

DESCRIPTION

TITLE OF THE INVENTION: INDOOR ENVIRONMENT ADJUSTMENT  
SYSTEM

5 TECHNICAL FIELD

**[0001]**

The present invention relates to an indoor  
environment adjustment system that utilizes a far-  
infrared radiating and absorbing phenomenon among  
10 different far-infrared radiating substances present in an  
indoor space to adjust the indoor space to a comfortable  
environment.

BACKGROUND ART

**[0002]**

15 The primary methods for adjusting the indoor  
environment have utilized the movement of thermal energy  
by convection of the heated or cooled air in an indoor  
space by a heating source or a cooling source disposed in  
the indoor space, or the transfer of thermal energy by  
20 convection of the air in the indoor space by providing a  
warm air or a cool air from outdoor to an indoor space.  
Recently, the applicant of the present invention  
has accomplished a remarkably highly efficient movement of  
thermal energy among the indoor surface-forming members  
25 such as the wall and the ceiling and a cooling source (or  
a heating source) by utilizing the far-infrared radiating  
and absorbing phenomenon occurring among the same far-  
infrared radiating substances, and thereby has developed  
an indoor environment adjustment system that is  
30 exceptionally highly energy-efficient as compared to the  
conventional technologies that utilized the convection of  
air in indoor spaces (see Patent Literatures 1 and 2).

**[0003]**

35 The novel indoor environment adjustment system  
mentioned above employs a principle whereby energy  
transfer among the same substances that exhibit the same  
far-infrared radiating and absorbing properties takes

place at high efficiency. As used herein the term "same substances" means substances that are identical on the molecular level, and the "molecule" means an assembly of atoms joined together by chemical bonding, and may include crystals of minerals forming natural stones.

CITATION LIST

Patent Literatures

[0004]

Patent Literature 1: Japanese Patent Publication No. 4422783

Patent Literature 2: Kokai (Japanese Unexamined Patent Publication) No. 2010-095993

SUMMARY OF THE INVENTION

Technical Problems

[0005]

The indoor environment adjustment system of prior art accomplishes the indoor environment adjustment (realization of comfortableness) by energy transfer via the radiation and absorption of far-infrared rays between the same substances having the far-infrared radiating and absorbing properties. This is because the use of the same substances having the same radiation characteristics to wavelength can attain an extremely highly efficient energy transfer (100% under an ideal condition).

[0006]

The above indoor environment adjustment system may be applied to various buildings. However, there are cases where it is not easy to use the same far-infrared radiating substance for the cooling source (or the heating source) and the indoor surface-forming member. For example, in applying the system to an existing building, it is easy to install the cooling source (or the heating source) alone without reforming the wall or the ceiling, but it may be difficult to obtain a substance identical to the far-infrared radiating substance included in the existing wall or the ceiling.

[0007]

It is an object of the present invention to provide an indoor environment adjustment system that was developed with a new perspective and that achieves the effective adjustment of an indoor environment even without using the same far-infrared radiating substance between the indoor surface-forming member and the cooling source (or the heating source).

Solution to the Problems

**[0008]**

The indoor environment adjustment system of the present invention uses different far-infrared radiating substances in the indoor surface-forming member such as the wall and the ceiling and the cooling source (or the heating source) that performs thermal energy exchange via the radiation and absorption of far-infrared rays with the indoor surface-forming member. The system of the present invention utilizes the exchange of thermal energy via far-infrared radiation and absorption between the indoor surface-forming member and the cooling surface of the cooling source (or the heating surface of the heating source) similarly to the indoor environment adjustment system disclosed in Patent Literatures 1 and 2 by the present inventors. However, the system of the present invention, in stead of using the same far-infrared radiating substance in the indoor surface-forming member and the cooling surface of the cooling source (or the heating surface of the heating source), uses different far-infrared radiating substances.

**[0009]**

The reason why the inventors of the present invention decided the use of the same far-infrared radiating substance in the indoor surface-forming member and the cooling surface of the cooling source (or the heating surface of the heating source) as a requirement in the system of the prior art technology described in Patent Literatures 1 and 2 is that our testing revealed the unless the same substance was used (in the case of

combination of different substances), the environment-adjusting effect was small or limited.

[0010]

5 After intensive and extensive research considering the usefulness of achieving an effective system without using the same far-infrared radiating substance in the indoor surface-forming member and the cooling surface of the cooling source (or the heating surface of the heating source), the present inventors have found that by  
10 satisfying the following requirements even if different far-infrared radiating substances were used, a system that can be sufficiently put into practical use can be obtained, and thus have completed the present invention. Thus,

15 (1) With regard to the cooling surface of a cooling source (or the heating surface of a heating source) and the surface of an indoor surface-forming member, each comprising a material including a different far-infrared radiating substance, the emissivity of both materials  
20 should be as high as possible, and integrated emissivity in the wavelength range of 4.5-20  $\mu\text{m}$  should be 0.70 or greater; and

(2) The above two materials should have as many wavelength regions as possible that can be shared in the  
25 operating temperature range (ordinary temperature region) of the system. Specifically, it is necessary that with regard to the cooling surface of a cooling source (or the heating surface of a heating source) and an indoor surface-forming member, each comprising a material  
30 including a different far-infrared radiating substance, an overlapping region in the spectral emission spectrum (for wavelengths of 4.5-20 $\mu\text{m}$ ) in the operating temperature range of the system should be 60% or greater of black body radiation. As used herein, the cooling  
35 surface of a cooling source (i.e. the heat-absorbing surface) is the far-infrared absorbing side and the indoor surface-forming member is the far-infrared

radiating side, whereas the heating surface of a heating source is the far-infrared radiating side and the indoor surface-forming member is the far-infrared absorbing side.

5     **[0011]**

        In order to solve the above problems, the present invention provides the following inventions:

        (1) An indoor environment adjustment system wherein the cooling surface of a cooling source is exposed in an indoor space and are constructed from a material including a far-infrared radiating substance A, the exposed surface of an indoor surface-forming member in the indoor space is constructed from a material including a far-infrared radiating substance B having a different type of molecule from the far-infrared radiating substance A, the cooling source is a device for cooling the cooling surface by means of a medium flowing in a flow path formed therein, the integrated emissivity of the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B is 0.70 or greater in the wavelength range of 4.5 to 20  $\mu\text{m}$ , and with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  in the operating temperature range of the system is 60% or greater of black-body radiation.

        (2) The indoor environment adjustment system according to the above (1), wherein with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, the overlapping region in the spectral emission spectrum for wavelengths of 7 to 12  $\mu\text{m}$  is 60% or greater of black-body radiation.

        (3) The indoor environment adjustment system

according to the above (1) or (2), wherein with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, the overlapping region is 70% or greater of black-body radiation.

(4) The indoor environment adjustment system according to any one of the above (1) to (3), wherein the overlapping region is 80% or greater of black-body radiation.

(5) The indoor environment adjustment system according to any one of the above (1) to (4), wherein the integrated emissivity of the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B is 0.80 or greater.

(6) The indoor environment adjustment system according to any one of the above (1) to (5), wherein 0.1-100 wt% of the far-infrared radiating substance B is present in the material forming the exposed surface of an indoor surface-forming member.

(7) The indoor environment adjustment system according to any one of the above (1) to (6), wherein 0.1-100 wt% of the far-infrared radiating substance A is present in the material forming the cooling surface of the cooling source.

(8) The indoor environment adjustment system according to any one of the above (1) to (7), wherein the area of the indoor surface-forming member constructed from the far-infrared radiating substance B is at least 0.05 times the total floor area of the space of which environment is to be adjusted.

(9) The indoor environment adjustment system according to any one of the above (1) to (8), wherein the area of the indoor surface-forming member constructed from the far-infrared radiating substance B is at least 0.3 times the total floor area of the space of which environment is to be adjusted.

(10) The indoor environment adjustment system according to any one of the above (1) to (9), wherein the area of the cooling surfaces including the far-infrared radiating substance A of the cooling source is not  
5 greater than 0.5 times the area of the indoor surface-forming member constructed from the material including the far-infrared radiating substance B.

(11) The indoor environment adjustment system according to any one of the above (1) to (10), wherein  
10 the area of the cooling surfaces including the far-infrared radiating substance A of the cooling source is 0.2-0.5 times the area of the indoor surface-forming member constructed from the material including the far-infrared radiating substance B.

