of a silver ion, a copper ion, and a zinc ion is preferable in that operability to cell activity is high. Additionally, the effect of increasing the ion incorporation amount by irradiation of the particular beam of light is notably exhibited with metal ions.

[0128] In the above configuration, as the metal ion, a metal ion contained in a metal ion-containing solution may be used.

This configuration facilitates ion contact of the cell. For example, when the metal ion-containing solution is a solution containing the above-described platinum complex, applying this solution onto the tumoral affected part enables it to bring the metal ion having an antitumor effect into contact with the tumor cell, and thereafter, irradiating the affected part with a particular beam of light enables it to kill or the like only the malignant tumor cell of the affected part.

[0129] For example, in the case of a stomach cancer, after the solution containing the platinum complex is drunk, the irradiation of the particular beam of light may be carried out to a particular site by using a fiber scope

having at its tip a light irradiation function while visually checking the particular site through the fiber scope. Alternatively, use of a fiber scope having at its tip both light irradiation function and solution application function enables it to irradiate the affected part (cancer cell) with light while applying the platinum complex-containing solution directly to the affected part. This enables it to kill only a cancer cell extremely reasonably.

[0130] In the above configurations, as the particular beam of light, a beam of light that acts on an ion-permeable channel of an animal cell membrane may be used.

Employing this configuration facilitates ion permeation through membrane because the irradiation of the particular beam of light opens the ion-permeable channel of the animal cell membrane. Thus, with this configuration, ions that are brought into contact with the animal cell can be efficiently incorporated inside the cell, thereby efficiently controlling the cell activity.

[0131] Here the "ion-permeable channel of an animal cell membrane" typically means a permeable channel in a substance transport mechanism in which membrane transport protein involves, but the ion-permeable channel will not be limited to the above but is used to encompass all channels that incorporate ions from outside to inside of the cell through the animal cell membrane.

[0132] In the above configurations, as the particular beam of light, a beam of light that has a peak wavelength of 300 to 600 nm may be used.

A beam of light that has a peak wavelength in the range of 300 to

600 nm is superior in the effect of reinforcing ion permeability with respect to animal cells, and thus is preferable as the particular beam of light.

Additionally, the irradiation intensity of the particular beam of light may be 500 to 500000 μW/cm^2.

[0133] The effect of reinforcing ion permeability with respect to animal cells is influenced by the wavelength and irradiation intensity of the light, and the effect can be sufficiently exhibited when the irradiation intensity of the light is within the above range.

In the above configurations, the animal cell may be a tumor cell.

A tumor cell is more active in proliferative activity than a normal cell, and thus bringing an ion into contact with the tumor cell after or while irradiating it with the particular beam of light significantly accelerates incorporation of the ion inside the tumor cell. The incorporated ion exhibits its effect more notably in a cell that is active in proliferative activity. Therefore, this inventive method has high selectivity and cell activity controllability with respect to tumor cells.

[0134] Here the tumor cell refers to a cell, irrespective of benign or malignant, that differs from normal cells physiologically, morphologically, or biochemically. In particular, when reference is made to a "malignant tumor cell," this is intended to mean a cell such as a cancer cell that has the property of invading a boundary with some other tissue (permeation) or metastasizing and proliferating in sites inside the animal body. Examples of the cancer cell include cells that form carcinomas that occur on epidermic cells (such as stomach cancer, colon cancer, lung cancer, liver cancer, and breast cancer), sarcomas that occur on non-epithelial cells

(such as osteosarcoma, chondrosarcoma, liposarcoma, and angiosarcoma), and hematopoietic tumors that occur on hematopoiesis cells (such as leukemia, malignant lymphoma, and myeloma).

[0135] In the above configuration, as the ion, such an ion may be used that has a greater proliferative disturbance effect against the tumor cell than a normal cell.

Since a normal cell and a tumor cell differ from one another in physiological or biochemical properties, the normal cell and the tumor cell in many cases have different degrees of proliferative disturbance or proliferative reinforcement for identical ion species. Therefore, with the above configuration, which uses an ion having a high proliferative disturbance effect against the tumor cell, and additionally, involves irradiation of a particular beam of light, only the proliferation of the tumor cell can be selectively controlled in a more intensive manner.

[0136] The second inventive group directed to a cell activity control apparatus to realize the above-described objects is characterized as follows. A cell activity control apparatus includes: a light source portion for outputting a beam of light having a peak wavelength in a range of 300 to 600 nm and an irradiation intensity of 500 to 500000 $\mu W/cm^2$; an irradiating portion for guiding the beam of light output from the light source portion to an animal cell and irradiating the animal cell with the beam of light; and a contact portion for bringing an ion into contact with the animal cell.

[0137] With this configuration, a beam of light having a peak wavelength in the range of 300 to 600 nm and an irradiation intensity of 500 to 500000

$\mu W/cm^2$ is output from the light source portion and guided to the animal cell and irradiated thereto by the irradiating portion. This opens the ion-permeable channel of the animal cell. Additionally, the contact portion brings an ion into contact with the animal cell. This enables the ion to be efficiently incorporated inside the animal cell. Thus, an apparatus having this configuration controls activity of the animal cell easily and rapidly.

Effects of the Second Inventive Group

[0138] The second inventive group provides the notable effect of causing ions to be efficiently incorporated in a cell, e.g., a human malignant tumor cell. Thus, suitably selecting the ion species to be incorporated and the particular beam of light enables it to control cell activity of any tumor cell, and to selectively inhibit proliferation of, for example, a cancer cell.

[0139]

Brief Description of the Drawings of the Second Inventive Group

Fig. 10 is a schematic diagram of an apparatus for generating a metal ion.

Fig. 11 is a diagram for illustrating a cell activity control method according to the second inventive group.

Fig. 12 is a schematic diagram of a cell activity control apparatus according to the second inventive group.

[0140]

[Description of Reference Numeral]

201 Metal ion storage vessel

202 Metal plate

203 Solution

222 Direct current source

204 Cell

205 Dish

206 Dish

207 Light source

208 Ion solution brought into contact with cell

209 Black box

211 Metal ion generating vessel

212 Metal plate

213 Applied voltage

214 Ion-light transport tube

215 Syringe portion

216 Light source portion

217 Application target portion (cell)

218 Fluorescence detecting portion

219 Computer

220 First control portion

221 Second control portion

[0141]

Best Mode for Carrying out the Second Inventive Group

The second inventive group provides a method for causing a larger number of ions to be incorporated in a living cell in a short period of time while at the same time providing a cell activity control apparatus to which the method is applied.

The "ion," which is a constituent element of the second inventive group, refers to a positively or negatively charged atom or a group of such atoms, and the second inventive group encompasses all ion species. Ions are highly reactive particles, and thus when put into a living cell, they have some effect on the living cell. The degree and substance of the effect depends on the kind of the ion species. The kind of the ion species refers to whether the ion is a positive ion or a negative ion, whether the ion is a metal ion, an organic ion, or an inorganic ion, what the constituent element is, and the like. Additionally, the degree of the effect varies, even in the case of identical ion species, depending on the kind of the cell to which the ion species is applied and on the amount of ions incorporated inside the cell. In view of these circumstances, selecting the ion species and incorporating a larger amount of the ion species inside the living cell enables it to reliably control the cell activity of the living cell.

[0142] The target cell of the second inventive group is a cell having a cell membrane, and any cells having cell membranes will be encompassed by the second inventive group, examples including plant cells, animal cells, microbial cells, bacteria, and viruses. The above-described ion will be selected according to the purpose of application (reinforcement or inhibition of cell activity), and from the viewpoint of inhibiting the activity of human and animal malignant tumor cells, metal ions (positive ions) are preferable. Examples of the metal ions superior in the effect of inhibiting cell activity include a silver ion, a copper ion, a zinc ion, a cadmium ion, and a mercury ion. Among these metal ions, silver and/or copper are highly safe for human body and have potent effects on tumor cells, and thus are useful

from the viewpoint of the purpose of inhibiting proliferation of malignant tumor cells.

[0143] While the application target of the second inventive group will not be limited to a particular kind of cell, a preferable application target is an animal cell having a membrane permeable channel that selectively allows metal ions to pass therethrough. Animal cells each have a cell membrane that prevents external substances (outside the cell) from passing therethrough, and irradiating the animal cell with a particular beam of light significantly increases the ion metal permeability. Thus, bringing the metal ion into contact with the animal cell after or while irradiating it with a particular beam of light provides a notable cell activity control effect.

[0144] The second inventive group provides a notable cell activity control effect particularly with malignant tumor cells. Examples of the malignant tumor cells to which the second inventive group is conveniently applied include tissue cells such as carcinomas that occur on epidermic cells (such as stomach cancer, colon cancer, lung cancer, liver cancer, and breast cancer), sarcomas that occur on non-epithelial cells (such as osteosarcoma, chondrosarcoma, liposarcoma, and angiosarcoma), and hematopoietic tumors that occur on hematopoiesis cells (such as leukemia, malignant lymphoma, and myeloma). Additionally, proliferation of pathogenic viruses can be inhibited by applying the second inventive group thereto.

[0145] The membrane permeable channel that selectively allows metal ions to pass therethrough is typically a permeable channel in which unique membrane transport protein in the animal cell membrane involves. This

permeable channel transports only particular molecules and ions (metal ions) inside the cell. Thus, when the membrane permeable channel involves in the permeation, it is speculated that some metals can pass through the membrane while other metals cannot pass therethrough depending on the kind of the membrane transport protein (i.e., selectivity occurs), and that the speed of passing through the membrane varies depending on the kind of the metal.

[0146] It is also speculated that the passing speed through membrane is related to the difference in ion concentration (concentration gradient or potential gradient) between outside and inside of the cell membrane. It is speculated that such membrane permeable channel is usually closed to atmosphere, and upon receipt of a predetermined level of stimulation, the channel opens to allow particular molecules and ions to pass therethrough.

[0147] In the second inventive group, the membrane permeable channel is stimulated by the particular beam of light and thereby functionally opened. Note, however, that the present invention will not be limited to permeable channels in which unique membrane transport protein involves. The ion-permeable channel referred to in the second inventive group encompasses all channels that increase their ion incorporation amount inside living cells upon irradiation of particular beams of light.

[0148] For the particular beam of light, which is a constituent element of the second inventive group, such a light wavelength should be selected, according to the kind of the application target cell, that can increase the ion incorporation amount inside the cell and/or the ion incorporation speed. That is, the particular beam of light may be selected according to the kind

of the application target cell, and generally, a beam of light having a peak wavelength in the range of 300 nm to 600 nm is used. Beams of light having peak wavelengths of greater than 600 nm are small in the effect of opening the ion-permeable channel, while with beams of light having wavelengths of smaller than 300 nm, the light itself might damage normal cells, which is not preferable. Additionally, the beams of light having wavelengths of smaller than 300 nm might damage operators to the detriment of operatability.

[0149] The irradiation intensity of the particular beam of light may be conveniently determined according to the state of the application target cell and the purpose of the cell activity. Generally, the irradiation intensity is in the range of 500 to 500000 $\mu W/cm^2$. This is because with a light irradiation intensity of 500 $\mu W/cm^2$ or more, the ion-permeable channel of the animal cell membrane can be stimulated, whereas when the light irradiation intensity exceeds 500000 $\mu W/cm^2$, the effect on the ion-permeable channel substantially reaches its maximum to the detriment of cost performance.

[0150] As the light source for generating the above-described particular beam of light, solid lights such as an LED (light emitting diode) and an LD (laser diode), and bulb-type lights such as a black light and a halogen light source may be used. The LED and LD are advantageous in that they are capable of controlling light wavelength, are easy to mount in the apparatus to control cell activity (cell activity control apparatus), and are advantageous in terms of cost.

[0151] The period of time for the light irradiation to the cell may be

conveniently set according to the kind of the ion to be used, the ion concentration, the cell species, and the cell volume. For example, in the case of inhibiting proliferation a squamous cell derived from laryngeal cancer, the light irradiation time is approximately 1 minute to 1 hour, and more specifically, an irradiation of 5 to 40 minutes or 10 to 20 minutes is carried out.

The particular beam of light can be transmitted to the application target site (cell) using a light transmission apparatus such as an optical fiber. Additionally, the ion can be easily brought into contact with the application target site (cell) as an ion-containing solution by means of, for example, a cannula or an injector.

[0152]

The second inventive group will be described in detail on the basis of test examples (test examples as examples according to the second inventive group).

(Example 1 of the Second Inventive Group)

Example 1 of the second inventive group relates to a cell activity control method.

[0153]

(First Test)

As the ion to control the cell activity, a silver ion was prepared. Silver is characterized in that it is small in its tendency for ionization, hardly emits electrons, is difficult to oxidize, and has a standard single electrode potential of +0.8V and thus hardly becomes a cation. Therefore, when silver in a metal state is put into water, the silver does not easily

elute. In view of this, in example 1, as the method by which to prepare the silver ion-containing solution, such a method was used that applied an electric field to the silver. Specifically, as shown in Fig. 10, two pure-silver plates 202 were immersed in a vessel 201 with a solution 203 therein, and a voltage of 50V or less was applied in order to flow a DC current 222 of 10 to 50 mA between the plates. Thus, silver ions were allowed to elute in the solution, thereby preparing a silver ion-containing solution 203.

[0154] As the above-described solution, a phosphate buffer solution (PBS(−)) made of 8.0 g/L of NaCl, 0.2 g/L of KCl, 1.15 g/L of Na_2HPO_4, 0.2 g/L of Na_2PO_4, and water was used. As the vessel 201 (Fig. 10) for generating the silver ion-containing solution, a beaker made of glass was used. The material of the vessel 201 is preferably inactive to the silver ion-containing solution, and it is therefore preferable to use a vessel made of glass, resin such as acrylic resin, Teflon (registered trademark), and stainless.

[0155] With the above-described method, an electrification of, for example, 60 seconds at 12.5 mA results in a silver ion solution of approximately 1 ppm.

It should be noted that the silver ion-containing solution may be prepared using silver ion zeolite. Specifically, 1 g of silver ion zeolite available from Sinanen Zeomic Co., Ltd. or NFG (NFG Ag ion zeolite) may be put into and stirred in 10 mL of pure water, thus preparing a silver ion-containing solution of 100 ppm.