(12) The indoor environment adjustment system according to any one of the above (1) to (11), wherein the cooling source also serves as a heating source that utilizes the cooling surface as the heating surface by heating the cooling surface by means of a medium flowing  
15 in a flow path formed therein.  
20

**[0012]**

The indoor environment adjustment system of the present invention is an indoor environment adjustment system wherein the cooling surface of a cooling source is  
25 exposed in an indoor space and are constructed from a material including a far-infrared radiating substance A, the exposed surface of an indoor surface-forming member in the indoor space is constructed from a material including a far-infrared radiating substance B having a  
30 different type of molecule from the far-infrared radiating substance A, the cooling source is a device for cooling the cooling surface by means of a medium flowing in a flow path formed therein, the integrated emissivity of the material including the far-infrared radiating  
35 substance A and the material including the far-infrared radiating substance B is 0.70 or greater in the wavelength range of 4.5 to 20  $\mu\text{m}$ , and with regard to the

material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  in the operating temperature range of the system is 60% or greater of black-body radiation.

**[0013]**

The indoor environment adjustment system of the present invention can be realized as one exhibiting a heating effect by replacing the cooling source with a heating source. The system in this case is an indoor environment adjustment system wherein the heating surfaces of a heating source are exposed in an indoor space and are constructed from a material including a far-infrared radiating substance A, the exposed surface of an indoor surface-forming member in the indoor space is constructed from a material including a far-infrared radiating substance B having a different type of molecule from the far-infrared radiating substance A, the integrated emissivity of the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B is 0.70 or greater in the wavelength range of 4.5 to 20  $\mu\text{m}$ , and with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  in the operating temperature range of the system is 60% or greater of black-body radiation. The heating source can be a device for heating the heating surface by means of a medium flowing in a flow path formed therein, and in this case the above system exhibiting a cooling effect can also serve as a system exhibiting a heating effect. The heating source may be, for example, a device for heating the heating surface with electricity.

EFFECTS OF THE INVENTION

[0014]

In accordance with the present invention, an indoor environment adjustment system that utilizes energy transfer by far-infrared radiation and absorption having excellent efficiency among the same substances can be expanded to a system that utilizes energy transfer among different substances. In the conventional technology that does not utilize energy transfer by far-infrared radiation and absorption, convection of the indoor air is indispensable, and energy (mainly a mechanical energy) was needed to cause the convection of air in addition to thermal energy required for the adjustment of the temperature and humidity of the entire air constituting the indoor environment, whereas the system of the present invention requires the involvement of thermal energy that is only needed for adjustment of the indoor environment which is felt comfortable to humans, and permits the adjustment of the indoor environment that is remarkably energy-efficient compared to the conventional technology.

Furthermore, in accordance with the system of the present invention, unlike the cases where air conditioners are used, there is no convection of a hot air or cold air, and thus an environment suitable for indoor foliage plants can be provided, and the foliage plants can be kept fresh for a long time. This is probably because the metabolism of plants is improved and a suitable environment is provided.

Also, in accordance with the system of the present invention, the temperature difference in the vertical direction from the ceiling to the floor can be remarkably minimized (for example, it can be reduced to 2°C or less for 3 m, which is a fraction of common difference), leading to a marked effect of preventing the diffusion of bacteria etc. suspended in the air.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

[Fig. 1]

The schematic diagram of the spectral integral emissivity curves of substance A and substance B.

[Fig. 2]

5 The schematic diagram of the spectral integral emissivity curves of substance A, substance B, and substance C.

[Fig. 3]

An illustration showing how to mount a fixed sample when the radiation characteristics is determined.

10 [Fig. 4]

An illustration showing how to mount a thin sample when the radiation characteristics is determined.

[Fig. 5]

15 An illustration showing an embodiment of a heat-absorbing device.

[Fig. 6]

An illustration showing a water channel in a heat-absorbing device.

[Fig. 7]

20 An illustration showing the spectral emission spectra of a material including substance A and a material including substance B used in Working Examples 1 and 6.

[Fig. 8]

25 An illustration showing the spectral emission spectra of a material including substance A and a material including substance B used in Working Example 2.

[Fig. 9]

30 An illustration showing the spectral emission spectra of a material including substance A and a material including substance B used in Working Example 3.

[Fig. 10]

An illustration showing the spectral emission spectra of a material including substance A and a material including substance B used in Working Example 4.

35 [Fig. 11]

An illustration showing the spectral emission spectra of a material including substance A and a material

including substance B used in Working Example 5.  
[Fig. 12]

5 An illustration showing the spectral emission spectra  
of a material including substance A and a material  
including substance B used in Working Example 7.  
[Fig. 13]

10 An illustration showing the spectral emission spectra  
of a material including substance A and a material  
including substance B used in Comparative Example 1.  
[Fig. 14]

An illustration showing the spectral emission spectra  
of a material including substance A and a material  
including substance B used in Comparative Example 2.  
[Fig. 15]

15 An illustration showing the spectral emission spectra  
of a material including substance A and a material  
including substance B used in Comparative Example 3.

#### DESCRIPTION OF EMBODIMENTS

##### [0016]

20 The indoor environment adjustment system of the  
present invention utilizes energy transfer by exchange of  
far-infrared rays between different substances having a  
property of radiating and absorbing far-infrared rays.  
An earlier application disclosed that the indoor  
25 environment can be adjusted by exchange (resonance) of  
far-infrared rays between the same substances.

##### [0017]

30 However, availability of a system using different  
substances in the exchange of far-infrared rays can  
impart flexibility in the construction of a system  
including a case where the system is applied to existing  
buildings (when a cooling source (or a heating source)  
alone is newly provided using a far-infrared radiating  
substance different from the far-infrared radiating  
35 substance included in the wall or the ceiling, without  
reconstructing the wall or the ceiling). Thus, after  
intensive and extensive research in order to obtain a

practical system that utilizes different substances in the exchange of far-infrared rays, such a system can be achieved by satisfying the requirements that:

5 (a) with regard to the cooling surface of a cooling source (or the heating surface of a heating source) and the surface of an indoor surface-forming member, each comprising a material including a different far-infrared radiating substance, the integrated emissivity of both materials in the wavelength range of 4.5 to 20  $\mu\text{m}$  is 0.70  
10 or greater and

(b) with regard to the cooling surface of a cooling source (or the heating surface of a heating source) and an indoor surface-forming member, each comprising a material including a different far-infrared radiating  
15 substance, an overlapping shared region in the spectral emission spectrum (wavelengths of 4.5 to 20  $\mu\text{m}$ ) in the operating temperature range of the system is 60% or greater of black body radiation.

**[0018]**

20 Before explaining the above requirement, the phenomenon of energy exchange by radiation and absorption between the same substances will be explained.

A member forming an indoor space (living space) is constructed with one or a plurality of substances (an  
25 assembly of atoms and molecules), and in those substances there are always inherent atomic or molecular oscillation corresponding to the temperature. This oscillation has a characteristic oscillation period depending on the bonding status between the same or different atoms.

30 Between the atomic bonds having the same oscillation period, the exchange of quantum energy by a resonance phenomenon is always taking place.

**[0019]**

35 The oscillation energy between atoms assumes a characteristic value (quantum energy) depending on the type of the atom, and the oscillation level takes a multi-stage structure of integral multiples of the

natural frequency. When an energy transits from an upper level to a lower level in the multi-stage energy structure, a light having a frequency (or wavelength) of an integral multiple of the natural frequency  
5 corresponding to the number of declining stages. This light may be absorbed into the atomic bonding having the same natural frequency in the same substance, or may be radiated outside of the substance, and absorbed in the atomic bonding part having the same natural frequency  
10 present in another member facing opposite to each other across the space. The energy of the atomic bonding part where absorption occurred jumps (is excited) to an upper level of an integral multiple of the natural frequency depending on the absorbed energy, which means  
15 that the temperature of the bonding part increases.

**[0020]**

Thus, the instant transfer of a part (transition energy) of the energy of the natural frequency of the atomic bonding in a substance to the oscillation between  
20 the atomic bonding present in the vicinity of the surface of a substance facing opposite to each other across a space is due to a resonance phenomenon of the same natural frequencies, which can never take place in the atomic bonding having different values of natural  
25 frequency. This is a reason why the exchange of energy via radiation and absorption between the same substances facing opposite to each other takes place at an extremely high efficiency (100% under an ideal condition).