[0156] Next, as an application target cell, a human laryngeal cancer-derived squamous cell (malignant tumor cell) was prepared. This

cell (in 2×10^5 pieces) was placed on a bottom surface of a 90-mm dish (polystyrene dish available from IWAKI Houseware Co.,Ltd.), and a suitable amount of a culture solution was put in the dish. As the culture solution, such a culture solution was used that a culture medium, Eagle MEM (Nissui Seiyaku Co., Ltd.), was mixed with 1% of L-glutamine, 10% of sodium hydrogen carbonate, 10% of fetal bovine serum, and a suitable amount of phenol red. Two test dishes C1 and D1 with malignant tumor cells therein were prepared.

[0157] The above-described test dishes C1 and D1 were placed in a CO_2 incubator for 2 to 3 days until the tumor cell proliferated to 8×10^5 pieces on the bottom surface of each dish. Then, the culture solution in the dish was removed using an aspirator and the cells were rinsed with 10 mL of Dulbecco's phosphate buffer solution/phosphate buffer solution (–). The rinsing is an operation for eliminating the influences of the culture solution and judging only effects realized by silver ions.

[0158] Similarly to the above, the phosphate buffer solution (–) is a solution made of 8.0 g/L of NaCl, 0.2 g/L of KCl, 1.15 g/L of Na_2HPO_4, 0.2 g/L of Na_2PO_4, and water.

[0159] As shown in Fig. 11, the test dish C1 (reference numeral 205 in Fig. 11) and the test dish D1 (reference numeral 206 in Fig. 11) were placed in the black box 209, and a 6-mL silver ion-containing solution having a silver ion concentration of 50 ppm and diluted with phosphate buffer solution (–) was injected to cells 204·204 using a syringe. After the injection, the test dish D1 (reference numeral 206 in Fig. 11) was irradiated with a beam of light having a peak wavelength of 365 nm and an irradiation intensity of 2

mW/cm^2 for 30 minutes. The test dish C1 (reference numeral 205 in Fig. 11) was not irradiated with light and was used as a reference with which to judge the light irradiation effect.

[0160] In the light irradiation, as the light source, Chip Type UV LED NCSU 033A(T) available from Nichia Corporation was used, and as a light lead from the light source to the cell surface, Deep UV Fiber (DUV-S), which used fluorine-containing silica glass (modified silica) and was available from SWCC Showa Holdings Co., LTD., was used. With an optical fiber of silica glass containing a minute amount of fluorine, the permeability in the ultraviolet spectrum improves and thus the irradiation resistance improves, which is preferable. Reference numeral 208 in Fig. 11 denotes a silver ion that is brought into contact with the cell.

[0161] Additionally, with the use of a phosphate buffer solution (–) not containing silver ions, two test dishes A1 and B1 were prepared in otherwise the same manner as in the above. These were placed in the black box 9 similarly to the above, and only the dish B1 was irradiated with a beam of light having a peak wavelength of 365 nm and an irradiation intensity of 2 mW/cm^2 for 30 minutes.

From these test dishes, the solutions were removed by suction with an aspirator, and then each of the test dishes was rinsed three times with 10 mL of phosphate buffer solution (–). After the rinsing, 4 mL of phosphate buffer solution (–) was dropped into the test dishes.

[0162] The test dishes A1 to D1 subjected to the above operations were examined for the degree of proliferative disturbance of tumor cells by fluorescent staining with the use of Cellstain-Double Staining Kit available

from Dojindo Laboratories.

[0163] First, the fluorescent staining will be described. In the Cellstain-Double Staining Kit, Calcein-AM and Propidium Iodide function as follows. Calcein-AM functions as a living cell staining fluorescent dye. Calcein-AM has its lipophilicity increased by acetoxymethylating four carboxyl groups of Calcein. Thus, Calcein-AM has high cell membrane permeability. Calcein-AM is not fluorescent by itself, but when in a living cell, Calcein-AM has its acetoxymethyl group hydrolyzed by esterase in the cell and thus begins to emit yellowish green fluorescent light. In a dead cell, esterase is deactivated and Calcein-AM is not hydrolyzed, and thus no fluorescent light is emitted.

[0164] In the Cellstain-Double Staining Kit, Propidium Iodide (PI) functions as a dead cell staining fluorescent dye. Propidium Iodide is incorporated inside the cell only when the cell membrane is broken and intercalates into the double helix structure of DNA to emit red fluorescent light. Propidium Iodide, on the other hand, cannot pass through the cell membrane of a living cell and thus does not emit fluorescent light with a living cell. In view of this, an observation using the Cellstain-Double Staining Kit through a band pass filter at a wavelength of 400 to 440 nm enables it to observe the dead cell and the living cell simultaneously.

[0165] In this test, 20 μL of Calcein-AM stock solution (1 mmol/L) as an A solution and 30 μL of PI stock solution (1.5 mmol/L) as a B solution were mixed in 10 ml of phosphate buffer solution (–). In the mixture solution, the Calcein-AM concentration was 2 μ mol/L and the PI concentration was 4 μ mol/L.

[0166] Two mL of this mixture solution was dropped into test dishes and incubated in a thermostatic chamber of 37°C for 15 minutes. Then with the use of a filter of 490 ± 10 nm, the number of cells stained with yellowish green (living cells) and the number of cells stained with red (dead cells) were counted.

The measurement results are listed in Table 201. Table 201 also lists estimations by a judgment standard of a human leucocyte antigen lymphocyte cytotoxicity test shown in Table 202.

[0167]

[Table 201] Cell Activity Test Results 1

Test	Test dish A1	Test dish B1	Test dish C1	Test dish D1
Silver ion concentration (ppm)	0	0	50	50
Light irradiation	None	Done	None	Done
Number of dead cells	12	18	104	570
Total cells observed	586	575	580	578
Dead cell ratio (%)	2.0	3.1	17.9	98.6
Judgment	Negative	Negative	Negative	Highly positive
Score	1	1	2	8

[0168]

[Table 202] Score Sheet

Score	Dead cell ratio (%)	Judgment
1	0–10	Negative
2	10–20	Negative
4	20–40	Weakly positive
6	40–80	Positive
8	80–100	Highly positive

0	Judgment impossible	

It has been confirmed from the results of Table 201 that applying both silver ions and light to the tumor cell significantly increases the dead cell ratio to 5.5 times the case of applying silver ions alone (no light irradiation). It also has been confirmed that this effect is not due to killing of the cells by the light.

[0169] Specifically, it has been revealed from a comparison between the results of the test dish A1 and the test dish B1 that only using the particular beam of light (ultraviolet light) of the irradiation intensity used in the above-described test substantially cannot serve as a disturbance to growth of the tumor cell. It also has been revealed from a comparison between the results of the test dish B1 and the test dish C1 that the difference between the dishes is due to application of silver ions.

[0170] A comparison between the results of the test dishes A1, B1, C1, and D1 in view of the above findings reveals that the significant increase in dead cell ratio in the test dish D1 is not due to a simple additive effect of the proliferative disturbance effect of the ultraviolet light itself and the proliferative disturbance effect of the silver ions themselves.

These findings lead to the speculation that the significant increase in dead cell ratio in the test dish D1 is a result of promoted metal ion incorporation inside the cell by the particular beam of light (ultraviolet light in this example) and a significantly improved disturbance effect of silver ions against growth or proliferation of the living body because of a larger amount of silver ions incorporated inside the cell.

[0171] This speculation was examined as follows. From tumor cells A1 to D1 processed under the same conditions as those in Table 201, samples of a nuclear fraction, a mitochondria fraction, a nuclear protein fraction, and a cytosol fraction were prepared. The samples were irradiated with radiation light from a large-size radiations facility (Spring–8) in order to measure fluorescent X-rays. For the fraction of the nuclear and the mitochondria, Mitochondria Isolation Kit available from Pierce was used, and for extraction of the nuclear protein fraction, a nuclear protein isolation kit (ReadyPrepCytoplasmic/Nuclear) available from Bio-Rad Laboratories, Inc. was used.

[0172] Additionally, for the analysis, Beamline BL37XU (hard X-ray undulator beamline, exciting X-rays: 30 keV, slit: 0.2 mm long × 0.5 mm wide) was used, and characteristic X rays emitted from the samples were measured with a fluorescent X-ray analyzer provided with a Si (Li) semiconductor detector.

[0173] As a result of above-described measurement, a comparison between the cell to which both silver ions and 365 nm wavelength light irradiation were applied, the cell to which only silver ions were applied, the cell to which only light was applied, and the cell to which none was applied confirmed that the cell to which both silver ions and 365 nm wavelength light irradiation were applied had a larger amount of ion incorporation in organelles such as the cell nucleus and mitochondria compared with the other cells. It also has been confirmed that a larger amount of silver was incorporated in the cell nucleus.

[0174] The cytosol had a small amount of silver was small and showed no

increase in incorporation amount by light irradiation. In order to more specifically analyze the incorporation of silver ions in the cell nucleus, the nucleus protein was extracted from the cell nucleus and separated from other components such as DNA to examine the existence of silver in the nucleus protein. As a result, it has been confirmed that the amount of silver in the nucleus protein tended to rather decrease than increase.

[0175] Considering the results together with the fact that the light-irradiated cell increased the amount of silver incorporation inside the nucleus compared with the case without light irradiation, it is speculated that the silver incorporated inside the cell binds to a nucleic acid component in the cell nucleus.

[0176] These findings have proved that applying silver ions and a particular beam of light to a living cell according to the present invention enables it to incorporate a notable amount of silver inside the living cell. It also has been proved that the above advantageous effect only requires weak light (particular beam of light) that does not disturb the growth or proliferation of the living cell.

[0177]

(Second Test)

In place of the laryngeal cancer-derived squamous cell (malignant tumor cell), a small intestine intestinal mucosa cell (normal cell) was used to prepare test dishes A2 to D2 in otherwise the same manner as in the first test in order to examine the influence of the particular beam of light. The results are shown in Table 203.

[0178]

[Table 203] Cell Activity Test Results 2

Test	Test dish A2	Test dish B2	Test dish C2	Test dish D2
Silver ion concentration (ppm)	0	0	50	50
Light irradiation	None	Done	None	Done
Number of dead cells	12	18	104	168
Total cells observed	586	575	580	578
Dead cell ratio (%)	2.0	3.1	18.0	29.3
Judgment	Negative	Negative	Negative	Weakly positive
Score	1	1	2	4

[0179] As clearly seen from the results shown in Table 203, it has been confirmed that even in the case of the small intestine intestinal mucosa cell (normal cell), which was not a malignant tumor cell, use of both silver ions and light irradiation significantly increases the dead cell ratio. However, it has been confirmed from a comparison between table 201 and table 203 that the effect of increasing the dead cell ratio (i.e., cell proliferation inhibitory effect) significantly varies between the case of the malignant tumor cell and the case of the normal cell, and that effect is significantly larger in the case of the malignant tumor cell.

[0180] In view of this, applying the method according to the present invention to, for example, cancer patients is convenient in that the advantageous effects of the method are potent against cancer cells and weak against normal cells. Additionally, the method according to the present invention uses a particular beam of light. Light has good

directivity and thus can be radiated only to an affected part. At the same time, the particular beam of light only needs to be a weak beam of light that does not damage the cell. This advantage, combined with the above-described property of weakness against normal cells, totally eliminates damage to normal cells, thereby enabling it to kill only the cancer cells.

[0181]

(Third Test in the Second Inventive Group)

A squamous cell derived from laryngeal cancer (malignant tumor cell) was placed in a half side of one dish, and a small intestine intestinal mucosa cell (normal cell) was placed in the other half of the dish. The cells were cultured under the same conditions in order to prepare test dishes A3 to D3 in otherwise the same manner as in the first test. Similarly to the first test, the test dishes A3 to D3 were used to observe living cells stained with yellowish green and dead cells stained with red.

[0182] As a result, an extremely clear difference was confirmed between one half and the other half of the test dish D3, which applied both silver ions and light irradiation. Specifically, red was significantly dominant in the half in which the squamous cell derived from laryngeal cancer was cultured, while yellowish green was dominant in the half in which the small intestine intestinal mucosa cell was cultured. This result agrees to the results of the first and second tests. Thus, the increase in the silver ion incorporation amount inside malignant tumors over normal cells by irradiation of a particular beam of light that does not damage the cell was also confirmed by the above-described result.

[0183]

(Fourth Test in the Second Inventive Group)

Test dishes E (25 ppm), F (25 ppm), G (10 ppm), and H (10 ppm) were prepared in the same manner as in the first test except that the silver ion concentration was set at 10 ppm and 25 ppm. These dishes were used to examine cell proliferative activity in the same manner as in the first example group. The results are shown in Table 204 together with the results in Table 201.

[0184]

[Table 204] Cell Activity Test Results 3

Test	Test dish A1	Test dish B1	Test dish C1	Test dish D1	Test dish E	Test dish F	Test dish G	Test dish H
Silver ion concentration (ppm)	0	0	50	50	25	25	10	10
Light irradiation	None	Done	None	Done	None	Done	None	Done
Number of dead cells	12	18	104	570	94	87	85	98
Total cells observed	586	575	580	578	567	589	584	577
Dead cell ratio (%)	2.0	3.1	17.9	98.6	16.6	14.8	14.6	17.0
Judgment	Negative	Negative	Negative	Highly positive	Negative	Negative	Negative	Negative
Score	1	1	2	8	2	2	2	2

[0185] In Table 204, a comparison between the results of C1, E, and C shows that in the case without irradiation of the particular beam of light, as the silver ion concentration increased in the order of G (10 ppm) → E (25 ppm) → C1 (50 ppm), such a tendency was observed that the dead cell ratio increased as 14.6%, 16.6%, and 17.9%. However, the differences were

extremely small. It has been confirmed from a comparison between the results of D1, F, and H that in the case of irradiation of the particular beam of light, the dead cell ratio significantly increased only in the case of 50 ppm compared with the cases of 10 ppm and 25 ppm.

[0186] This result means that the control effect of the cell activity has a dependency on concentration of silver ions, but the concentration is not in a linear relationship with cell death. In view of this, it is necessary to suitably select the metal ion concentration according to the purpose of the cell activity control. The reason for the non-linear relationship between the silver ion concentration and cell death is speculated such that although irradiation of the particular beam of light accelerates incorporation of silver ions inside the cell, an excessively low concentration of external silver ions reduces the absolute amount of silver ions to be incorporated inside the cell within a predetermined period of time, thus failing to cause death of the cell.

[0187]

(Fifth Test in the Second Inventive Group)

An examination was conducted for the relationship between the kind of light and the silver ion incorporation amount of a squamous cell derived from laryngeal cancer in the same manner as in the first test under the conditions such that as particular beams of light, beams of light having wavelengths of 365 nm, 400 nm, 525 nm, 600 nm, and 660 nm were used, and that the light intensity was set at an irradiation intensity of 2 mW/cm^2. The results are shown Table 205. It should be noted that in the case of the 365 nm wavelength, another test was carried out in addition to the first

test.

[0188]

[Table 205] Cell Activity Test Results 4

Test	X1	X2	X3	X4	X5
Silver ion concentration (ppm)	50	50	50	50	50
Light wavelength (nm)	365	400	525	600	660
Number of dead cells	570	550	560	546	101
Total cells observed	578	575	580	578	567
Dead cell ratio (%)	98.6	96.0	97.0	94.0	18.0
Judgment	Highly positive	Highly positive	Highly positive	Highly positive	Negative
Score	8	8	8	8	2

[0189] Table 205 shows that the dead cell ratio varies depending on the wavelength of the irradiated light, and the variation is particularly large between the wavelength of 600 nm and 660 nm, where the dead cell ratio decreases from 94% to 18%.

This has led to the finding that applying a particular beam of light effectively opens the ion-permeable channel of the cell membrane. The tendency read from Table 205 indicates that the effect of inhibiting the cell activity can be obtained with wavelengths less than 365 nm. Note, however, that beams of light having wavelengths less than 300 nm themselves damage DNAs of normal cells and therefore are not suitable as the light to open the ion-permeable channel of the cell membrane. In view of this, the particular beam of light is preferably 300 nm to 660 nm, more

preferably 300 nm to 600 nm or 300 nm to 525 nm, further more preferably 365 nm to 525 nm.

[0190]

(Example 2 of the Second Inventive Group)

Example 2 of the second inventive group relates to a cell activity control apparatus to which the cell activity control method described in Example 1 of the second inventive group is applied. Fig. 12 shows the cell activity control apparatus according to the present invention. A schematic of the cell activity control apparatus of example 2 of the second inventive group will be described by referring to Fig. 12.

[0191] This apparatus includes a metal ion generating vessel 211 connected to a first control portion 220, a metal plate 212, an ion-light transport tube 214, a syringe portion 215, a light source portion 216 connected to a second control portion 221, an application target portion (cell) 217, a fluorescence detecting portion 218, and a computer 219. The first control portion 220 is a device for applying voltage to the metal ion generating vessel 211 by suitably controlling requirements such as the amount of voltage application and the period of time for application in accordance with programs stored in the computer 219. The second control portion 221 is a device for controlling the light source portion 216 so that it emits a particular beam of light under suitable conditions (such as the light irradiation intensity and the period of time for irradiation) in accordance with programs stored in the computer 219.

[0192] Inside the metal ion generating vessel 211 is located the metal plate 212, and a voltage 213 is applied to the metal plate 212. The metal ion

generating vessel 211 is also provided with a solution inlet (not shown) through which a solution can be injected. A solution is injected through the inlet as necessary.

[0193] At least one of the metal plates in the metal ion generating vessel 211 is a silver plate, and a phosphate buffer solution (–), described later, is injected through the solution inlet (not shown). Then, the metal plate 212 is applied with voltage, thus preparing a metal ion (silver ion)-containing solution having silver ions eluting in the phosphate buffer solution.

[0194] The ion-light transport tube 214 is composed of a hollow portion and an optical fiber portion surrounding the hollow portion. The hollow portion, which is at a shaft center, functions as a pathway through which an ion solution passes, and the optical fiber portion functions as an optical transmission pathway. The syringe portion 215 quantitatively sends the metal ion solution to the hollow portion. The syringe portion 215 is located between the metal ion generating vessel 211 and the ion-light transport tube 214 and made of, in the apparatus example in Fig. 3, an optical fiber material capable of transporting light to outside the syringe portion 215.

[0195] The light source portion 216 has a light source capable of generating light (particular beam of light) having a peak wavelength in a range of 300 to 600 nm and an irradiation intensity of 500 to 500000 $\mu W/cm^2$, and is connected at its tip to an optical fiber material outside the syringe portion 215. Thus, the particular beam of light generated at the light source portion is guided to the application target portion (cell) 217 through the fiber material of the syringe portion 215 and the fiber portion

of the ion-light transport tube 214. It should be noted that the syringe portion 215 is not essential and the light source portion 216 may be directly connected to the optical fiber portion of the ion-light transport tube 214 without mediation of the syringe portion 215.

[0196] As the light source, Chip Type UV LED NCSU 033A(T) available from Nichia Corporation may be used. Such a configuration is possible that one LED or a plurality of LEDs is fixed to an aluminum substrate of 1 mm thick provided with both cooling fan and heat sink. Additionally, a configuration capable of varying the light output is possible.

[0197] The application target portion 217 is an area where the target cell to which the cell activity control method is applied. In the example of Fig. 12, the cells placed in the dish are the application target portion 217. In the actual application, for example, an affected tumor part of a patient is the application target portion 217.

The fluorescence detecting portion 218 is a device for optically reading the state of a cell at the application target portion to which the cell activity control method is applied, and has an optical sensor for irradiating fluorescent light and detecting reflected light thereof. Information detected by the optical sensor of the fluorescence detecting portion 218 is output to the computer 219. The computer 219 processes the information on the basis of an image processing program set in advance, determines the proliferation activity level of the cell existing in the application target portion, and displays the level on, for example, a display of the computer 219. As the fluorescent sensor, for example, a CCD (Charge Coupled Device) may be used.

[0198] It is possible to connect to the injection inlet of the metal ion generating vessel 211 a solution injection apparatus for quantitatively or continuously injecting a solution. In this case, the syringe portion 215, which quantitatively or continuously sends a metal ion solution, is not necessary.

[0199] In the above-described cell activity control apparatus, the optical fiber portion of the ion-light transport tube 214 serves as the irradiating portion for guiding the light output from the light source portion to the animal cell and irradiating the light to the animal cell. The tip portion of the hollow portion of the ion-light transport tube 214 serves as the contact portion for bringing the metal ion into contact with the cell. That is, in the above-described apparatus, the ion-light transport tube 214 serves as both contact portion and irradiating portion.

[0200]

Industrial Applicability of the Second Inventive Group

The cell activity control method and the cell activity control apparatus according to the second inventive group can be applied to, for example, cancer patients. Applying the present invention enables it to cause ion species exhibiting the antitumor effect to be efficiently incorporated only inside malignant tumor cells. This realizes selective killing of malignant tumor cells. Therefore, the industrial applicability of the method and the apparatus is considerable.

(Third Inventive Group)

[0201]

Background Art of the Third Inventive Group

Household refrigerators and the like are usually equipped with automatic ice making apparatuses. Generally, the automatic ice making apparatuses provided in refrigerators are each composed of a water feeding tank located in the refrigerator, an ice making tray located in a portion of a freezer compartment, a water conduit for guiding water stored in a storage tank to the ice making tray, and an ice storage vessel for storing blocks of ice thus made. The water conduit assumes the role of guiding the water in the water feeding tank located in the refrigerator to the freezer compartment side, and since the refrigerator and the freezer compartment are partitioned by a heat insulating material, the water conduit is plumbed through the heat insulating material.

[0202] In automatic ice making apparatuses of this structure, the water feeding tank and part of the water conduit are located inside the refrigerator, and the temperature inside the refrigerator usually 1 to 6°C, which enables microorganisms to grow. Thus, through a long period use, molds and bacteria may proliferate inside the tank and the water conduit.

[0203] In view of this, such a technique was proposed that makes these members detachable and easy to wash. Examples of techniques related to automatic ice making apparatuses include patent documents 3-1 to 3-3.

[Patent document 1] Japanese Patent Application Publication No. 5-306858.

[Patent document 2] Japanese Patent Application Publication No.

2002-295935.

[Patent document 3] Japanese Patent Application Publication No. 2007-333325.

[0204]

Disclosure of the Third Inventive Group

Problems that the Third Inventive Group is to Solve

In refrigerators provided with automatic ice making apparatuses, the water feeding tank needs to occasionally detached and supplied with water. Thus the water feeding tank is easy to wash because it can be washed while being supplied with water. However, detaching and washing the water conduit attached to the refrigerator and putting the water conduit back into place is a great burden for general users. Additionally, the interior of the water conduit is difficult to visually recognize from outside, which causes reluctance to clean the water conduit, resulting in problems including insanitation.

[0205] Incidentally, it is conventionally known that metal ions such as of silver and copper have antibacterial potency against microorganisms such as molds. However, the metal ions having antibacterial potency are substances having bioactivity and therefore have influences on human body and natural environments. In view of this, when these metal ions are used in antibacterial applications, the amount of use needs to be minimized.

[0206] The present inventors conducted an extensive study on the method for controlling growth of microorganisms such as molds and animal and plant cells. As a result, it has been found that the ions (especially metal

ions) having antibacterial potency significantly enhance the effects of the antibacterial potency in the presence of a particular beam of light.

The third inventive group has been made in view of the above knowledge. It is an object of the third inventive group to provide an ice making apparatus having an automatic antibacterial processing function of keeping the interior of an automatic ice making apparatus of a refrigerator always clean.

[0207]

Means of Realizing the Object of the Third Inventive Group

The third inventive group directed to realize the above-described objects is characterized as follows.

A refrigerator provided with an automatic ice making apparatus is characterized in that the automatic ice making apparatus includes: an ice making portion; a water feeding tank; a water conduit for guiding water stored in the water feeding tank to the ice making portion; an ion supply portion for supplying an ion to an interior of the water feeding tank and/or the water conduit; and a light source portion for irradiating the interior of the water feeding tank and/or the water conduit with a particular beam of light.

[0208] A refrigerator provided with an automatic ice making apparatus is characterized in that the automatic ice making apparatus includes: an ice making portion; a water conduit for guiding water to the ice making portion; an ion supply portion for supplying an ion to the water conduit; and a light source portion for irradiating the water conduit with a particular beam of light.

[0209] A refrigerator provided with an automatic ice making apparatus is characterized in that the automatic ice making apparatus includes: an ice making portion; a water conduit for guiding water to the ice making portion; and a light source portion for irradiating the water conduit with a particular beam of light, and in that the water conduit contains a silver ion elution material for eluting a silver ion.

[0210] A refrigerator provided with a refrigerating compartment, a freezer compartment isolated from the refrigerating compartment, and an automatic ice making apparatus is characterized in that the automatic ice making apparatus includes: a water feeding tank located in the refrigerating compartment; an ice making tray located in a portion of the freezer compartment; a water conduit for guiding water stored in the refrigerating compartment to the ice making portion; and an ion supply portion for supplying an ion to an interior of the water feeding tank and/or the interior of the water conduit, and in that the water conduit is light transmissive; and a light source portion for irradiating the water conduit with a particular beam of light is located near the water conduit.

[0211] In the refrigerator provided with the automatic ice making apparatus of the above-described configuration, the water feeding tank of the automatic ice making apparatus may be light transmissive; and a light source portion for irradiating the water conduit with a particular beam of light may be located near the water feeding tank.

The particular beam of light may have a peak wavelength in the range of 300 to 600 nm.

The particular beam of light may have an irradiation intensity of

500 to 500000 μW/cm^2.

[0212] In the automatic ice making apparatus with the above configurations, the ion supply portion supplies ions to the interior of the water conduit or to the interior of the water conduit and the interior of the water feeding tank, and the light source portion irradiates the water conduit and so forth with the above-described particular beam of light. This enables it to prevent microorganisms and the like from proliferating in the interior of the water conduit or in the interior of the water conduit and the interior of the water feeding tank, and to germicide proliferating microorganisms and the like with a small concentration of ions.

[0213] That is, the automatic ice making apparatus with the above configurations automatically carries out antibacterial processing of the interior of the water conduit and the like. This keeps water-existing portions of the automatic ice making apparatus always clean without the need for removing and washing the water conduit and the water feeding tank, and this advantageous effect is realized with an extremely low concentration of ions. The realization of the above-described advantageous effect with the above configurations is because the above configurations employ an antibacterial method that combines a particular beam of light with ions. The principle of this antibacterial method is that irradiating microorganisms and the like with the particular beam of light opens the inherent function of tissues of microorganisms and the like (including animals and plants) to shield off foreign substances (i.e., opens the ion-permeable channel), thereby causing ions to be effectively incorporated inside a body. Incorporating an increased number of ions

inside the microorganism body enables the ions to sufficiently exhibit effects such as metabolism disturbance, thereby inhibiting growth of the microorganisms and the like and germiciding them.

[0214] In the above-described configuration, the ion supply portion may be a silver ion supply portion for supplying silver ions.

Silver ions are particularly potent in antibacterial effect among ions, and thus notably exhibit the above-described advantageous effect.

[0215] The ion supply portion may be a silver ion supply portion for supplying a silver ion-containing aqueous solution having a silver ion concentration of 100 to 1100 ppb.

[0216] Use of a silver ion-containing solution having a silver ion concentration of 100 to 1100 ppb provides the antibacterial effect with a short period of light irradiation. Additionally, the above concentration enables it to make the concentration of the silver ions existing in the interior of the water conduit and the like such a concentration that will not adversely affect human body by washing with water.

[0217] The silver ion supply portion may be a silver ion supply portion for supplying a silver ion-containing aqueous solution having a silver ion concentration of less than 100 ppb.

[0218] Aqueous solutions that contain silver ions of extremely low silver ion concentrations of less than 100 ppb are usable as beverages, and therefore the above-described configuration secures high safety in the case where the water conduit and the like are not washed with water after the antibacterial processing.

[0219] The silver ion supply portion may have a structure of directly

supplying the water conduit with the silver ion-containing aqueous solution having a silver ion concentration of less than 100 ppb.

Since water conduits are not easy to wash and easily causes insanitation, antibacterialization of the water conduits is particularly in need. Additionally, the capacity of a water conduit is significantly smaller than that of a water feeding tank, and therefore the above configuration reduces the absolute amount of silver ions, thereby easily securing safety.

[0220] The irradiation period of time of the particular beam of light may be 30 minutes or more.

Even with silver ions of an extremely low concentration of approximately 60 ppb, 30 minutes or more of light irradiation realizes the antibacterial effect.

[0221] In the above configuration, the silver ion supply portion may have a cartridge filled with silver ions.

A cartridge filled with silver ions may only need to be mounted during an antibacterial operation. Additionally, specifying the amount of silver ions to fill the cartridge facilitates control of the amount of silver ions to supply to the interior of the water conduit and the like.

[0222] The cartridge may have a silver ion-containing aqueous solution having a silver ion concentration of less than 100 ppb, and the irradiation period of time of the particular beam of light may be 30 minutes or more.

This configuration realizes sufficient antibacterial effects while securing safety of edible ice.