**[0021]**

30 As described above, energy transfer between the same substances via far-infrared radiation and absorption is a physical phenomenon that takes place instantly by resonance of natural oscillations of the bond between atoms forming the radiation-side substance and the  
35 absorption-side substance. This is why the present inventors have previously stated that when the same substance is not used (in the case of combination of

different substances), the environment adjustment effect cannot be obtained or may be limited. Also, when the present inventors constructed a cooling source (also serving as a heating source) in connection to the development of the indoor environment adjustment system of prior art and actually installed the cooling source at several existing rooms which do not have a far-infrared radiating substance used in the cooling source (the heating source), the cooling effect (or the warming effect) was small or limited.

**[0022]**

However, if the use of different far-infrared radiating substances in the indoor surface-forming member and the cooling source (or the heating source) could give a certain level of indoor environment adjustment effect though the effect may smaller than when the same substance was used in both, the present inventors thought, it could expand the application of the indoor environment adjustment system, disclosed previously by the present inventors, that is in principle energy-efficient, and therefore research on the efficient energy exchange between different far-infrared radiating substances was continued.

**[0023]**

In energy exchange via radiation and absorption between different substances, the natural oscillation frequency of bond between atoms of both substances does not agree or only partly agree. In this case, the efficiency of energy exchange between different substances is smaller than that between the same substances as described above, and a detectable cooling (warming) effect could not be obtained in the original experiment by the present inventors as described above. However, as long as there is the ability of radiating and absorbing far-infrared rays even between the different substances, there should be a certain level of energy transfer between them.

[0024]

When the energy level of natural oscillation based on the atomic bonding of molecules present in a substance transits from an upper to a lower level, an  
5 electromagnetic wave (light) having a frequency corresponding to the transition energy is radiated. When this radiation takes place on the surface of the substance, the frequency of the electromagnetic wave or the wavelength is equal to the transition energy, whereas  
10 when the radiation took place inside the substance, it could be completely absorbed by the bond between same atoms present in the vicinity of said atomic bond, or it travels within the substance while the direction is being altered by other atoms and atomic bonds having different  
15 frequencies, finally reaching the surface of the substance. Part of the electromagnetic wave that reached the surface is radiated outside the substance, and the rest is reflected at the interface of the substance and the ambient air (atmospheric air) and travels within the  
20 substance again. At this time, the energy of the electromagnetic wave radiated outside, i.e. the frequency or wavelength, repeats gradual slowing down or acceleration while traveling within the substance, with a result that the oscillation values are slightly extended  
25 around the original natural oscillation value. Thus, the spectral emission spectrum of the light radiated outside the substance is not an assembly of monochromatic peaks of the natural oscillation value, but generally assumes an equalized shape with a plurality of sloped peaks.  
30 Also, with regard to the frequency or wavelength of the electromagnetic wave entering the substance, electromagnetic waves having different frequencies around the natural oscillation present within the  
substance, except for those that are fully reflected on  
35 the surface of the substance, enter the substance, and continue gradual slowing down or acceleration via interaction with atoms or atomic bonds within the

substance, and part of them is absorbed by resonance due to the agreement with the natural oscillation within the substance. The presence of such a mechanism is considered a reason why the electromagnetic waves that were radiated outside are absorbed by the other end to a certain degree between the same substances with different temperatures or even between different substances having different molecular structures.

**[0025]**

The amount of energy exchanged between the substances via far-infrared radiation and absorption, even if it is exchange between different substances, may become greater as the integrated emissivity (absorptivity) of both substances becomes greater. Thus, in the system of the present invention, the integrated emissivity of the materials including the far-infrared radiating substances on the cooling surface (the heating surface) of a cooling source (or a heating source) and the indoor surface-forming member must be 0.70 or greater. More preferably, the integrated emissivity of a material including the far-infrared radiating substance A and a material including the far-infrared radiating substance B may be 0.80 or greater, more preferably 0.90. This is the requirement (a) described above.

**[0026]**

In Japan, the "far-infrared rays" refers to electromagnetic waves with a wavelength of 3  $\mu\text{m}$  to 1000  $\mu\text{m}$ , and the emissivity of a substance is defined as  $W/W_0$ , wherein  $W_0$  is the radiation energy for the far-infrared rays of an ideal black body under the same conditions, and  $W$  is the radiation energy for the far-infrared rays of the substance. The spectral emission spectra of a material including a far-infrared radiating substance A and a material including a far-infrared radiating substance B used in the system of the present invention do not greatly change in the temperature range of an indoor environment to which the system is applied. Thus,

when the "integrated emissivity" is simply mentioned in the present invention, an integrated emissivity determined in the range of 4.5 to 20  $\mu\text{m}$  in the vicinity of the target value (a temperature which is felt comfortable to humans) of the indoor temperature actually adjusted by the system of the present invention can preferably be adopted. The reason why the wavelength range for measurement is set as 4.5 to 20  $\mu\text{m}$  will be described below.

10 [0027]

The integrated emissivity in the wavelength range of 4.5 to 20  $\mu\text{m}$  according to the present invention can be determined in the following manner.

15 The radiation energy of far-infrared rays in the ordinary temperature range can generally be determined using spectral emission determination by Fourier transform infrared spectroscopy (FT-IR). Thus, a sample for measurement is provided in a sample chamber encircled by pseudoblack body walls, far-infrared rays radiated from the sample are guided through micropores to the spectrometer, and guided simultaneously to a detector together with far-infrared rays extracted from a standard black body furnace maintained at a temperature almost the same as the sample, and then energy intensities (luminance) for each predetermined frequency interval or predetermined wavelength interval are measured. The energy intensity (luminance) for each predetermined wavelength interval, expressed over the predetermined wavelength interval together with black body radiation, is referred to as a "spectral emissivity curve".

20 Expression, over the entire wavelength interval, of the ratio (0-1.0) of the radiant luminance from the sample to the luminance from black body for a predetermined wavelength interval is designated as a "spectral emissivity curve" or a "spectral emission spectrum".

25

30

35

As used herein the term "spectral emissivity" refers

to a ratio of the radiation energy intensity (luminance) of a sample at a certain wavelength to the radiation energy intensity (can be theoretically calculated) of black body at the same temperature and the same wavelength, and the "total emissivity" refers to a ratio of the total radiation energy from a sample at a specific temperature to the total radiation energy (can be theoretically calculated) from black body at the same temperature. Also, the ratio of the radiation energy intensity (luminance) of a sample at a specific temperature and a specific wavelength interval to the radiation energy intensity (luminance) of black body at the same temperature and the same wavelength interval is referred to as the "integrated emissivity".

15 [0028]

Research to elucidate the wavelength and intensity of electromagnetic waves (light) emitted from various objects started in the first half of 1990's. Initially, the total energy of ultraviolet rays, visible rays, infrared rays etc. could only be measured for those emitted from high-temperature objects. Thereafter, however, due to the progress in the spectroscopic technology, measurable ranges of wavelength and energy intensity were gradually expanded, and in the second half of the 20th century, the measurement of the spectral emission spectrum of far-infrared rays became possible. However, since electromagnetic waves incident on the spectrometer from the surface of a sample include, in addition to radiation from the sample per se, components of environment radiations from objects in the surrounding of the sample that were reflected on the surface of sample, it was difficult to discriminate the radiation from the sample per se, unless the sample temperature is significantly higher than the ambient temperature. Specifically, it was considered impossible to determine far-infrared radiation from an object at around ordinary temperature, but in the 1990's a research group of Japan

including the present inventors developed an ordinary temperature FT-IR spectral emissivity meter to which special functions were imparted, with a result that it became possible to obtain the spectral emission spectra of far-infrared rays radiated from a sample per se in an ordinary temperature range of 30-50°C. Subsequently, this ordinary temperature spectral emissivity meter rapidly spread, and dozens of instruments are in operation in Japan today.

10     **[0029]**

As far-infrared radiating substances A and B, those that satisfy the above requirements can be selected from inorganic materials such as minerals and ceramics and organic materials such as organic polymer materials. Generally metal materials have short bond lengths and large natural oscillation frequencies of interatomic bonds within the metal, and thus unless elementary particles such as electrons or electromagnetic waves (lights) having a large energy approach, transition between oscillation levels does not occur, and far-infrared rays having small frequencies are reflected on the surface of metals without being absorbed. Therefore, metal materials are not suitable for use as far-infrared radiating substances A or B.