[0223] Also in the third inventive group, the term "antibacterial," as used herein, is not only intended to prevent proliferation of microorganism

instead of extinction thereof, but to encompass all the following concepts: "sterilization (which means killing all the microorganisms)," "germicide (which means killing at least part of the microorganisms)," "disinfection," "fungus eradication," "bacteriostaticity (which means inhibiting proliferation of microorganisms)," "fungicide," "preservation," and the like.

[0224]

Brief Description of the Drawings of the Third Inventive Group

Fig. 13 is a schematic diagram for illustrating an automatic ice making apparatus according to Example 1 of the third inventive group.

Fig. 14 is an enlarged schematic diagram for illustrating a method for irradiating a water conduit with light.

Fig. 15 is a schematic diagram for illustrating an automatic ice making apparatus according to Example 2 of the third inventive group.

Fig. 16 is a diagram for illustrating a water conduit covered with a light conduction layer.

Fig. 17 is a schematic diagram for illustrating an automatic ice making apparatus according to Example 3 of the third inventive group.

Fig. 18 is a graph showing results of antibacterial effect confirmation test 1.

Fig. 19 is a graph showing results of antibacterial effect confirmation test 2.

[0225]

[Description of Reference Numeral]

301: water feeding tank, 302: water conduit, 303: ice making tray, 304: ice storage vessel, 305: heat insulating material, 306: silver ion supply

portion, 307: electromagnetic valve, 308: light source A, 309: reflecting plate, 310: reflecting plate, 311: reflecting plate, 312: light source B, 313: reflecting plate, 314: solution sending pump, 315: electromagnetic valve, 316: three-way divergent pathway with electromagnetic valve, 317: three-way divergent pathway with electromagnetic valve, 318: drainage channel, 319: light conduction layer-covered water conduit, 320: light conduction layer.

[0226]

Best Mode for Carrying out the Third Inventive Group

Embodiments of the third inventive group will be described below with reference to Examples. It should be noted that the following examples are provided for exemplary purposes and not for limiting purposes.

[0227]

(Example 1 of the Third Inventive Group)

A refrigerator provided with an automatic ice making apparatus according to example 1 of the third inventive group is a refrigerator that at least includes a refrigerating compartment (refrigerating compartment → in Fig. 1) controlled at approximately 1 to 6°C, and a freezer compartment (freezer compartment → in Fig. 1) controlled at a temperature less than 0°C (generally less than −18°C). Additionally, this refrigerator has built therein an automatic ice making apparatus. The elements of this refrigerator other than the automatic ice making apparatus may be configured on the basis of known techniques and not particularly limited. Accordingly, here description will be made of the automatic ice making

apparatus, which is the main portion of the refrigerator, by referring to Fig. 13.

[0228] Fig. 13 is a schematic perspective diagram for illustrating the automatic ice making apparatus. This automatic ice making apparatus includes a detachable water feeding tank 301, a water conduit 302, an ice making tray 303, an ice storage vessel 304, a heat insulating material 305, a silver ion supply portion 306, an electromagnetic valve 307 that opens and closes for the flow of silver ions injected from the silver ion supply portion 306 to the water conduit 302, a light source A 308, a solution sending pump 314, and an electromagnetic valve 315.

[0229] The water feeding tank 301 and a part of the water conduit 302 are located in the refrigerating compartment, while the other part of the water conduit 302, the ice making tray 303, and the ice storage vessel are located in portions of the freezer compartment. The refrigerating compartment and the freezer compartment are partitioned by the heat insulating material 305.

[0230] The ice making tray 303 is rotatable by a rotating motor, not shown. A heat plate is located on a bottom surface of the ice making tray.

[0231] Between the water feeding tank 301 and the solution sending pump 314, the electromagnetic valve 315 is provided to open and close for the flow of water that enters the water conduit 302 from the water feeding tank 301. The solution sending pump 314 is controlled to send a predetermined amount of water at predetermined intervals.

[0232] All the operations including rotation of the ice making tray 303, turning ON/OFF of the heat plate, turning ON/OFF of the electromagnetic

valves, driving of the solution sending pump are controlled by a microcomputer (not shown). Additionally, the ice storage vessel is provided with, for example, a height sensor such that when the amount of stored ice reaches a predetermined height, the height sensor emits a signal to the microcomputer to restrict driving of the solution sending pump.

[0233] The silver ion supply portion 306 is composed of a tank made of Teflon (registered trademark) and stores a silver ion aqueous solution having a concentration of 60 ppb.

The water conduit 302 is composed of a light transmissive material such as transparent resin and transparent glass.

The light source A is a light source that provides a beam of light having a peak wavelength in a range of 300 to 600 nm and an irradiation intensity of 500 to 500000 $\mu W/cm^2$. In this example, an LED having a peak wavelength of 525 nm is used so that an irradiation intensity of 500000 $\mu W/cm^2$ (50 mW/cm^2) is secured.

[0234] While Fig. 13 shows one light source, the light source A is not limited to one and a plurality of light sources A may be provided as necessary. It is also possible that the light source A comprise a fluorescent lamp.

[0235] In the automatic ice making apparatus of this structure, the peak wavelength of the light source A, the light irradiation intensity, and the irradiation period of time may be suitably selected considering the light transmission property of the water conduit, the silver ion concentration, necessary antibacterial potency, and so forth. This is because when the selected light source has a peak wavelength at which the wall of the water

conduit is difficult to transmit, light cannot be delivered to the interior of the water conduit sufficiently, thereby failing to secure the antibacterial potency reinforcing effect by the light irradiation, while when the silver ion concentration is low, the light irradiation intensity is set small, and the irradiation period of time is shortened, then an insufficient antibacterial effect results. In view of this, the irradiation period of time is usually 30 minutes or more, and 60 minutes in example 1.

[0236] The reflecting plates 309, 310, and 311 are materials for securing that sufficient light is applied to the entire water conduit 302. Each reflecting plate is made of a light reflective material such as, for example, a mirror plate of aluminum.

[0237] Fig. 14 shows an enlarged schematic of the reflecting plate, although it is not essential. In the case where the light source alone suffices in applying sufficient light to the entire water conduit 302, the reflecting plates may not be provided. It should be noted that in the third inventive group, all the elements, such as the light source and the reflecting plates, involved in irradiating light to the water conduit are referred to as a light source.

[0238] The ice making operation of the ice making apparatus will be described.

When the water feeding tank 301 is filled with water and placed inside the refrigerator, then a sensor (any sensor may be used) provided on an attaching portion of the water feeding tank 301 senses the placement of the water feeding tank. This causes the electromagnetic valve 315 to open and the solution sending pump 314 to activate to send a predetermined

amount of water in the water feeding tank 301 to the ice making tray 303. In the meantime the electromagnetic valve 307 is closed.

[0239] The water stored in the ice making tray 303 is cooled for a period of time (for a predetermined period of time) until the water is sufficiently frozen. Then, the ice making tray 303 is half-rotated by a rotating motor, not shown, and the heat plate is turned ON with the bottom surface of the ice making tray 303 up and the bottom surface is heated. This causes the ice in the ice making tray 303 to melt at the contact surface with the ice making tray 303 and drop inside the ice storage vessel 304 to be stored there.

[0240] Then, the ice making tray 303 is half-rotated back in place by the rotating motor, and synchronously, the solution sending starts again.

The series of operations are integrally controlled by a microcomputer, not shown.

While the above example employs the system in which the heat plate is placed on the bottom surface of the ice making tray and the ice making tray is rotated by 180 degrees upon freezing of the water inside the ice making tray, the means of storing and retrieving prepared ice is not particularly limited and any known method may be used.

[0241] Next, the bacteria elimination operation (also referred to as cleaning operation) of the water conduit 302 will be described.

First the electromagnetic valve 315 is closed and the electromagnetic valve 307 is opened. With this state, a predetermined amount of the silver ion aqueous solution having a concentration of 60 ppb stored in the silver ion supply portion 306, which is located inside the

refrigerating compartment, is injected inside the water conduit 302 through the solution sending pump 314. The predetermined amount is such a solution amount that the water conduit 302 is filled with the silver ion aqueous solution.

[0242] This operation is carried out at predetermined intervals (e.g., once a week) or on the basis of an arbitrary operation instruction from a user. With such a state that a predetermined amount of silver ions is allowed to flow into the water conduit 302, the electromagnetic valve 307 is closed.

[0243] The light source A turns on to irradiate light to the inner wall of the water conduit 302 over the period of time before (30 to 10 minutes before) and while the operation of injecting the silver ion aqueous solution inside the water conduit 302, or after the water conduit 302 is filled with the silver ion aqueous solution. The period of time for light irradiation is set at 60 minutes.

[0244] The injecting operation of the silver ion aqueous solution, the timing of the light irradiation, and the period of time for lighting of the light source A (light irradiation time) are all controlled by a microcomputer.

After injection of the silver ion aqueous solution inside the water conduit 302 and the antibacterial operation by light irradiation are complete, a silver ion elimination operation is carried out as necessary.

[0245] The silver ion elimination operation is an operation of washing away silver ions existing in the water conduit and the like. However, since the automatic ice making apparatus of example 1 is not provided with any bypass pathway, water (washing water) flowing through the water conduit 302 is stored in the ice making tray 303. In view of this, in the

silver ion elimination operation in this Example, the water inside the water feeding tank is allowed to flow into the ice making tray 303, and the water or ice inside the ice making tray is discharged. It should be noted, however, that eliminating the silver ion washing step causes no particular inconveniences because this example uses a silver ion aqueous solution having an extremely low concentration of 60 ppb.

[0246]

(Example 2 of the Third Inventive Group)

Fig. 15 shows schematic perspective view of an automatic ice making apparatus according to Example 2. Example 2 of the third inventive group is characterized in that: a three-way divergent pathway 316 with electromagnetic valve capable of opening/closing each of its pathways is provided along the water conduit 302 and between the water feeding tank 301 and the solution sending pump 314, and one of the pathways is connected to a silver ion supply portion 306; a similar three-way divergent pathway 317 with electromagnetic valve is provided along the water conduit 302 and near an end thereof at the side of the refrigerating compartment, and one of the divergent pathways is connected to a drainage channel 318 for washing away silver ions; in place of the reflecting plates, a light conduction layer-covered water conduit 319 having the water conduit 302 covered with a light conductive layer made of a light conductive material (optical fiber) is employed; and a silver ion aqueous solution having a concentration of 1100 ppb is stored in the silver ion supply portion 306. The other matters were the same as in Example 1.

[0247] Fig. 16 is a diagram for illustrating the light conduction

layer-covered water conduit 319. Fig. 16A shows the light conduction layer-covered water conduit 319 and Fig. 16B shows an X-Y cross section of Fig. 16A. In Fig. 16B, reference numeral 302 denotes a water conduit, and 320 denotes a light conduction layer for covering the water conduit. To the light conduction layer 320, light is injected from outside through the optical fiber. The use of the light conduction layer-covered water conduit 319 enables it to easily irradiate light to the water conduit 302.

[0248] The automatic ice making apparatus according to Example 2 of the third inventive group operates as follows.

During normal driving, the electromagnetic valves and the solution sending pump operate so that water is supplied from the water feeding tank 301 to the ice making tray 303, thus carrying out ice making. At a predetermined timing, e.g., at one-month intervals, an antibacterial processing operation is carried out.

[0249] The antibacterial processing operation operates the valve of the three-way divergent pathway 316 to break the flow of water from the water feeding tank 301, operates the valve of the three-way divergent pathway 317 to break the flow of water to the ice making tray 303, and causes water to flow from the three-way divergent pathway 317 to the drainage channel 318.

[0250] Next, the antibacterial processing operation operates the three-way divergent pathway 316 so that the silver ion aqueous solution inside the silver ion supply portion 306 flows into the light conduction layer-covered water conduit 319, and causes the solution sending pump 314 to send the silver ion aqueous solution into the light conduction layer-covered water

conduit 319.

[0251] In synchronization with the sending of the silver ion aqueous solution, the antibacterial processing operation introduces the light conductive layer of the light conduction layer-covered water conduit 319 a beam of light that has a peak wavelength of 525 nm and provides a light irradiation intensity of 50 mW/cm^2 for 30 minutes. This causes the inner wall of the water conduit to be irradiated with light, thereby antibacterializing microorganisms attached to or proliferating on the inner wall.

[0252] In this regard, the silver ion aqueous solution may be left running to the drainage channel 318. Alternatively, it is possible to stop the solution sending pump 314 at the stage where the interior of the water conduit 302 is substituted with the silver ion aqueous solution and to close all the pathways of the three-way divergent pathways 316 and 317, and with this state, to carry out the 30-minute light irradiation. This reduces the amount of the silver ion aqueous solution used.

Subsequent to the above-described antibacterial processing operation, the three-way divergent pathways 316 and 317 are switched to form a flow of "water feeding tank 301"–"water conduit 302"–"drainage channel 318," through which the water inside the water feeding tank 301 is allowed to flow for a predetermined period of time (e.g., 5 minutes). This silver ion elimination operation causes the silver ions inside the water conduit 302 to be pushed out to the drainage channel, thus eliminating the silver ions inside the water conduit.

The drainage channel 318 preferably has such a structure that is

capable of taking the washing solution out of the refrigerator.

[0253] After the antibacterial processing operation and the silver ion elimination operation end, the electromagnetic valves are operated so that normal ice making is carried out.

[0254] While in the above description the silver ion supply portion 306 stores a silver ion aqueous solution having a 1100 ppb concentration, it is also possible for the silver ion supply portion 306 to store a silver ion aqueous solution having a higher concentration and then be mixed with water supplied from the water feeding tank 301 so that the concentration of the silver ions inside the water conduit 302 becomes approximately 1100 ppb.

[0255]

(Example 3 of the Third Inventive Group)

Fig. 17 shows a schematic perspective view of an ice making apparatus according to example 3. In Example 3 of the third inventive group, the light irradiation can be made to the water feeding tank 301, and the silver ion supply portion (including the electromagnetic valve 307) is connected to the water feeding tank 301. Additionally, the silver ion supply portion stores a silver ion aqueous solution having a 60 ppb concentration. The other matters were the same as in example 2.

[0256] In the ice making apparatus according to this example, the water inside the water feeding tank contains silver ions while at the same time the water feeding tank is irradiated with light, thus facilitates the attempt to antibacterialize the water feeding tank.