25     **[0030]**

In accordance with the present invention, a far-infrared radiating substance A included in the surface of the indoor surface-forming member and a far-infrared radiating substance B included in the cooling surface of a cooling source (or the heating surface of a heating source) are composed of different molecular species. As used herein the term "different molecular species" means that the far-infrared radiating substance A and the far-infrared radiating substance are different on the molecular level. As used herein the "molecule" means an assembly of atoms bound by chemical bonds (atomic bonding). Therefore, the "molecule" as used herein

includes crystals etc. of minerals forming natural stones. The same minerals in which similar elements have been substituted or solid dispersed are considered substances of the same molecular species.

5     **[0031]**

For each of the far-infrared radiating substances A and B, a single substance (for example, minerals, ceramics etc.) or a plurality of substances may be used. For example, as the far-infrared radiating substance A, a  
10     mixture of different minerals A1 and A2 may be used. Similarly, as the far-infrared radiating substance B, a mixture of different ceramics B1 and B2 may be used.

**[0032]**

The present inventors have evaluated far-infrared  
15     ray characteristics for a variety of objects such as metals, inorganic materials (ceramics), organic polymer materials, coating materials and natural products using the above-mentioned ordinary temperature-type FT-IR spectral emissivity meter (a broadband MCT detector) by  
20     obtaining spectral emission luminance curves and spectral emission spectra at the ordinary temperature region. When the practical range of measured wavelength is assumed to be 4.5-20  $\mu\text{m}$ , the spectral emission luminance curve of black body radiation at 300°K (Kelvin) or 27°C  
25     may become a curve C in Fig. 2 according to the MaxPlank radiation equation. The wavelength of radiation from black body at 27°C is distributed in the range of 30-70  $\mu\text{m}$ , and the wavelength (peak wavelength) at which the maximum radiation luminance can be obtained is 9.7  $\mu\text{m}$   
30     according to the Wien's law ( $\gamma=2897/T$ ). Also, when the reliable range of measurable wavelength range is assumed to be 4.5-20  $\mu\text{m}$  for samples of existing objects, the energy of black body radiation at 27°C measured at this wavelength range is 70% of the entire radiation, and the  
35     rest of 2% is less than 4.5  $\mu\text{m}$  and 28% exceeds 20  $\mu\text{m}$ . For the existing objects, there is the spectral

emissivity of 0 to 1.0 relative to black body for each wavelength, and it is not rare that when the spectral emissivity at 9.7  $\mu\text{m}$  which is a peak wavelength of black body is low, the peak wavelength is in another wavelength zone. It may be measured at a wavelength range of 4-25  $\mu\text{m}$ , but since the radiation luminance even of black body at the ordinary temperature region of about 30-50°C is less than 4.5  $\mu\text{m}$ , and is very small at a wavelength zone of greater than 20  $\mu\text{m}$ , and the sensitivity of the detector decreases, making the discrimination from the noise (background) difficult, and therefore reliable data cannot be obtained.

**[0033]**

In the ordinary temperature region of 30-50°C, examples of far-infrared radiating substances that satisfy the above requirement (a) of the present invention may include the following:

<Name of substance><Integrated emissivity>

|    |                                                                                                                 |      |
|----|-----------------------------------------------------------------------------------------------------------------|------|
|    | $\alpha$ -alumina ( $\text{Al}_2\text{O}_3$ ) powder:                                                           | 0.89 |
| 20 | Porous alumina ( $\text{Al}_2\text{O}_3$ ) powder:                                                              | 0.91 |
|    | Silicon nitride ( $\text{Si}_3\text{N}_4$ ) powder:                                                             | 0.88 |
|    | Silica ( $\text{SiO}_2$ ) powder:                                                                               | 0.88 |
|    | Far-infrared radiating ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder:                      | 0.94 |
| 25 | Ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder-added synthetic woven fabric:                | 0.88 |
|    | Ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder-added acrylic plate (3 mm thick):            | 0.82 |
| 30 | Ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder-added polypropylene (PP) sheet (2 mm thick): | 0.91 |
| 35 | Ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder-added polyethylene (PE) sheet (1 mm thick):  | 0.83 |

Anodic oxidized aluminum alloy plate (Al-Si-Fe) (2 mm thick):

0.85

[0034]

5           In the case of energy exchange via radiation and  
absorption between different substances, the natural  
oscillation frequencies of the substances may not agree  
or may agree only partly. When the natural oscillation  
frequencies of two far-infrared radiating substances A  
10   and B do not agree, their integrated emissivity curves  
relative to wavelength do not agree except the  
intersection point of the curves as shown in the  
schematic diagram of Fig. 1. In the region where they do  
not agree, the far-infrared rays emitted from a far-  
15   infrared radiating substance A is only partly absorbed by  
the other far-infrared radiating substance B (when the  
integrated emissivity of one substance>the integrated  
emissivity of the other substance), or fill only part of  
the amount capable of being absorbed by the other  
20   substance (when the integrated emissivity of one  
substance<the integrated emissivity of the other  
substance). Based on this or on experience of the  
present inventors, it was inconceivable that a practical  
indoor radiation cooling system could be constructed,  
25   since such restrictive radiation and absorption between  
different substances would produce a lot of energy loss.  
Thus, unless the integrated emissivity curves of two far-  
infrared radiating substances agree even if their  
integrated emissivities of the two far-infrared radiating  
30   substances are high, the energy exchange between them was  
thought to be far too short of that between the same  
substances.

[0035]

35           Despite the above assumption, the present inventors  
continued to search a technology that permits efficient  
exchange of far-infrared ray energy between different  
substances. And finally, the present inventors have

found that if, in addition to the requirement (a) with regard to the surface (the cooling surface or heating surface) of an indoor surface-forming member including a far-infrared radiating substance B and a cooling source (or a heating source) including a far-infrared radiating substance A, the integrated emissivity of both materials is 0.70 or greater, the requirement (b) with regard to two materials on the cooling surface (or a heating source) of an indoor surface-forming member including a far-infrared radiating substance B and a cooling source (or a heating source) including a far-infrared radiating substance A, an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  in the operating temperature range of the system is 60% or greater of black-body radiation is satisfied, a practical indoor environment adjustment could be realized. Thus, the present inventors have found that, with regard to two materials on the surface (the cooling surface or heating surface) of an indoor surface-forming member including a far-infrared radiating substance B and a cooling source (or a heating source) including a far-infrared radiating substance A, an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  in the operating temperature range of the system is also important.

**[0036]**

This will be explained with reference to the schematic diagram in Fig. 2. Fig. 2 shows spectral emission spectra (spectral emission energy luminance) at 27°C for three substances A, B and C. Substance C is an ideal substance of black body having the maximum spectral emission energy luminance. Substances A and B are different substances, and have different spectral emission energy luminance curves, reflecting different natural oscillation frequencies. When substances A and B were allowed to exchange far-infrared rays between them,

the amount of energy that is transferred from one substance to the other may be expressed by the "effective radiation and absorption region between A and B" (Fig. 2) in which the spectral emission energy luminance curves of the two are overlapped. In accordance with the present invention, this "effective radiation and absorption region between A and B" is set as the "overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$ ". As used herein "an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  is 60% or greater of black-body radiation" means that the area of the "overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$ " corresponding to the "effective radiation and absorption region between A and B" is 60% or greater of the area inside the spectral emission energy luminance curve of black-body (substance C) in Fig. 2.

**[0037]**

As shown in Working Examples described below, for example, if the overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  between a material including the far-infrared radiating substance A and a material including the far-infrared radiating substance B of the present invention is 60% or greater, the sensible temperature will decrease (or increase) by 5-10°C at 10 minutes after the start of the experiment, providing a sufficient cooling (or warming) effect.

Specifically, in the system of the present invention, between a material including the far-infrared radiating substance A and a material including the far-infrared radiating substance B, it may be preferred that an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu\text{m}$  or a region sandwiching a wavelength region in which the emission energy (spectral emission energy luminance) from black body is at the maximum may be 60% or greater.

For the purpose of the present invention, the greater the above overlapping region, the better. Thus, as the overlapping region increases, for example, 70%, 80%, 85%, and 90% of black body radiation, the energy efficiency of the system of the present invention is enhanced.

**[0038]**

The spectral emission spectrum (spectral emission energy luminance) of a material including two different substances (substances A and B) for use in the present invention may be determined using, for example, a FT-IR spectroscopic method. According to the FT-IR spectroscopic method, the spectral emission spectrum of a far-infrared radiating substance at a temperature (operating temperature range) wherein the system of the present invention is active can be easily determined.

**[0039]**

As used herein, the far-infrared ray emission spectrum was measured by the following method. In the measurement, the shape and form of the sample is important, and it may be preferred that the physical condition of the sample is as close to that actually used in the system of the present invention as possible. In this measurement method, when a method of fixing the sample in a vertical direction is used, a powder sample cannot be subjected to measurement as it is. Thus, when substance A or B is a powder, and its emission characteristics per se is to be measured, the powder is directly press-formed (at a pressure of 100 kg/cm<sup>2</sup> or greater), or if it cannot be formed as it is, it may be diluted (at a concentration of 1 wt%) using KBr (manufactured by Merck, for infrared analysis) having a high transparency at the infrared region, mixed and press-formed (at a pressure of 100 kg/cm<sup>2</sup> or greater) to obtain a solid sample.

(1) Evaluation of emission characteristics

Instrument: FT-IR JIR-3505/Infrared radiation unit

IR-IRR200 manufactured by JEOL Ltd.

Resolution:  $16\text{ cm}^{-1}$

Cumulated No.: 200

Wavelength region measured:  $2200\text{--}500\text{ cm}^{-1}$  ( $4.5\text{--}20\text{ }\mu\text{m}$ )

5        Measurement temperature: about  $30\text{--}50^\circ\text{C}$  (standard  
40°C) at the surface of the sample

(2) Method of mounting a sample

i. Solid sample

10        An aluminum mirror is placed on the sample stage,  
and thereupon a solid sample in a plate form is placed  
and fixed with a jig (Fig. 3)

ii. Thin sample such as cloth and fabric

15        An aluminum plate is placed on the sample stage, and  
an aluminum mirror is placed in the center and fixed.

Thereupon, a stretchable thin sample (usually  $10\text{ }\mu\text{m}$  to  $3\text{ mm}$ ) is placed. While drawing so that the sample on the mirror may have a uniform temperature distribution, both ends are pressed with an aluminum plate, and fixed from above using an aluminum spacer (donut shape of  $30\text{ mm}\phi$ ;  $500\text{ mm}\phi$ ) (Fig. 4).

20        (3) Method of measuring the temperature of a sample

Thermocouple: T thermocouple ( $0.05\text{ mm}\phi$ ) manufactured by Ishikawa Sangyo Co., Ltd.

25        Recorder: Digital process reporter DPR330  
manufactured by Yamatake Honeywell Co., Ltd.

For temperature measurement, the thermocouple is fixed on the surface of the sample and an aluminum plate of the sample basecoat using Ag paste, and the bias setting of thermocouple is performed at the measurement temperature.

30        (4) Correction of environment radiation (background radiation)

By setting the reflectance of the aluminum mirror surface at 98%, and correction is made by subtracting the radiation luminance of the mirror surface itself (determined by calculating 2% of black body luminance at

35

the measuring temperature) from the radiation luminance of the aluminum mirror surface to obtain the environment radiation.

**[0040]**

5           Also, the area of the "overlapping region in the spectral emission energy (luminance) for wavelengths of 4.5 to 20  $\mu\text{m}$ " corresponding to the "effective radiation and absorption region between B and C" in Fig. 1 can be determined in the following manner. The spectral  
10          emission energy (luminance) curves of substance A and substance B are drawn on the same picture plane, and points on which both curves intersect in the measured wavelength region are set as P1, P2, P3, . . . Pn, and wavelengths corresponding to the respective points are set  
15          as  $\lambda_1$ ,  $\lambda_2$ ,  $\lambda_3$ , . . .  $\lambda_n$ . The spectral emission energy (luminance) for the lower line in the wavelength interval of adjoining two points are added, and the values obtained are added for all sections. By determining the  
20          ratio of the added value to the added value of emission energy (luminance) of black body for the same temperature and same interval, the integrated emissivity for the overlapping region of the spectral emission luminance of substance A and substance B can be determined.

**[0041]**

25           As used herein the "operating temperature range" is defined as the range of temperature that is observed in the system when the system is put into practical use. In the system of the present invention in which the indoor environment is adjusted by the exchange of far-infrared  
30          rays, the exchange of far-infrared rays takes place between the indoor surface-forming member such as the wall and the ceiling and the cooling source or heating source. More specifically, in the case of environment adjustment by the cooling effect, far-infrared rays  
35          radiated from substance B at the indoor surface-forming member side are absorbed by substance A at the cooling source side, and the oscillation energy level of

interatomic bonding within the substance that radiated  
transits to a lower level, thereby reducing the  
temperature of substance B at the radiation side  
(radiation cooling). In the case of environment  
5 adjustment by the heating effect, far-infrared rays  
radiated from substance A at the heating source side are  
absorbed by substance B at the indoor surface-forming  
member side, and the oscillation energy level of  
interatomic bonding within the substance that absorbed  
10 transits to a higher level, thereby increasing the  
temperature of substance B at the radiation side  
(radiation heating). As can be seen from this, in the  
system of the present invention, generally the lowest  
temperature (during heating) or the highest temperature  
15 (during cooling) during the practical use of the system  
is considered to be the temperature of the indoor  
surface-forming member (the temperature of the wall that  
is most vulnerable to the effect of external temperature)  
at the time of starting the system. The system of the  
20 present invention is used at various climatic conditions  
of external temperature from a frigid temperature of  
about -50°C to an extremely high temperature of about  
+50°C. Considering the possibility that the temperature  
of the indoor surface-forming member may be nearly equal  
25 to the external temperature depending on the climatic  
conditions, the operating temperature range of the system  
of the present invention may be assumed to be -50 to +  
50°C. During the practical use of the heat absorbing and  
radiating surface, the operating temperature range may be  
30 about 5-20°C during cooling and about 30-60°C during  
warming. The spectral emission spectra at wavelength of  
4.5-20  $\mu\text{m}$  of a material including the far-infrared  
radiating substance A and a material including the far-  
infrared radiating substance B at the operating  
35 temperature range do not vary greatly in this degree of  
temperature range, and thus in practical uses, for a

material including the far-infrared radiating substance A and a material including the far-infrared radiating substance B, the spectral emission spectrum of far-infrared ray emission at any temperature within the operating temperature range (-50 to + 50°C) may be measured and can be compared. Strictly, however, if the overlapping region of the spectral emission spectrum of far-infrared ray emission of a material including the far-infrared radiating substance A at a temperature within the operating temperature range and the spectral emission spectrum of far-infrared ray emission of a material including the far-infrared radiating substance B at a temperature within the operating temperature range is 60% or greater, the requirement (b) of the present invention can be satisfied.

**[0042]**

While the "far-infrared ray" generally means, as described above, an electromagnetic wave with a wavelength of about 3  $\mu\text{m}$  to 1000  $\mu\text{m}$ , the present invention focuses on far-infrared rays with a wavelength of 4.5 to 20  $\mu\text{m}$  (preferably 7-12  $\mu\text{m}$ ) as far-infrared ray in the operating temperature range. This is because, under the state of art technology, the wavelength at which the far-infrared ray emission characteristics of a substance in the ordinary temperature range can be stably measured is limited to this range, and the wavelength range in which the emission energy (spectral emission energy density) value from black body at ordinary temperature (about 27°C) is at the maximum is in this region sandwiching the wavelength of about 10  $\mu\text{m}$ , i.e. the wavelength range of 4.5-20  $\mu\text{m}$  (specifically, 7-12  $\mu\text{m}$ ) can be regarded as a region in which the emission energy of a far-infrared radiating substance other than black body is large. Based on this, in accordance with the present invention, the wavelength range in which the overlapping shared region of the far-infrared ray

emission side and the absorption side is 60% or greater of black body radiation is defined as 4.5-20  $\mu\text{m}$ .