[0257] In the automatic ice making apparatus of this structure, such a

configuration is preferable that in place of the silver ion aqueous solution having a 60 ppb concentration, a silver ion aqueous solution having a high concentration of, e.g., 2000 ppb is stored in the silver ion supply portion, and the supply of the silver ion aqueous solution is adjusted so that the concentration of the silver ions inside the water feeding tank becomes 60 ppb (or lower).

[0258]

(Common Matters)

As the silver ion supply portion of examples 1 to 3, a cartridge filled with silver ions may be employed. For example, the use of a disposable-type cartridge that stores a predetermined amount of a silver ion aqueous solution having a predetermined concentration enables it to easily control the amount of silver ions supplied to the interior of the water conduit and the like.

[0259] Additionally, such a method may be employed that, instead of storing the silver ion aqueous solution in the silver ion supply portion 306, places two silver plates in the silver ion supply portion 306 (or the water feeding tank) and applies DC current to the plates, thus generating silver ions.

[0260] Alternatively, it is possible to store silver ion-containing zeolite or the like in the silver ion supply portion 306 and extract the silver ion-containing zeolite using water when in use.

Alternatively, it is possible to employ such a mechanism that, instead of additionally providing the silver ion supply portion, provides the interior of the water conduit with a silver ion elution material such as

silver ion-containing zeolite and silver ion elution glass so that the silver ions elute upon contact of the zeolite with water.

[0261] Alternatively, it is possible to contain, by kneading for example, a silver ion elution material in the materials constituting the water feeding tank, and/or the water conduit, and/or the ice making tray, and/or the ice making partitions. With such silver ion elution material, the concentration of the silver ions after the silver ion elution cannot be greatly heightened, thus securing high safety. However, at the same time, the inability to provide a high concentration means that high advantageous effects cannot be obtained. In view of this, the irradiation of light as in the present invention enhances the advantageous effects. Therefore, high advantageous effects can be obtained even with a low silver ion concentration.

[0262] In the case of the structure where silver plates are placed in the water feeding tank 301, the silver plates and the application means provided in the water feeding tank 301 correspond to the silver ion supply portion 306.

[0263]

(Antibacterial Effect Confirmation Test 1)

A test was conducted to confirm that the interior of the water conduit and the like is antibacterialized in the antibacterial step described in Example 1 of the third inventive group. The test method is as follows.

[0264]

(i) As the antibacterial target microorganism, a *Candida albicans* NBRC-1060 standard strain (eukaryote) having an initial bacterial count of

approximately 5×10^7/mL was prepared. This bacterial body was dispersed in a phosphate buffer (50 mM concentration), thus preparing a spore suspension (bacterial solution). As the vessel for preparing the spore suspension, a glass vessel was used.

[0265]

(ii) 1 mL of the spore suspension was put into 500 mL water to prepare microorganism-contaminated water having an initial bacterial count of 1×10^5/mL. This was put into the water feeding tank 301.

The ice making apparatus was set at a flow of "water feeding tank 301"–"water conduit 302"–"ice making tray 303." The solution sending pump 314 was driven to allow the microorganism-contaminated water to flow inside the water conduit 302, and 15 minutes, 30 minutes, and 60 minutes thereafter, the microorganism-contaminated water was sampled from the ice making tray 303 (test solution: contaminated water).

[0266]

(iii) With the use of similar contaminated water to the one in (ii), the water conduit 302 filled with this contaminated water was irradiated with a beam of light having a peak wavelength of 525 nm and an irradiation intensity of 50 mW/cm^2 for 15 minutes, 30 minutes, and 60 minutes. A test solution of each of the cases was sampled from the ice making tray 303 (test solution: contaminated water + light).

[0267]

(iv) To 450 mL water, 1 mL of the spore suspension and 50 mL of silver ion aqueous solution having a silver ion concentration of 600 ppb were added, thus preparing microorganism-contaminated water having a

silver ion concentration of 60 ppb (bacterial count: 1×10^5/mL). Similarly to (ii), this contaminated water was sampled from the ice making tray 303 (test solution: contaminated water + silver ions).

[0268] (v) Silver ion-containing contaminated water similar to the one in (iii) was irradiated with a beam of light having a peak wavelength of 525 nm and an irradiation intensity of 50 mW/cm^2 for 15 minutes, 30 minutes, and 60 minutes. Antibacterial processed contaminated water of each of the cases was sampled from the ice making tray 303 (test solution: contaminated water + silver ions + light).

[0269]

(Antibacterial Effect Confirmation Test 2)

Similarly to test 1, test solutions using Escherichia coli were sampled except that *Escherichia coli* (NBRC-3972) was used as the antibacterial target microorganism, in place of *Candida albicans* NBRC-1060.

[0270] 100 μL of each of the test solutions sampled above was applied onto a potato agar and cultured for four days at 25°C followed by counting the number of colonies on the agar. By this method, the antibacterial effect was examined.

[0271]

(Results)

The results of test 1 are shown in Fig. 18, and the results of test 2 are shown in Fig. 19.

Referring to Fig. 18, a comparison between the case of only contaminated water containing *Candida albicans* (indicated as ▲ in the

figure) and the case of irradiating the contaminated water (indicated as Δ in the figure) shows that no germiciding effects can be obtained by light irradiation alone.

A comparison between the case of involving silver ions without light irradiation (indicated as ● in the figure) and the case of the antibacterial method involving silver ions and light irradiation (indicated as ○ in the figure) shows that the light irradiation provides a significant germiciding potency reinforcing effect that makes the remaining *Candida albicans* count more than single-digit lower.

[0272] Additionally, Fig. 19 shows that similar results are obtained with *Escherichia coli*.

Additionally, Figs. 18 and 19 show that as the period of time for light irradiation becomes long, the difference in the resulting antibacterial effect between the case of involving light irradiation and the case involving silver ions without light irradiation (indicated as ● in the figure) tends to become large.

[0273]

These results lead to the following conclusion.

The irradiation intensity (50 mW/cm^2) of the ultraviolet light (525 nm) used in the above test is sufficiently lower than the intensity with which fungi can be antibacterialized. Thus, it is speculated that the difference in the antibacterial potency between the case of the antibacterial method involving silver ions and light irradiation (indicated as ○ in the figure) and the case of involving silver ions without light irradiation (indicated as ● in the figure) is not attributed to the germiciding effect of

the ultraviolet light itself but results from the promoted incorporation of silver ions inside the fungus body by the ultraviolet light irradiation. That is, the irradiation of the beam of light having a peak wavelength of 525 nm and an irradiation intensity of 50 mW/cm^2 increases the amount of silver ions incorporated inside the fungus body of *Candida albicans* and *Escherichia coli*, thereby enhancing the silver ion antibacterial effect.

[0274] While in the above-described example silver ions are used as the antibacterial ions, the application of the present invention will not be limited to silver ions. For example, copper ions or zinc ions may be used.

Additionally, while in the above-described example description is made of the example where water is supplied from the water feeding tank, tap water may be supplied through a valve or the like. In this case, microorganisms will not grow in the tank because there is no tank, but microorganisms may grow in the water conduit.

[0275]

Industrial Applicability of the Third Inventive Group

It is not easy to clean the interior of pipes of an ice making apparatus of a refrigerator, and thus microorganisms such as molds and staphylococci might grow in the pipes through a long period of use. It is also not easy to find out the microorganisms. The third inventive group enables it to automatically antibacterialize and wash, using a minute amount of silver ions, molds and staphylococci that proliferate in water-existing portions of the pipes and the like, and to prevent in advance the occurrence of the microorganisms. Therefore, the industrial applicability of the third inventive group is considerable.

(Fourth Inventive Group)

[0276]

Background Art of the Fourth Inventive Group

With the advent of an aging society, there have been increasing opportunities for families to have to take care of bedridden elderly family members and senile family members, in addition to infants. Infants and bedridden elderly are liable to insanitation on their bodies but have little resistance to disease-causing bacteria, thus needing higher levels of cleanliness than healthy adults.

[0277] In particular, for bedridden elderly, clothing such as clothes and sheets that come in direct contact with their skin are desirably sterilized, for disease diagnostic reasons and for quality of life.

[0278] Additionally, with increasing health consciousness, significant cleanliness is in demand for clothing of office workers and the like.

[0279] Under such social circumstances, washing machines are playing a more important role than ever as tools to keep clothes clean.

[0280] Generally, clothes that need washing not only have sweat and dirt attached thereon but, frequently, also have saprophytes and minute animals and plants attached thereon. Occasionally, clothes and sheets (bedclothes) on people suffering from diseases have serious disease-causing bacteria attached thereon such as staphylococcus aureus and trichophyton.

[0281] Washing at home is usually such that various clothes are put together and washed in a single washing machine. This occasionally causes contamination of microorganisms among the laundry during washing.

Additionally, bacteria may remain in fine gaps in the tank of the washing machine and proliferate over the period of time before the next washing, which may contaminate the laundry.

[0282] In order to prevent these troubles, methods that use detergents containing disinfectants are conventionally employed. Additionally, methods that bacteria-eliminate the laundry by heating the interior of the washing machine to 60°C or higher are conventionally employed. Additionally, for example, patent documents 4-1 to 4-4 propose methods that add antibacterial metal ions to the rinsing water during washing.

[Patent document 4-1] Utility Model Registration Application Publication No. 5-74484.

[Patent document 4-2] Japanese Patent Application Publication No. 2001-276484.

[Patent document 4-3] Japanese Patent Application Publication No. 2004-215817.

[Patent document 4-4] Japanese Patent Application Publication No. 2004-321313.

[0283]

Disclosure of the Fourth Inventive Group

Problems that the Fourth Inventive Group is to Solve

However, clothes come in direct contact with skin, and therefore it is difficult to use strong antibacterial agents for clothes.

Additionally, clothes are repeatedly used by washing, and therefore it is difficult to use heating germicide methods that may impair colors and texture.

[0284] Although the techniques recited in patent documents 4-1 to 4-4 excel in bacteria-elimination washing without impairing the clothes, the metal ions used by these techniques are substances having biological activity and thus may have some influence on natural environment. This causes such an inconvenience that the concentration of the metal ions cannot be made sufficiently high.

[0285] The present inventors have conducted an extensive study on the method of controlling growth of microorganisms such as molds and bacteria, and found out that ions (especially metal ions) having antibacterial potency significantly reinforces their advantageous effects in the presence of a particular beam of light. The present inventors also have conducted a study on a rotating drum type washing machine and found that molds and bacteria are likely to proliferate on the rear side of the rotating drum, and that by bringing ions into contact with the rear side of the rotating drum in a state where the rear side of the rotating drum is irradiated with a particular beam of light, the molds and bacteria occurring on the rear side of the rotating drum can be prevented.

[0286] The fourth inventive group has been made in view of the above knowledge. It is an object of the fourth inventive group to provide a rotating drum type washing machine capable of preventing microorganism contamination (internal washing machine contamination) during washing while at the same time carrying out antibacterial processing of the laundry.

[0287]

Means of Realizing the Object of the Fourth Inventive Group

A basic configuration of the fourth inventive group to realize the

above-described object is characterized as follows.

A rotating drum type washing machine at least includes: a water tank capable of containing water and discharging contained water; a rotating drum located in the water tank and rotatably driven in the water tank; and ion supply means of supplying ion water to the rotating drum and/or the water tank, wherein: the rotating drum includes, on a wall thereof, a plurality of pores through which water is able to pass between an interior of the rotating drum and an interior of the water tank; and the water tank includes, on an inner side surface thereof, a first irradiating portion for irradiating an outer side surface of the rotating drum with a particular beam of light.

[0288] With this configuration, the ion supply means supplies ion water inside the water tank and/or the rotating drum, thereby carrying out ion antibacterial processing of the laundry contained inside the rotating drum.

[0289] Additionally, since the rotating drum is provided with a plurality of pores through which water is able to pass back and forth, the ions supplied by the ion supply means spread to the space between the rotating drum and the water tank, resulting in such a state that the outer side surface of the rotating drum is wet.

[0290] This configuration realizes ion antibacterial processing of the outer side surface of the rotating drum as well as realizing ion antibacterial processing of the laundry. In this regard, the outer side surface of the rotating drum is irradiated with a particular beam of light by the first irradiating portion, and this particular beam of light reinforces the antibacterial effect of the ions. This facilitates the attempt to

bacteria-eliminate the outer side surface (rear surface) of the rotating drum, where molds and saprophytes occur.

[0291] The configuration of irradiating the particular beam of light to the outer side surface of the rotating drum while being wet with ion water is an application of such an antibacterial principle that irradiates microorganisms with the particular beam of light while bringing ions into contact with the microorganisms. This principle opens the ion-permeable channel of the microorganism and causes ions to be efficiently incorporated inside the microorganism body. This significantly reinforces the antibacterial potency of ions. The "outer side surface of the rotating drum" is intended to encompass the side surfaces and bottom surface of the rotating drum.

[0292] In the above-described basic configuration, the rotating drum may include, on the outer side surface thereof, a reflecting area for reflecting the particular beam of light.

With this configuration, the light irradiated to the outer side surface of the rotating drum by the first irradiating portion is reflected by the reflecting area provided on the outer side surface of the rotating drum and irradiated to the inner side surface of the water tank. Thus, this configuration reliably antibacterializes not only the outer side surface of the rotating drum but also the inner side surface of the water tank.

[0293] The reflecting area may be formed in a strip shape in a direction orthogonal to a rotating direction of the rotating drum.

Since the drum rotates, forming the reflecting area in a strip shape in a direction orthogonal to a rotating direction of the rotating drum

requires only a small reflecting area in spreading the light to the entire inner side surface of the water tank, which opposes to the rotating drum.

[0294] Additionally, the reflecting area may be formed in a spiral manner relative to a rotating direction of the rotating drum.

Forming the reflecting area in a spiral manner relative to a rotating direction of the rotating drum efficiently spreads the light to the entire inner side surface of the water tank, which is an opposing surface to the rotating drum.

[0295] Additionally, a plurality of reflecting areas each in an island shape may be formed sporadically on the outer side surface of the rotating drum, each of the reflecting areas being in a convex shape.

Forming each of the reflecting areas in a convex shape and in an island shape reduces the reflecting material. Additionally, the light is reflected diffusely in a complicated manner by the rotation of the drum and thus spreads thoroughly to the inner side surface of the water tank, which is an opposing surface of the drum. This reinforces the antibacterial potency of the whole of the interior of the water tank.

[0296] Instead of the convex and island shape, the reflecting area may be simply in a island shape. It is also possible to arrange convex and island shaped reflecting areas in a spiral manner relative to the rotating direction of the rotating drum.

[0297] Additionally, in the rotating drum type washing machine having the above-described configurations, the light irradiating portion may be composed of the first irradiating portion provided on the inner side surface of the water tank and a second irradiating portion provided on an inner

bottom surface of the water tank, and the reflecting area may be provided on both a side surface and a bottom surface of the rotating drum.

[0298] This configuration realizes antibacterial processing of the entire outer surface of the rotating drum including the bottom surface thereof and the entire inner side surface of the water tank, that is, the whole of the washing machine tank.

[0299] In the above-described basic configuration, the particular beam of light may have a peak wavelength of 300 to 600 nm.

Additionally, the particular beam of light may have an irradiation intensity of 500 to 500000 $\mu W/cm^2$.

Additionally, the ion supply means may be silver ion supply means of supplying silver ion water.

Additionally, the silver ion supply means may supply silver ion water having a concentration of 30 ppb to 1100 ppb.

[0300] In this regard, the rotating drum type washing machine according to the present invention applies an antibacterial method that combines together a particular beam of light and ions. The principle of this antibacterial method is that irradiating microorganisms and the like with the particular beam of light opens the inherent function of tissues of microorganisms and the like (including animals and plants) to shield off foreign substances (i.e., opens the ion-permeable channel), thereby causing ions, which are foreign substances, to be effectively incorporated inside a body. It is speculated that the ion-permeable channel of a microorganism is effectively opened by the irradiation of a particular beam of light having a peak wavelength in the range of 300 to 600 nm. That is, the

antibacterial potency reinforcing effect is large within this range of wavelength.

[0301] Additionally, with the particular beam of light having an irradiation intensity of 500 to 500000 μW/cm^2, a sufficient antibacterial potency reinforcing effect is obtained. Additionally, silver ions have strong antibacterial potency and thus exhibit the antibacterial potency reinforcing effect further more notably. Additionally, when the concentrations of the silver ions supplied from the silver ion supply means is 30 ppb to 1100 ppb, the load on natural environment is small and thus is preferable.

[0302] Although the antibacterial reinforcing effect can be obtained with beams of light of less than 300 nm, ultraviolet light of less than 300 nm is not preferable in that members of the washing machine may be degraded and the laundry may be damaged.

[0303] In the above-described basic configuration, the rotating drum type washing machine may include washing operation control means of controlling a washing operation, and the washing operation control means may control the silver ion supply means so as to secure that the silver ion supply means supplies silver ion water during a laundry rinsing step.

[0304] The rinsing step requires a smaller amount of water than that in the washing step, and thus the method involving silver ion water added in the rinsing step provides a sufficient effect with a small amount of silver ion water. Additionally, with the method involving silver ion water added in the rinsing step, the following drying step turns the fiber of the laundry into a state of being coated with silver ions. Clothes coated with silver ions maintain the antibacterial effect for a long period of time, resulting in

long period of cleanliness.

[0305] In the above-described configuration, the washing operation control means may control the light-irradiating portion so as to secure that the particular beam of light is irradiated for 30 minutes or more.

Bringing bread molds and staphylococcus aureus into contact with silver ions while irradiating the bread molds and staphylococcus aureus with a particular beam of light for 30 minutes or more significantly enhances the silver ion antibacterial effect.

[0306] In the above-described basic configuration, the rotating drum type washing machine may include a door for closing a release opening of the water tank, and the door may include a third irradiating portion for irradiating the interior of the rotating drum with a particular beam of light.

[0307] Additionally, in this configuration, the particular beam of light may have a peak wavelength of 300 to 600 nm, and the irradiation intensity of the particular beam of light may be 500 to 500000 $\mu W/cm^2$.

With this configuration, the interior of the rotating drum is irradiated with a particular beam of light, and thus the effect of silver ions and the particular beam of light efficiently promotes antibacterialization of the laundry contained in the rotating drum. Additionally, when the washing tank (rotating drum plus water tank) itself is cleaned, the interior of the rotating drum is efficiently antibacterialized.

[0308]

A second basic configuration of the fourth inventive group to realize the above-described object is as follows.

A rotating drum type washing machine at least includes: a water tank capable of containing water and discharging contained water; a rotating drum located in the water tank and rotatably driven in the rotating drum; and silver ion supply means of supplying silver ion water to the rotating drum and/or the water tank, wherein: the rotating drum includes a plurality of pores through which water is able to pass between an interior of the rotating drum and an interior of the water tank; a baffle for rolling over a laundry is formed on an inner wall surface of the rotating drum; and the baffle incorporates therein a light irradiating portion for irradiating light to the interior of the rotating drum.

[0309] With this configuration, in which the baffle provided in the rotating drum incorporates therein a light irradiating portion, the distance between the light source and the laundry and the inner wall of the rotating drum becomes short. This improves the efficiency of light irradiation and thus enhances the antibacterial effect.

[0310] In this configuration, the water tank may include, on an inner side surface thereof, a first irradiating portion for irradiating light to an outer circumferential surface of the rotating drum and include, on an inner bottom surface of the water tank, a second irradiating portion for irradiating light to an outer bottom surface of the rotating drum, and a reflecting area may be provided on both the outer circumferential surface and the outer bottom surface of the rotating drum. Additionally, the light may have a peak wavelength of 300 to 600 nm, and the irradiation intensity of the particular beam of light may be 500 to 500000 $\mu W/cm^2$.

[0311] This configuration realizes antibacterialization of the entire

washing tank as well as the antibacterial processing of the laundry.

It should be noted that the term "bacteria-elimination" is intended to mean reduction in the number of microorganisms such as molds and saprophytes, and the term "antibacterial" is not only intended to prevent proliferation of microorganism instead of extinction thereof, but in the broadest sense to encompass all the following concepts: "sterilization (which means killing all the microorganisms)," "germicide (which means killing at least part of the microorganisms)," "disinfection," "fungus eradication," "bacteriostaticity (which means inhibiting proliferation of microorganisms)," "fungicide," "preservation," and the like.

[0312]

Effects of the Fourth Inventive Group

The present invention provides a rotating drum type washing machine with an automatic antibacterial processing function capable of carrying out bacteria-elimination processing of clothes without damaging them, of keeping the interior of the washing tank always clean, and of eliminating damage to natural environment.

[0313]

Brief Description of the Drawings of the Fourth Inventive Group

Fig. 20 is a schematic cross sectional view of a rotating drum type washing machine according to Example 1 of the fourth inventive group.

Fig. 21 is a schematic cross sectional view of a rotating drum type washing machine according to Example 2 of the fourth inventive group.

Fig. 22 is a schematic cross sectional view of a rotating drum type washing machine according to Example 3 of the fourth inventive group.

Fig. 23 is a perspective view of a rotating drum according to Example 3 of the fourth inventive group when viewed from an outer side bottom direction.

Fig. 24 is a cross section of the X-X line in Fig. 22 for illustrating a light source arranged on a circumferential wall of a cylindrical water tank.

Fig. 25 is a schematic diagram illustrating a reflecting area provided on the outer side surface of the rotating drum.

Fig. 26 is a schematic diagram illustrating the structure of a first irradiating portion and a second irradiating portion.

Fig. 27 is an enlarged schematic diagram illustrating a baffle portion of a rotating drum type washing machine according to Example 4 of the fourth inventive group.

Fig. 28 is a schematic cross sectional view of a light irradiating portion incorporated in the baffle.

Fig. 29 is a graph showing a bacteria-elimination effect for the laundry in confirmation test 1 of the fourth inventive group using *Candida albicans*.

Fig. 30 is a graph showing a bacteria-elimination effect for members of the washing tank in confirmation test 1 of the fourth inventive group using *Candida albicans*.

Fig. 31 is a graph showing a bacteria-elimination effect for the laundry in confirmation test 2 of the fourth inventive group using *Cladosporium cladosporioides*.

Fig. 32 is a graph showing a bacteria-elimination effect for the laundry in confirmation test 3 of the fourth inventive group using

Escherichia coli.

[0314]

[Description of Reference Numeral]

400: rotating drum type washing machine with antibacterial processing function, 401: outer frame body, 402: water tank, 403: rotating drum, 404: motor, 405: washing machine door, 406: water feeding pathway, 407: water discharge pathway, 408: pore, 409: silver ion supply unit, 410: light source (first irradiating portion), 411: light source (second irradiating portion), 412: baffle, 415: rotating drum outer side bottom surface, 430: third irradiating portion, 431: light source, 432: reflecting plate, 440: reflecting area, 441: reflecting area, 450: second irradiating portion, 451: reflecting plate, 452: transparent cover, 460: baffle incorporating a light irradiating portion, 461: light source, 462: reflecting plate.

[0315]

Best Mode for Carrying out the Fourth Inventive Group

Embodiments of the fourth inventive group will be described below with reference to examples. It should be noted that the following examples are provided for exemplary purposes and not for limiting purposes.

[0316]

(Example 1 of the Fourth Inventive Group)

A rotating drum type washing machine with antibacterial processing function according to Example 1 of the fourth inventive group will be described with reference to Fig. 20. Fig. 20 is a schematic cross sectional view for illustrating the interior of the washing machine.

[0317] The rotating drum type washing machine 400 with antibacterial processing function at least includes an outer frame body 401, a water tank 402, a rotating drum 403, a motor 404 for rotating the rotating drum, a washing machine door 405, a water feeding pipe 406, a water discharge pipe 407, a silver ion supply unit 409 that constitutes silver ion supply means, and a light source 410 acting as a first irradiating portion.

[0318] The water feeding pipe 406 is a pipe through which to introduce water into the washing machine so that such a structure is employed that the water tank 402 accepts tap water for washing or rinsing through the water feeding pipe 406 and discharges the water out of the washing machine through the water discharge pipe 407.

[0319] In front of the water tank 402, an opening through which the laundry is taken in and out is provided, and this opening is attached with a door 405 so as to make the water tank openable/closable.

[0320] The rotating drum 403 is located in the water tank 402 and coupled at the bottom surface to the motor 404 so as to be able to reciprocally rotate inside the water tank 402. Additionally, the rotating drum 403 has an opening on the front through which the laundry is taken in and out, and on the inner side (inner circumferential surface) of the rotating drum, a baffle 412 for rolling over the laundry in the rotating direction during the rotation is provided.

[0321] Additionally, on the side surface (circumferential surface) of the rotating drum 403, a multiplicity of pores 408 are provided. The pores 408 function to transfer water between the interior of the water tank and the water tank during washing and to discharge water or heated air in the

rotating drum out of the drum during rinsing, centrifugal dewatering, and drying.

[0322] The silver ion supply unit 409 is provided along the water feeding pipe 406 and generates silver ions to supply them to water (usually tap water). Generated silver ions are supplied to inside the rotating drum through the water feeding pipe 406.

[0323] The silver ion supply unit 409 is composed of two silver plates and a power supply for applying DC voltage to them, and the silver ion concentration of the silver ion water generated by the silver ion supply unit 409 is controlled by making the DC voltage applied to the silver plates variable and/or by varying the amount of water supply, i.e., is microcomputer-controlled so that silver ions of a desired concentration are supplied to the interior of the rotating drum as necessary.

[0324] The silver ion concentration of the silver ions supplied to the interior of the rotating drum is 1 ppb to 10 ppm, preferably 5 ppb to 1100 ppb, more preferably 10 ppb to 900 ppb, and further more preferably 30 ppb to 100 ppb or 30 ppb to 60 ppb. As the silver ion concentration becomes high, the antibacterial potency can be made strong, while as the silver ion concentration becomes low, comfortability for natural environment including humans improves. When the concentration of the supplied silver ion water is in excess of 2000 ppb, the silver ion supplied unit is provided with zeolite or ceramics holding silver ions.

[0325] The light source 410 acting as the first irradiating portion is a light source for irradiating a particular beam of light to the outer circumferential surface of the rotating drum. In this example 1, the light

source 410 is fixed to the inner side surface of the cylindrical water tank 402, and a plurality of light sources 410 are arranged so that the light on the outer circumferential surface of the rotating drum is not discontinuous in the rotation axis direction. The rotating drum 403 rotates, and this rotation causes the light to be irradiated to the entire circumferential surface of the rotating drum.

[0326] As shown in Fig. 20, in the case of such a structure that the rotation axis of the rotating drum is slanted relative to the earth's axis, the light sources 410 are preferably arranged at an upper side (a higher side of the water tank wall surface). Providing the light sources 410 at an upper side of the water tank reduces the opportunities of the light sources being immersed in water, thereby minimizing the influence of water.

[0327] The particular beam of light has a peak wavelength in the range of 300 to 600 nm and an irradiation intensity of 500 to 500000 $\mu W/cm^2$. With light with this properties, an excellent antibacterial potency reinforcing effect is obtained.

[0328] As the material to constitute the light sources 410, a light-emitting diode (LED), a laser diode (LD), a halogen lamp, or the like may be used. While a single light source 410 or a plurality of light sources 410 may be provided, a reflecting plate (see Fig. 26) is preferably used in order to make the light irradiation effective with a small number of light sources. Examples of the method for fixing the light sources 410 to the inner wall surface of the water tank include fixing with the use of nuts and bolts.

[0329] In this example, LEDs each having a peak wavelength of 525 nm are used as the light sources 410. This is because beams of light around

525 nm are convenient in that they are not likely to be absorbed in water, are safety to human body, and excel in economy. Beams of light on the side of shorter wavelengths than 525 nm are absorbed in water and thus are poor in light irradiation efficiency, and increases the possibility that the light itself damages the appliance and human body.

[0330] Next, a series of operations using the rotating drum type washing machine having the above-described structure will be described.

A general washing operation using this washing machine is as follows.

(1)→(2)→(3)→(4). Alternatively, (1)→(2)→(3)→(4')→(4").

Additionally, (5)→(6) are carried out as necessary.

(1) Main washing for the laundry (washing step).

(2) Rinse washing with silver ions put into the laundry (rinsing step).

(3) Dehydrating the laundry (dehydrating step).

(4) Taking out the laundry from the rotating drum (taking-out step).

Alternatively, (4') air drying using heated air or dehumidified air (drying step),

(4") taking out the laundry from the rotating drum (taking-out step).

(5) Cleaning the interior of the washing tank by putting silver ion water inside the rotating drum (washing tank cleaning step).

(6) Drying the interior of the washing tank by sending heated air or dehumidified air inside the rotating drum (inner tank drying step).

[0331] The above-described (4')→(4") flow is a flow in the case where the laundry is dried in the washing machine and may not necessarily be carried out.