**[0043]**

5 As used herein, as examples of combination of substance A and substance B included in a material that simultaneously satisfies the above requirements (a) and (b), there can be mentioned, for example,

A (or B): Porous alumina ( $\text{Al}_2\text{O}_3$ ) powder, integrated emissivity 0.91

10 B (or A): Silica ( $\text{SiO}_2$ ) powder, integrated emissivity 0.93

The integrated emissivity of the overlapping region of both spectral emission spectra 0.89 (thus, the overlapping shared region is 89% of black body radiation)

15 A (or B): Far-infrared ray emission ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ ) powder, integrated emissivity 0.94

B (or A): Silicon nitride ( $\text{Si}_3\text{N}_4$ ) powder, integrated emissivity 0.88

20 The integrated emissivity of the overlapping region of both spectral emission spectra 0.85 (thus, the overlapping shared region is 85% of black body radiation)

**[0044]**

25 On the other hand, as examples of combination of substance A and substance B included in a material that satisfies the above requirement (a) and does not satisfy the above requirement (b), there can be mentioned, for example,

A (or B): Sintered alumina substrate (0.6mm thick), integrated emissivity 0.72

30 B (or A): Polyester-based synthetic woven fabric, integrated emissivity 0.71

The integrated emissivity of the overlapping region of both spectral emission spectra 0.58 (thus, the overlapping shared region is 58% of black body radiation)

35 **[0045]**

As used herein the "indoor surface-forming member" refers to a member that forms an exposed surface of a

closed space which is the subject of environment adjustment. The closed space can have an opening-closing means such as a door and a window that permits communication of the inside and the outside. A  
5 representative example of a closed space is a room or hallway of a building where humans live and work, and besides there can be mentioned spaces for preserving or displaying articles (for example, a warehouse room, a  
10 showcase of commodities or display case for works of art), buildings for keeping animals including domestic animals, and spaces for moving bodies for transporting humans and goods (automobiles, railway vehicles, sea  
vessels, aircraft etc.) and the like. To name a few  
15 examples of houses where humans live, representative examples of the indoor surface-forming member are members (building materials) forming the wall surface, the ceiling surface, and floor surface. Openable and  
closable joinery (doors, paper doors, sliding doors, windows etc.) that are provided as part of the wall to  
20 separate the interior and the exterior of a room, partitions provided in a room and the like are also included in the indoor surface-forming member. Doors, sliding doors etc. for storage attached to a room are  
also included in the indoor surface-forming member. In a  
25 case where a section for storage attached to a room that is the subject of environment adjustment is of a structure that cannot be completely separated with a door or sliding door from the room, a member forming the  
surface of the storage section exposed to the room can  
30 also be included in the indoor surface-forming member.  
**[0046]**

The "cooling source" is a device for cooling the cooling surface exposed into a closed space (indoor  
space) which is to be the subject of environment  
35 adjustment by means of a medium flowing in a flow path formed therein. It may be, for example, a (radiation) heat absorbing device 110 having two groups of fins 115

and 116 extending in a vertical direction, as shown in a top plan view in (a) of Fig. 5 and in (b) of Fig. 5 which is a front view seen from the direction of an arrow 112 in (a) of Fig. 5. This device 110 is fixed to the floor surface 113 and the wall surface 114 of a room of which environment is to be adjusted by the system of the present invention. The heat absorbing device 110 having fins 115 and 116 can be fabricated with a metal or an alloy material having a favorable thermal conductivity such as aluminum, iron, copper and an alloy thereof, and may be provided with a water channel 115c (see Fig. 6) for allowing cold water to pass through it, and a plate-like part 115a surrounding the water channel 115c. On the surfaces of fins 115 and 116, there are provided a coating layer 115b formed with a coating material containing a far-infrared radiating substance B. A plurality of fins 115 and 116 are disposed at an oblique angle ( $45^\circ$  in this example) relative to the wall surface 114. This angle can be selected from the range of  $15^\circ$  to  $75^\circ$ . In this example, the surfaces of fins 115 and 116 form the cooling surface. As shown in (b) of Fig. 5, cold water is supplied by a water-supply pipe 117 that penetrates the upper part of the fins 115 and 116. Water that cools the cooling surface and that itself is warmed while it passes through the water channel 115c (Fig. 6) inside the fins 115 and 116 can be recycled to a cold water-generating device (not shown) through a water discharge pipe 118 that penetrates the lower part of the fins 115 and 116. Both sides of the water-supply pipe 117 and a water-discharge pipe 118 are supported by support pillars 119 and 120. Water drops generated on the cooling surface by dew condensation since the temperature of the cooling surface became lower than the dew point of indoor air are collected by allowing it to drop into a drainpipe 121 and can be discharged outdoors through a water-discharge pipe 122.

**[0047]**

The heat absorbing device 110 can be made a heat radiating device by replacing cold water with warm water, and can also be used as a heating source. The surfaces of fins 115 and 116 exposed to the closed space (indoor space) which is the subject of environment adjustment become a heating source. As the heating source, devices that heat the heating surface by using a heat medium such as oil and ethylene glycol in stead of warm water, electricity or a hot air (combustion heat) can also be used.

**[0048]**

The cooling surface of a cooling source (the heating surface of a heating source) and the surface (exposed surface) of an indoor surface-forming member may each be formed with a material including a far-infrared radiating substance A and a far-infrared radiating substance B which are different from each other.

**[0049]**

In order to form the surface (exposed surface) of the indoor surface-forming member with a material containing the far-infrared radiating substance B, the indoor surface-forming member may be produced with the far-infrared radiating substance B or a material in which the far-infrared radiating substance B is mixed, or a material on which surface a coating comprising the far-infrared radiating substance B is formed.

**[0050]**

On the other hand, in order to construct the cooling surface of a cooling source with a material including the far-infrared radiating substance A, it may be preferred to form a coating with the material including the far-infrared radiating substance A on the surface involved in the radiation/absorption of far-infrared rays of the cooling source. This coating may, for example, be formed by applying (applying a solvent-type coating material or applying a powder-type coating

material without using a solvent) a coating material including the far-infrared radiating substance A onto the substrate of the surface. When the substrate is a metal, a metal oxide coating can be formed by an anode oxidation treatment etc. Alternatively, other suitable technologies for forming coating, for example the PVD technology such as thermal spraying and vapor deposition or the CVD technology can also be used. Similar technologies can also be used in forming the heating surface of a heating source with a material including the far-infrared radiating substance A when a heating source and a cooling source are separately provided.

**[0051]**

The radiation and absorption of far-infrared rays becomes most efficient when two substances that exchange far-infrared rays are facing directly opposite to each other. Thus, in accordance with the system of the present invention, it may be preferred that both of the far-infrared radiating substance A of the cooling surface of a cooling source (or the heating surface of a heating source) and the far-infrared radiating substance B of the indoor surface-forming member are exposed to indoor space. However, it is not necessary that the far-infrared radiating substances A and B are coated with a coating (protective layer) of a material having high transparency to far-infrared rays, said coating formed with a thickness that does not significantly prevent the radiation or absorption of the far-infrared rays, for example, to prevent the detachment thereof. Thus, the cooling surface (or the heating surface) including the far-infrared radiating substance A of the cooling source (or the heating source) or a surface including the far-infrared radiating substance B of the indoor surface-forming member may be coated with a coating film, a varnish layer, a wall paper or the like with a suitable thickness. While the thickness may differ with the application method, it may be 500  $\mu\text{m}$  or less, about 10-

100  $\mu\text{m}$  when applied by the spray method, and preferably  
15-50  $\mu\text{m}$ . When a sheet or a plate including the far-  
infrared radiating substance A or B is formed without  
using the application method, it may usually be selected  
5 from about 0.5-5 mm.

**[0052]**

In accordance with the system of the present  
invention, far-infrared rays are exchanged between the  
substances facing opposite to each other. By the  
10 radiation and absorption of far-infrared rays based on  
the transition of (molecular) vibration of interatomic  
bonding within the substances facing opposite to each  
other across a space, rapid (close to the velocity of  
light) heat transfer occurs. The greater the temperature  
15 difference between the two substances and the greater the  
difference in the amount of both of the facing (exposed)  
substances is, the greater the amount of heat transferred  
becomes. The exposed surface of the indoor surface-  
forming member of the system of the present invention can  
20 be formed so as to include 100% of the far-infrared  
radiating substance B by forming it with a stone material  
including the far-infrared radiating substance B. Also,  
the cooling surface of a cooling source (or the heating  
surface of a heating source) of the system of the present  
25 invention can also be formed so as to include 100% of the  
far-infrared radiating substance A by forming it by  
thermal spraying powders of a stone material including  
the far-infrared radiating substance A onto the surfaces  
of fins 115 and 116 of the heat absorbing device 110 in  
30 (a) and (b) of Fig. 5.

**[0053]**

It was surprisingly found that whether or not the  
indoor environment adjustment system of the present  
invention can be put into practical use greatly depends  
35 on the area of the surface of the indoor surface-forming  
member including the far-infrared radiating substance B,  
and furthermore on the area of the cooling surface of a

cooling source (or the heating surface of a heating source), in addition to the amount (combined amount) of the far-infrared radiating substances A and B. It was found that when the area of the surface of the indoor surface-forming member including the far-infrared radiating substance B is greater than a given amount, even if the concentration of the far-infrared radiating substance B included in the surface of the indoor surface-forming member is low, a practical indoor environment adjustment system can be realized. Conversely, it was found that unless the area of the surface of the indoor surface-forming member including the far-infrared radiating substance B is greater than a given amount, even if the concentration of the far-infrared radiating substance B included in the surface of the indoor surface-forming member is high, a practical indoor environment adjustment system cannot be realized. The area of the surface of the indoor surface-forming member including the far-infrared radiating substances required to realize this practical indoor environment adjustment system depends mainly on the floor area. Thus, in the case of a room with a ceiling height of 2.5-3 m, for example, the area of the surface of the indoor surface-forming member including the far-infrared radiating substance B may preferably be 0.05 times or greater of the floor area forming the indoor space. A more preferred area is 0.3 times or greater of a floor area forming the indoor space, more preferably 0.8 times or greater. Depending on the interior and exterior environment (an extremely hot area, a conventional home, an office, a store, a beauty parlor etc.) or the height of the ceiling etc., 1.5 times or greater, furthermore 2.0 times or greater may be preferred depending on the structure such as the height of the ceiling. Practically, the system of the present invention can also be applied to indoor spaces having a high ceiling and a very large space volume such as a factory building, a

sports facility, and a theater hall. In such large space buildings, the increase ratio of the area of indoor surface compared to the increase ratio of the volume is small, and thus the advantages of the present invention of the subject of energy exchange become enhanced. The indoor surface-forming member (represented by the wall and the ceiling) may include the far-infrared radiating substance B in all or only a part of the surface thereof. For example, the far-infrared radiating substance B may be included in all or a part of the ceiling surface, or in all or only a part of the wall surface, or these may be combined.

**[0054]**

With regard to the floor area of an indoor space, while the floor area of a close space can be easily calculated, small openings that are negligible from the viewpoint of cooling should be disregarded when there is an opening at a part of the space, and the indoor floor area can be calculated,.

**[0055]**

On the other hand, while the area of the cooling surface including the far-infrared radiating substance A of a cooling source (or the heating surface of a heating source) is not so important as that of the surface of the indoor surface-forming member including the far-infrared radiating substance B, generally it may be efficient and preferred that the area is smaller than that of the surface of the indoor surface-forming member including the far-infrared radiating substance B. The area of a standard room being 0.5 times or smaller, even 0.4 times or smaller the area of the surface of the indoor surface-forming member including the far-infrared radiating substance B, is sufficient, but in a room having many heat sources, 0.5 times or greater, for example 0.8 times or smaller, may be preferred. While the lower limit may depend on the type and concentration of the far-infrared radiating substance A, generally it may be 0.15 times or

greater the area of the surface of the indoor surface-forming member including the far-infrared radiating substance B, preferably 0.2 times or greater, and more preferably 0.3 times or greater. That the area of the cooling surface including the far-infrared radiating substance A of a cooling source (or the heating surface of a heating source) can be made smaller than the area of the surface of the indoor surface-forming member including the far-infrared radiating substance B, and conversely that the area of the cooling surface including the far-infrared radiating substance B of a cooling source (or the heating surface of a heating source) can be made greater than the area of the cooling surface including the far-infrared radiating substance A of a cooling source (or the heating surface of a heating source) make an important contribution to achieving the effect of the present invention. That not only the far-infrared radiating substance A of the cooling surface of a cooling source (or the heating surface of a heating source) but also the far-infrared radiating substance B resonating therewith included in the surface of the indoor surface-forming member function indirectly as a cooling source (heating source) is considered a reason why the marked performance and the efficiency of the indoor environment adjustment can be achieved as compared to the conventional cooling surface (or the heating source). Thus, when the requirement (b) can be satisfied by the resonance of the far-infrared radiating substance A of the cooling surface of a cooling source (or the heating surface of a heating source) and the far-infrared radiating substance B of the surface of the indoor surface-forming member, thereby remarkably enhancing the performance and efficiency of the indoor space adjustment, even if the far-infrared radiating substance A of the cooling surface of a cooling source (or the heating surface of a heating source) and the far-infrared radiating substance B of the surface of the indoor

surface-forming member are not identical, it may be thought to be why an effect equal to that in the case of the identical far-infrared radiating substances can be exhibited.

5     **[0056]**

Since the concentration of the far-infrared radiating substances A and B defines the amount of energy with which an effective exchange of far-infrared rays occurs between the substances A and B facing opposite to each other, they are important. For example, when the far-infrared radiating substance B is contaminated into the exposed surface of an indoor surface-forming member, the addition of only 0.5 wt% of solids of the coating material can give a sufficient effect though it also depends on the type of the far-infrared radiating substances A and B. The amount of the far-infrared radiating substance B included in the exposed surface of the indoor surface-forming member may usually be 0.1-100 wt%, preferably 0.5-20 wt% of solids of the exposed surface substrate. When the concentration of the far-infrared radiating substance B is too low, the amount of heat transfer with the cooling surface (or heating surface) may decrease, thereby reducing the cooling (or heating) efficiency, whereas when the concentration is high, it may gradually become less economical though the performance may be excellent. Also, when the far-infrared radiating substance A is included in the cooling surface of a cooling source (or the heating surface of a heating source), the addition of only 1 wt% of solids of the coating material can give a sufficient effect. The amount of the far-infrared radiating substance A forming the cooling surface of a cooling source (or the heating surface of a heating source) may usually be 0.1-100 wt%, preferably 0.5-20 wt% of solids of the exposed surface substrate. When the concentration of the far-infrared radiating substance A is too low, the amount of heat transfer with the indoor surface-forming member may

decrease, thereby reducing the cooling (or heating) efficiency, whereas when the concentration is high, it may make the production of the cooling surface difficult or gradually become less economical, though the  
5 performance may be excellent. However, since the preferred concentration of the far-infrared radiating substances A and B also depends on such factors as the type and form of the far-infrared radiating substances A and B, the type of the substrate, the method of mixing  
10 the far-infrared radiating substances A and B and their thickness, the above ranges are not limiting. In the anode oxide coating, thermal spray coating etc. formed on the surface of the substrate, a metal material, the concentration of the far-infrared radiating substance can  
15 be considered to be 100%.

The additive rate of the far-infrared radiating substance A to the cooling surface (or the heating surface), i.e. a heat absorbing surface (or a heat radiating surface), or the total weight (strictly, the  
20 number of molecules) thereof on the surface is theoretically the most important factor. Because the total amount of energy absorbed by the above surface and emitted from the indoor surface is defined by a) the total area of the cooling surface (or the heating  
25 surface), b) the effective emissivity between the above surface and the indoor surface (ratio of the overlapping region of the spectral emission curve relative to black body), and c) the difference in the temperature of both surfaces. The total weight of the far-infrared radiating  
30 substance B disposed on the surface of the indoor surface-forming member is greater than that of the far-infrared radiating substance A usually disposed on the cooling surface (or the heating surface). When the weight ratio is very large (for example, 10 times or  
35 greater), the additive rate of the far-infrared radiating substance B disposed on the surface of the indoor surface-forming member can be made smaller than that of

the far-infrared radiating substance A, or the ratio of the indoor surface-forming member in which the far-infrared radiating substance B is disposed to the total area of the indoor surface-forming member can be  
5 decreased. Thus, the additive rate of the far-infrared radiating substances A and B disposed on the cooling surface (or the heating surface) and the surface of the indoor surface-forming member may preferably be  $A > B$ .

**[0057]**

10 In the system of the present invention, the cooling source (or the heating source) including the far-infrared radiating substance A on the cooling surface (or the heating surface) and the indoor surface-forming member including the far-infrared radiating substance B may  
15 preferably be in the same room. This is because the system of the present invention utilizes exchange via the radiation and absorption of far-infrared rays between the cooling surface (or the heating surface) and the indoor surface-forming member facing opposite to each other, and  
20 the maximum effect can be obtained when they are present in the same room. However, if the exchange of far-infrared rays between the exposed surface of the indoor surface-forming member including the far-infrared radiating substance B in a room different from the room  
25 which a cooling source (or a heating source), as described in Patent Literatures 1 and 2, has been installed and the cooling surface of the cooling source (or the heating surface of the heating source) can be achieved [e.g., a case in which there is direct exchange  
30 of far-infrared rays between the wall including the far-infrared radiating substance B in the other room and the cooling surface of the cooling source (or the heating surface of the heating source), a case in which, even if there is no direct exchange of far-infrared rays between  
35 the wall including the far-infrared radiating substance B in the other room and the cooling source (or the heating source), there is indirect exchange of far-infrared rays

between the two by the action of the far-infrared radiating substance B included in the wall surface at a site that can be clearly viewed by the two, etc.], the environment adjustment effect by the system of the present invention can be extended to the other room. Therefore, the indoor surface-forming member including the far-infrared radiating substance B on the exposed surface can be said to be present at all the rooms that are the subject of adjustment.