The (5)→(6) flow is a flow in the case where only the interior of the washing tank is washed for a sufficient period of time. This flow may not necessarily be carried out for every washing. Preferably, only on a particularly significant occasion (e.g. once a month), a washing tank cleaning step involving light irradiation of 30 minutes or more may be carried out using silver ion water of a higher concentration (e.g., 600 ppb to 1100 ppb). Additionally, the amount of the silver ion water used is preferably such a small amount that the outer circumferential surface of the rotating drum becomes moist.

[0332] In the rinsing step or the dehydrating step, or the rinsing step and the dehydrating step in usual washing, the interior of the washing tank becomes wet with the silver ion water, and thus on this occasion, the light irradiating portion is driven to irradiate light to the interior of the washing tank. This facilitates the attempt to bacteria-eliminate or antibacterialize not only the laundry but also the interior of the washing tank.

[0333] The concentration of the silver ion water used in the rinsing step is preferably 30 ppb to 100 ppb. Carrying out the rinsing step using silver ion water coats the clothes with silver ions, thereby providing such an advantageous effect that the bacteria elimination effect is maintained even during dehydration drying and when the clothes are worn.

[0334]

(Example 2 of the Fourth Inventive Group)

Fig. 21 shows a rotating drum type washing machine according to Example 2 of the fourth inventive group. Fig. 21 is a schematic cross sectional view for illustrating the entire washing machine.

[0335] As shown in Fig. 21, the rotating drum type washing machine according to Example 2 of the fourth inventive group differs from example 1 of the fourth inventive group in that a third irradiating portion 430 for irradiating a particular beam of light to the interior of the rotating drum 403 is located in the washing machine door 405, and that the light sources 411 are located on the inner side bottom surface of the water tank 402 as well as on the inner side surface thereof. The other matters are the same as in example 1 of the fourth inventive group.

[0336] As shown in Fig. 21, the washing machine door 405 of Example 2 of the fourth inventive group has a concave shape at its central portion that is depressed toward the rotating drum, and the bottom of the concave portion is made of transparent glass.

The opening portions of the outer frame body 401, which is in contact with the outer circumference portion of the washing machine door 405, and the water tank 402 are provided with rubber packing (not shown) so that the water tank 402 is sealed when the washing machine door 405 is closed.

[0337] The third irradiating portion 430 is composed of a light source 431 and a reflecting plate 432 for reflecting the light emitted from this light source toward the rotating drum. The light source 431 uses a LED capable of emitting light having a peak wavelength of 525 nm, and the reflecting plate 424 uses a mirror plane body of aluminum or stainless steel.

These members are fixed to the concave bottom portion of the washing machine door 405 with, e.g., an adhesive.

[0338] Similarly to the case of Example 1 of the fourth inventive group, this rotating drum type washing machine with an antibacterial processing function supplies silver ion water inside the rotating drum 403 usually on the stage (rinsing step) where the laundry is rinsed, and irradiates particular beams of light from the first irradiating portion and the second irradiating portion for the period of time between the rinsing step and the following dehydrating step.

[0339] With the rotating drum type washing machine of the above-described structure, since the interior of the rotating drum 403 is directly irradiated with particular beams of light, the bacteria elimination effect for the laundry increases while at the same time facilitating the attempt to bacteria-eliminate both the interior and outer circumferential surface of the rotating drum 403.

[0340]

(Example 3 of the Fourth Inventive Group)

Example 3 of the fourth inventive group is characterized in such a structure that is capable of irradiating a particular beam of light to the entire circumferential surface and bottom surface of the rotating drum 402 while at the same time applying the particular beam of light to the entire inner surface of the cylindrical water tank 402.

[0341] Example 3 of the fourth inventive group will be described on the basis of Figs. 22 to 24. Fig. 22 is a schematic cross sectional view of the rotating drum type washing machine according to this example. Fig. 23 is

a perspective view of the rotating drum when viewed from the outer side bottom direction. Fig. 24 is a cross section at the X-X line of the washing tank (rotating drum plus water tank).

[0342] As shown in Fig. 22, also in this example, the washing machine door 405 is provided with the third irradiating portion 430 for irradiating a particular beam of light to the interior of the rotating drum 403.

As shown in Fig. 24, in this example, a plurality of light sources 409 are provided along the axis direction of the cylindrical water tank 402 at points that divide the inner circumference of the water tank 402 three ways.

[0343] As shown in Figs. 22 and 23, strip-shaped reflecting areas 440 are provided on the outer circumferential surface of the rotating drum 403, and a strip-shaped reflecting area 441 is provided on the outer side bottom surface of the rotating drum.

In the rotating drum type washing machine of this structure, the light emitted from the third irradiating portion 430 is irradiated to the interior of the rotating drum 403, and the light emitted from the light sources 410 and 411 lights the entire outer surface of the rotating drum.

[0344] With the rotation of the rotating drum, the light emitted from the light sources 410 and 411 is reflected by the reflecting areas 440 and 441, which are respectively provided on the circumferential surface and outer bottom surface of the rotating drum 403, in order to light the interior of the water tank 402. Thus, the rotating drum type washing machine of this structure is capable of irradiating a particular beam of light to the front and rear surfaces of the rotating drum and the entire inner side surface of

the water tank.

[0345] Also in this washing machine, similarly to Examples 1 and 2 of the fourth inventive group, upon supply of silver ion water to the interior of the rotating drum 403, the rotational centrifugal force of the rotating drum rushes out the silver ion water through the pores 405. This makes the inner wall of the water tank and the outer surface of the rotating drum wet with the silver ion water, and the irradiation effect of the above-described particular beam of light is exhibited. Thus, a superior antibacterial potency is exhibited with a lower concentration of silver ions.

[0346] The operation of the washing machine according to this example is similar to that in Example 1 of the fourth inventive group.

[0347] The reflecting area formed on the outer surface of the rotating drum will be described.

The reflecting area formed on the outer surface of the rotating drum may be such that a reflecting member such as an aluminum foil and a stainless steel foil is attached to a predetermined position by welding or with a water-resistant adhesive.

[0348] While the embodiment of the reflecting area is not particularly limited, such an embodiment is preferable that spreads the light from the light irradiating portion to the inner surface of the water tank. For example, as shown in Fig. 25(a), the reflecting area may be formed on the outer circumferential surface of the rotating drum in a strip shape in a direction orthogonal to the rotating direction. Providing a strip-shaped reflecting area extensive from the bottom surface to the opening is preferable in that one rotation of the rotating drum inevitably causes the

reflected light to be irradiated to the entire outer circumferential surface of the rotating drum.

[0349] Additionally, as shown in Fig. 25(b), the reflecting area may be formed in a spiral manner relative to a rotating direction of the rotating drum. This embodiment elongates the period of time for reflection associated with the rotation.

Additionally, as shown in Fig. 25(c), a plurality of reflecting areas each in an island shape may be formed sporadically on the outer circumferential surface of the rotating drum. It is also possible that the entire outer surface of the rotating drum reflects the light.

[0350] Furthermore, a plurality of reflecting areas each in an island shape may be formed sporadically on the entire outer side surface of the rotating drum, and each of the reflecting areas may be in a convex shape. An island shape reduces the reflecting material, and making the island a convex shape reflect the light diffusely in various directions, and thus the light spreads thoroughly to the inner side surface of the water tank, which is preferable. In this regard, it is preferable to arrange the convex, island-shaped reflecting areas in a spiral manner relative to a rotating direction of the rotating drum. With this structure, the light is reflected diffusely in a complicated manner by the rotation of the drum and thus is irradiated uniformly to the inner side surface of the water tank. This realizes antibacterial processing without non-uniformity.

[0351] While an example of the reflecting area provided on the outer side bottom surface of the rotating drum is shown in Fig. 23 as reference numeral 441, the above-described idea can be applied to the reflecting area

provided on the outer side bottom surface of the rotating drum. That is, the shape of the reflecting area may be spiral from the rotation axis, and the reflection surface may be in a concave/convex shape.

[0352] While in this example description is made of the structure in which the light source is located on the inner surface of the water tank and the reflecting area for reflecting the light from the light source is provided on the outer surface of the water tank, it is also possible to employ such a structure that the light source is provided on both the inner surface of the water tank and the outer surface of the rotating drum, or such a structure that a light source for irradiating light toward the water tank side is provided on the outer surface of the rotating drum while at the same time a reflecting area is provided on the inner surface of the water tank.

[0353] While in Figs. 20 to 22 the first irradiating portion and the second irradiating portion (450) are only the light source 410 and light source 411, the light irradiating portion may be configured to include a light source (410), a reflecting plate (451) for broadening the range of light irradiation, and additionally, a water-resistant, light-transmissive protection cover (452), as shown in Fig. 26. The light irradiating portion may be fixed to the wall surface with a fixing member such as a screw and an adhesive. Reference numeral 453 in Fig. 26 denotes the inner side bottom surface of the water tank.

[0354]

(Example 4 of the Fourth Inventive Group)

Example 4 of the fourth inventive group is characterized in such a structure that a baffle provided in the rotating drum incorporates therein a

light irradiating portion for irradiating light to the interior of the rotating drum. The other matters are the same as in Example 3 of the fourth inventive group except in the above-described respect and that the washing machine door 405 is not provided with the third irradiating portion 430.

[0355] Fig. 27 shows an enlarged schematic diagram illustrating the baffle portion of a rotating drum type washing machine according to Example 4 of the fourth inventive group, and Fig. 28 is a schematic cross sectional view of the light irradiating portion incorporated in the baffle.

[0356] The front surface and side surface of the body of a baffle 460 is formed of a resin material, and the baffle 460 incorporates therein reflecting plates 462 made of aluminum mirror surface plates and light irradiating portions composed of LED light sources 461 (and power supply, not shown) that emit beams of light having a peak wavelength of 525 nm.

[0357] The baffle 460 has such a structure that water will not enter the interior of the baffle 460. Additionally, in order to enhance the strength of the baffle 460 and facilitate attachment thereof to the rotating drum, the baffle 460 is held in a metal frame of resin material and attached to the wall surface of the rotating drum with a fixing member such as a screw and a bolt.

[0358] Additionally, in this example, a cylindrical rotating drum having an inner diameter of 50 cm and a depth of 60 cm is used, and on this drum, three baffles each having a length of 57 cm, a bottom width of 5 cm, and a height of 5 cm are arranged in parallel to the rotation axis direction and with uniform intervals in the circumferential direction of the rotating drum.

[0359] Additionally, as shown in Fig. 27, each baffle incorporates three LEDs.

Additionally, the power supply to the light sources 461 housed in the baffle has such a structure that supplies power through a power supply lead (not shown) arranged from the side of the motor 404, which rotates the drum, along the drum outer wall. It is also possible to use a battery power supply.

[0360] Additionally, as the light generated at the light irradiation 461 in this example, a beam of light having a peak wavelength of 525 nm is used. The light of this wavelength is particularly preferable in that it is not likely to be absorbed water. Note, however, that the light generated at the light irradiation 461 may be any of the peak wavelengths of 300 nm to 600 nm.

[0361] In this regard, the light intensity degrades in the presence of a large amount of water even when the light is of 525 nm wavelength. Meanwhile, there is no need for a large amount of silver ion water in securing antibacterialization of microorganisms; it is only necessary that silver ions of approximately 10 ppb to 1100 ppb be present near microorganisms. Additionally, considering cost performance and reduction in load to natural environment, the antibacterial processing is preferably carried out with a small amount of silver ion water. In view of these circumstances, in this example, in the final stage of the rinsing step, 10 L silver ion water of 60 ppb concentration was put into the rotating drum to carry out a rinse finishing step for 10 minutes and a dehydrating step for 20 minutes, and meanwhile, all the light irradiating portions (410, 411, 461) were activated.

[0362] In this regard, a driving control portion having a computer was provided and a setting program was housed in the computer so that the driving control portion carried out the above-described setting.

Furthermore, the rotating drum type washing machine according to this example has such a structure that is capable of carrying out a washing tank cleaning step by giving an instruction to the above-described driving control portion from an operator.

[0363] The washing tank cleaning step refers to an optional step carried out to more strongly antibacterial-process the interior of the washing tank. Specifically, 10 L silver ion water of, for example, 900 ppb to 1100 ppb concentration is put into the rotating drum and all the light irradiating portions are lit, and with this state, the rotating drum is rotated for approximately 20 to 60 minutes. This realizes antibacterial processing of the entire interior of the washing tank including the rear side of the rotating drum. This washing tank cleaning step is carried out, for example, once a month, or once a week in the cases of terrible contamination.

[0364] When this washing tank cleaning step is carried out using silver ion water of 900 ppb to 1100 ppb concentration, a small amount of silver ion water (an amount that makes the interior of the washing tank moist) suffices. As necessary, after the antibacterial processing using the silver ion water, it is preferable to wash the interior of the washing tank with a relatively large amount of water (for a washing period of time of 3 to 5 minutes), followed by drying of the interior of the tank.

[0365] Carrying out these antibacterial processing operations enable it to

efficiently and reliably carry out bacteria elimination or antibacterialization in a short period of time against actinomycete, Staphylococcus aureus, Escherichia coli, photosynthetic bacteria (prokaryotes), eukaryotes such as Cladosporium cladosporioides and trichophyton, yeasts such as Candida bacteria, and pathogenic viruses.

It should be noted that in place of silver ion water or together with silver ion water, ion water containing copper ions and/or zinc ions may be used.

[0366] Fig. 28 is a schematic cross sectional view of an embodiment of the baffle incorporating therein a light irradiating portion, and the baffle incorporating therein a light irradiating portion is not limited to the embodiment shown in the figure.

The shape, location position, inclined angle relative to the rotating direction, and the like of the baffle are not particularly limited. Usually, a plurality of baffles extensive in a direction parallel to the rotation axis are provided, and in order to thoroughly apply light to the laundry, all the baffles preferably incorporate therein a light irradiating portion. It is also preferable to irradiate the light from both the entire surface and side surface of the baffles 460. Nevertheless, for economic reasons, some of the baffles preferably incorporate therein a light irradiating portion.

[0367] As the resin material constituting the baffle body, it is preferable to use a resin with a high transmissivity for beams of light having a wavelength of 525 nm, and the light irradiation intensity is such that the intensity of the light irradiated to the laundry is 500 to 500000 $\mu W/cm^2$.

[0368]

(Antibacterial Processing Effect Confirmation Test 1)

A test was conducted to confirm antibacterial effects in the antibacterial processing operations with the use of the rotating drum type washing machine according to example 4 of the fourth inventive group. The test method is as follows.

(1) As the antibacterial processing target microorganism, a *Candida albicans* NBRC-1060 standard strain (eukaryote) was prepared. The bacterial body of a bacterial count of approximately 1×10^6 to 5×10^7/1mL was dispersed in a phosphate buffer (50 mM concentration), thus preparing a spore suspension. Then 1 mL of the spore suspension was sampled onto a test cloth of cotton (36 cm^2; Shirting #3 of Japanese Standards Association). This test cloth will be referred to as a contaminated test cloth.

(2) The above-described contaminated test cloth was attached with a water-resistant adhesive onto the inner circumferential surface (test site B1) and the inner side bottom surface (test site B2) of the water tank, and onto the outer circumferential surface (test site C1) and outer side bottom surface (test site C2) of the rotating drum, and additionally, a contaminated test cloth was put into the interior of the rotating drum (test site A). By this method, the antibacterial processing effect on each site of the washing tank was examined.

[0369] The test site B1 was set in the vicinity of a center portion of both the depth direction and the width direction of the water tank in the cross section of the washing machine shown in Fig. 20 and the like.

The test site C1 was set in the vicinity of a center portion of both

the depth direction and the width direction of the rotating drum in the cross section shown in Fig. 20 and the like.

[0370] The test site B2 was set above the center of the circular water tank bottom. The test site C2 was set in the vicinity of the outer circumference of the circular bottom surface of the rotating drum.

Under the assumption that all the sites were the same, the test was repeated under antibacterial processing conditions (described below).

[0371]

[2-1] (Only Water)

While the rotating drum was being rotated at 50 rpm, 10 L of tap water was put into the rotating drum, and with all the light irradiating portions turned off, the rotating drum was rotated for a predetermined period of time. After the period of time of rotation, each test cloth was collected. The predetermined period of time was set at 15 minutes, 30 minutes, and 60 minutes. These will be referred to as samples G1 (sample group 1).

It should be noted that in the case where 10 L of water is poured into the rotating drum while being rotated at 50 rpm, it is confirmed that the water is dispersed outside the rotating drum due to the centrifugal force, with the result that the contaminated test cloth attached to each site of the washing tank is wet with water.

[2-2] (Water + Particular Beam of Light)

With the light irradiating portions turned on, the whole of the washing tank was irradiated with a particular beam of light having a peak wavelength of 525 nm and an irradiation intensity of 50 mW/cm^2. The

other matters were the same as in [2-1]. Samples obtained here will be referred to as samples G2.

[2-3] (Only Silver Ion Water)

A similar test was carried out in the same manner as in [2-1] except that silver ion water of 60 ppb concentration was used in place of tap water. Samples obtained here will be referred to as samples G3.

[2-4] (Silver Ion Water + Particular Beam of Light)

A similar test was carried out in the same manner as in [2-2] except that silver ion water of 60 ppb concentration was used in place of tap water. Samples obtained here will be referred to as samples G4.

[0372]

(3) After carrying out driving under the above-described conditions, the contaminated test cloths were collected. Bacteria bodies were extracted from the collected test cloths and the extracted solutions were applied onto a potato agar, where the extracted solutions were cultivated for four days at 25°C. Then the number of colonies on the agar was counted. By this method, the antibacterial effect of each of the above-described conditions was examined.

[0373]

(Antibacterial Processing Effect Confirmation Test 2)

A confirmation test 2 was carried out in the same manner as in confirmation test 1 except that *Cladosporium cladosporioides* (NBRC 6348) was used in place of *Candida albicans* NBRC-1060, and that the silver ion concentration was set at 100 ppb.

[0374]

(Antibacterial Processing Effect Confirmation Test 3)

A confirmation test 3 was carried out in the same manner as in confirmation test 1 except that *Escherichia coli* (NBRC-3972) was used in place of *Candida albicans* NBRC-1060.

[0375]

[Test Results]

(1) Fig. 29 shows the results of confirmation test 1 at the test site A. It has been confirmed from Fig. 29 that a single-digit higher germiciding effect was exhibited in samples G4 (indicated as ○ in the figure), in which the contaminated test cloths contaminated with *Candida albicans* were irradiated with a particular beam of light while being brought into contact with silver ion water, than in samples G3 (indicated as ● in the figure), in which the contaminated test cloths were brought into contact with silver ion water without irradiation of the particular beam of light.

[0376] It also has been confirmed from a comparison between samples G2 (indicated as Δ in the figure) and samples G4 (indicated as ▲ in the figure) that the irradiation of the particular beam of light alone provides no antibacterial effects.

[0377] Fig. 30 shows a bar graph of antibacterial effect at each site of the washing tank for samples G4 in confirmation test 1. It has been confirmed from Fig. 30 that substantially equal antibacterial effect was obtained from the contaminated test cloths located on the sites of the washing tank.

[0378]

(2) Fig. 31 shows antibacterial results of samples G4 using test

cloths contaminated with *Cladosporium cladosporioides*, and Fig. 32 shows antibacterial results of samples G4 using test cloths contaminated with *Escherichia coli*.

It has been confirmed from the results shown in Figs. 31 and 32 that similar antibacterial effects can be obtained for any of the microorganisms.

[0379] These results can be construed as follows. The irradiation intensity of the particular beam of light used in the rotating drum type washing machine with an antibacterial processing function according to the present invention is sufficiently lower than the intensity with which fungi can be directly antibacterialized. Thus, the results of G4 are not caused by addition of the antibacterial potency of the light to the antibacterial potency of the silver ions but by promoted metal ion incorporation inside the bacteria body by the particular beam of light.

[0380]

Industrial Applicability of the Fourth Inventive Group

With the rotating drum type washing machine with an antibacterial processing function according to the fourth inventive group, which is capable of automatically supplying silver ion water inside the washing tank while at the same time capable of automatically irradiating a particular beam of light to the entire surface of the washing tank, the particular beam of light promotes incorporation of metal ions inside the bacteria body, thereby facilitating the attempt to automatically carry out bacteria elimination or antibacterialization of the laundry and the whole of the washing tank with silver ion water of a lower concentration.

Therefore, the industrial applicability of the present invention is considerable.

What is claimed is:

1. An antibacterial method for preventing growth of a microorganism using an antibacterial metal ion, the method comprising a step of bringing the microorganism into contact with the antibacterial metal ion after or while irradiating the microorganism with a particular beam of light,
wherein
the particular beam of light has a peak wavelength of 300 to 600 nm.

2. The antibacterial method according to claim 1, wherein:
the antibacterial metal ion is a silver ion contained in a silver metal ion-containing solution having a concentration of 1100 ppb or less; and
the particular beam of light has an irradiation intensity of 1000 μW/cm^2 or more.

3. An antibacterial method for preventing growth of a microorganism using an antibacterial metal ion, the method comprising a step of irradiating the microorganism with a particular beam of light in a state where the microorganism is in contact with the antibacterial metal ion,
wherein
the particular beam of light has a peak wavelength of 300 to 600nm.

4. The antibacterial method according to claim 3, wherein:
the antibacterial metal ion is a silver ion contained in a silver metal ion-containing solution having a concentration of 1100 ppb or less; and
the particular beam of light has an irradiation intensity of 1000 μW/cm^2 or more.

5. An antibacterial apparatus comprising:
ion generating means of generating an antibacterial metal ion;
contact means of bringing the antibacterial metal ion generated at the antibacterial metal ion generating means into contact with a microorganism; and
irradiating means of irradiating the microorganism with a particular beam of

light in a state where the microorganism is in contact with the antibacterial metal ion by the contact means,

wherein

the particular beam of light has a peak wavelength of 300 to 600nm.

6. The antibacterial apparatus according to claim 5, wherein the particular beam of light has an irradiation intensity of 500 to 500000 μW/cm^2.

7. The antibacterial apparatus according to claim 6, wherein the antibacterial metal ion is a silver ion.

8. An antibacterial apparatus comprising:

ion generating means of generating an antibacterial metal ion;

irradiating means of irradiating the microorganism with a particular beam of light; and

contact means of bringing the microorganism irradiated with the particular beam of light into contact with the antibacterial metal ion generated at the ion generating means,

wherein

the particular beam of light has a peak wavelength of 300 to 600nm.

9. The antibacterial apparatus according to claim 8, wherein the particular beam of light has an irradiation intensity of 500 to 500000 μW/cm^2.

10. The antibacterial apparatus according to claim 9, wherein the antibacterial metal ion is a silver ion.

11. An animal cell activity control apparatus comprising:

a light source portion for outputting a beam of light;

an irradiating portion for guiding the beam of light output from the light source portion to an animal cell and irradiating the animal cell with the beam of light; and

a contact portion for bringing an antibacterial metal ion into contact with the

animal cell,

wherein

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

12. A refrigerator provided with an automatic ice making apparatus having an automatic antibacterial processing function for preventing growth of a microorganism in a water conduit,

the automatic antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and the automatic ice making apparatus comprising:

an ice making portion;

a water feeding tank;

a water conduit for guiding water stored in the water feeding tank to the ice making portion;

an ion supply portion for supplying an antibacterial metal ion to an interior of the water feeding tank or the water conduit; and

a light source portion for irradiating the interior of the water feeding tank or the water conduit with the particular beam of light,

wherein

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

13. A refrigerator provided with an automatic ice making apparatus having an automatic antibacterial processing function for preventing growth of a microorganism in a water conduit,

the automatic antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and the automatic ice making apparatus comprising:

an ice making portion;

a water conduit for guiding water to the ice making portion;

an ion supply portion for supplying an antibacterial metal ion to the water

conduit; and

a light source portion for irradiating the water conduit with a particular beam of light,

wherein

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

14. A refrigerator provided with an automatic ice making apparatus having an automatic antibacterial processing function for preventing growth of a microorganism in a water conduit,

the automatic antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and the automatic ice making apparatus comprising:

an ice making portion;

a water conduit for guiding water to the ice making portion; and

a light source portion for irradiating the water conduit with a particular beam of light,

wherein

the water conduit contains a silver ion elution material for eluting a silver ion, and

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

15. A refrigerator provided with an automatic ice making apparatus having an automatic antibacterial processing function for preventing growth of a microorganism in a water conduit,

the automatic antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and the automatic ice making apparatus comprising:

a water feeding tank;

an ice making tray; and

a water conduit for guiding water from the water feeding tank to the ice

making tray,

wherein:

at least one material of the water feeding tank, the ice making tray, and the water conduit contains a silver ion elution material for eluting a silver ion;

a light source portion for irradiating the water conduit with the particular beam of light is located near the material; and

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

16. A refrigerator provided with a refrigerating compartment, a freezer compartment isolated from the refrigerating compartment, and an automatic ice making apparatus having an automatic antibacterial processing function for preventing growth of a microorganism in a water conduit,

the automatic antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and, the automatic ice making apparatus comprising:

a water feeding tank located in the refrigerating compartment;

an ice making tray located in a portion of the freezer compartment;

a water conduit for guiding water stored in the water feeding tank to the ice making portion; and

an ion supply portion for supplying an antibacterial metal ion to an interior of the water feeding tank or the interior of the water conduit,

wherein:

the water conduit is light transmissive;

a light source portion for irradiating the water conduit with the particular beam of light is located near the water conduit; and

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 μW/cm^2.

17. The refrigerator provided with the automatic ice making apparatus according to claim 16, wherein:

the water feeding tank of the automatic ice making apparatus is light transmissive; and

a light source portion for irradiating the water conduit with a particular beam of

light is located near the water feeding tank.

18. A rotating drum type washing machine capable of preventing microorganism contamination during washing and carrying out antibacterial processing of the laundry,

the microorganism contamination prevention and antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and the rotating drum type washing machine at least comprising:

a water tank capable of containing water and discharging contained water;

a rotating drum located in the water tank and rotatably driven in the water tank; and

ion supply means of supplying ion water containing antibacterial metal ion water to the rotating drum or the water tank,

wherein:

the rotating drum includes, on a wall thereof, a plurality of pores through which water is able to pass between an interior of the rotating drum and an interior of the water tank;

the water tank includes, on an inner side surface thereof, a first irradiating portion for irradiating an outer side surface of the rotating drum with a particular beam of light; and

the particular beam of light has a peak wavelength of 300 to 600 nm.

19. The rotating drum type washing machine according to claim 18, wherein the rotating drum includes, on the outer side surface thereof, a reflecting area for reflecting the particular beam of light.

20. The rotating drum type washing machine according to claim 19, wherein the reflecting area is formed in a strip shape in a direction orthogonal to a rotating direction of the rotating drum.

21. The rotating drum type washing machine according to claim 19, wherein the reflecting area is formed in a spiral manner relative to a rotating direction of the rotating drum.

22. The rotating drum type washing machine according to claim 19, wherein a plurality of reflecting areas each in an island shape are formed sporadically on the outer side surface of the rotating drum, each of the reflecting areas being in a convex shape.

23. The rotating drum type washing machine according to claim 19, wherein:

the light irradiating portion is composed of the first irradiating portion provided on the inner side surface of the water tank and a second irradiating portion provided on an inner bottom surface of the water tank; and

the reflecting area is provided on both a side surface and a bottom surface of the rotating drum.

24. The rotating drum type washing machine according to claim 18, wherein:

the ion supply means is a silver ion supply means for supplying silver ions; and

the particular beam of light has an irradiation intensity of 500 to 500000 $\mu W/cm^2$.

25. A rotating drum type washing machine capable of preventing microorganism contamination during washing and carrying out antibacterial processing of the laundry,

the microorganism contamination prevention and antibacterial processing comprising:

a step of irradiating the microorganism with a particular beam of light; and

a step of bringing the microorganism into contact with an antibacterial metal ion,

and the rotating drum type washing machine at least comprising:

a water tank capable of containing water and discharging contained water;

a rotating drum located in the water tank and rotatably driven in the water tank; and

silver ion supply means of supplying silver ion water to the rotating drum or the water tank,

wherein:

the rotating drum includes a plurality of pores through which water is able to pass between an interior of the rotating drum and an interior of the water tank;

a baffle for rolling over a laundry is formed on an inner wall surface of the rotating drum;

the baffle incorporates therein a light irradiating portion for irradiating light to the interior of the rotating drum; and

the particular beam of light has a peak wavelength of 300 to 600 nm and an irradiation intensity of 500 to 500000 $\mu W/cm^2$.

26. The rotating drum type washing machine according to claim 25, wherein:

the water tank includes, on an inner side surface thereof, a first irradiating portion for irradiating light to an outer circumferential surface of the rotating drum and includes, on an inner bottom surface of the water tank, a second irradiating portion for irradiating light to an outer bottom surface of the rotating drum; and

a reflecting area is provided on both the outer circumferential surface and the outer bottom surface of the rotating drum.