That the surface of the indoor surface-forming member that is not facing opposite to the cooling surface (or the heating surface) is also involved in the transfer of thermal energy via the radiation and absorption of far-infrared rays, with a result that the original difference in temperature between the two can be reduced is considered to be due to the following physical optical mechanisms:

1) When there is a temperature difference between the cooling surface (or the heating surface) and the surface of the indoor surface-forming member facing directly opposite to each other, the transfer of thermal energy occurs depending on the temperature difference  $\Delta T$ , the effective integrated emissivity of the two, the surface area of the two, and the amount of the far-infrared radiating substances A and B present in the vicinity of the surface of the two, thereby reducing the temperature at the high temperature side (the emission side) and increasing the temperature at the low temperature side (the absorption side) [primary absorption and radiation].

2) At the cooling surface (or the heating surface) side, rapid thermal transfer occurs by the cold (or warm) thermal medium flowing therein, and returns to the originally set temperature, thereby maintaining the temperature difference from the surface of the indoor surface-forming member.

3) When the primary absorption and radiation caused

a temperature difference between the indoor surface-forming members, energy transfer immediately occurs by the radiation and absorption of far-infrared rays, thereby canceling the temperature difference [secondary absorption and radiation].

4) The [secondary absorption and radiation] of 3) also occurs even between the cooling surface (or the heating surface) and the surface of the indoor surface-forming member that is not facing directly opposite to each other, thereby increasing or reducing the surface temperature of the indoor surface-forming member that is not facing directly opposite to the cooling surface (or the heating surface) in the same room.

5) As a result of the [secondary absorption and radiation] phenomenon, the temperature of the surface of the indoor surface-forming members in the same room becomes identical, and quickly becomes the predetermined temperature, thereby achieving the indoor comfort. The thermal energy transfer rate in the [primary absorption and radiation] and the [secondary absorption and radiation] phenomena is almost equal to the velocity of light, and it is an momentary event in terms of time even if it passes through multistages. However, change in the surface temperature by about 10°C of the indoor surface-forming member actually takes about 10 minutes, and the time required to reduce the temperature difference from the temperature of the cooling surface (or the heating surface) depends greatly on the properties of far-infrared ray absorption and radiation of the far-infrared radiating substances A and B disposed on the surfaces of the two, the heat insulating property of the substrate of the indoor surface-forming member, and the density and thickness of the surface layer including the far-infrared radiating substance B.

6) The temperature of the surface of the indoor surface-forming member partitioned by a screen (for example, a paper door, a sliding door, a partition, a

curtain, a glass door, etc.) that is slightly transparent to far-infrared rays is also accompanied by a slight delay or temperature difference depending on the amount transmitted, but it finally reaches the same state.

5           7) There is no direct exchange of energy by far-infrared rays between the far-infrared radiating substance B disposed on the surface of the indoor surface-forming member in another room partitioned by a screen (for example, a door, a double sliding door, a  
10           partition made of metal, etc.) impervious to far-infrared rays and the far-infrared radiating substance A disposed on the surface of the cooling surface (or the heating surface). But, once these screens are removed, the exchange of thermal energy instantly occurs by the  
15           primary or secondary absorption and radiation mechanism, thereby canceling the temperature difference between the two surfaces. [Tertiary absorption and radiation] The time required to reduce the temperature difference between the surfaces of the indoor surface-forming member  
20           is influenced by the far-infrared ray absorption and radiation property and thickness of the indoor surface-forming member, thermal characteristics of the substrate and the surface material, and the amount of the incoming and outgoing heat from the outdoor environment in the  
25           other room.

          8) There is no direct exchange of energy by far-infrared rays between the surface of the indoor surface-forming member in another room partitioned by the wall from the room where the cooling surface (or the heating  
30           surface) was disposed and the cooling surface (or the heating surface). But since paper, wood, synthetic resins, inorganic building materials, glass etc. are materials that absorb or radiate far-infrared rays thereby to increase or reduce the temperature, there is a  
35           slight energy exchange via these wall materials. Therefore, they are not completely unrelated to the mechanism and effect of the present invention, though the

time required to cancel the temperature difference may differ depending on the absorption and radiation characteristics thereof to far-infrared rays, and density and thickness of these materials.

5           As described above, as compared to the conventional indoor environment adjustment system that controls the air temperature and humidity of an indoor space, the present invention focuses on the transfer of thermal energy at the level of light velocity via the absorption and radiation of infrared rays between substances, and  
10           investigated the radiation characteristics of far-infrared radiating substances disposed on the cooling surface (or the heating surface) provided indoors and on the surface of the indoor surface-forming member, their  
15           amount and the effective area responsible for the exchange of thermal energy, and have achieved an indoor environment adjustment system that has excellent comfort and high energy efficiency.

#### EXAMPLES

#### 20    [0058]

Experimental conditions in the following Working Examples 1 to 7 and Comparative Examples 1 to 3 are as follows:

25           To five surfaces except the floor surface of a room with a width of 2.5 m, a depth of 1.5 m and a height of 2.2 m, a 30 mm urethane foam insulating plate (lined with aluminum foil) was stuck, and 5 to 10 samples 1 (1 m × 1 m) comprising a material including a far-infrared radiating substance B used in Working Examples and  
30           Comparative Examples were provided thereon. On the other hand, for the floor surface, samples 2 comprising a material including a far-infrared radiating substance A were mounted on a heat radiating/absorbing device (a heating/cooling plate) having a 2 m<sup>2</sup> of a radiating and  
35           absorbing surface. After the surface temperature of the sample 2 comprising the far-infrared radiating substance A on the heat radiating/absorbing device reached a

predetermined temperature, a heat insulating material (an aluminum-vapor deposited foamed polyethylene sheet) that had been provided to block the transfer of radiation energy between the sample 1 and the sample 2 was removed. Then, changes with time in the surface temperature of the samples 1 and samples 2 disposed in various places in the room, indoor air temperature, sensible temperature in the room, and temperature felt to the experimenter were measured. Methods of measuring each temperature were as follows:

1) Surface temperature: The apical part of a K thermocouple with a line diameter of 0.3 mm was stuck to the surface of the sample using an aluminum adhesive tape (10 mm × 10 mm × 0.1 mm).

2) Indoor air temperature: The apical part of a K thermocouple with a line diameter of 0.3 mm was sandwiched between two insulating adhesive tapes (4 mm × 8 mm × 0.1 mm), which was further sandwiched between two adhesive tapes (10 mm × 10 mm × 0.1 mm), and then mounted at a predetermined position in the indoor space with a support pillar.

3) Sensible temperature in the room: The apical part of a K thermocouple with a line diameter of 0.3 mm was sandwiched between two insulating black body adhesive tapes (10 mm × 10 mm × 0.1 mm), and then mounted at a predetermined position in the indoor space with a support pillar.

4) Temperature felt to the experimenter: "Comfortable sensation" felt by the experimenter or the observer of the experiment in the room was evaluated at 5 ranks of A (comfortable), B (slightly comfortable), C (usual), D (less comfortable), and E (uncomfortable).

[0059]

Working Example 1

A: Integrated emissivity of an anode oxidation treated Al-Si-Fe-based aluminum alloy plate (thickness: 2

mm, oxide coating: 20  $\mu$ m): 0.87

B: Integrated emissivity of a polyester synthetic  
fiber fabric into which far-infrared radiating ceramics  
( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder was kneaded to 10 wt% and  
5 spun: 0.93

Integrated emissivity of the overlapping region of  
both spectral emission spectra: 0.87 (i.e., the  
overlapping shared region is 87% of black body radiation)

These spectral emission spectra are shown in Fig. 7.  
10 When the side of the material including a far-infrared  
radiating substance A is set at 40°C and the side of the  
material including a far-infrared radiating substance B  
is set at 15°C, changes in surface temperature at the side  
of the material including the far-infrared radiating  
15 substance B after removing the screen between the two  
were as follows:

1 minute later: 17°C (+2°C)

3 minutes later: 20°C (+5°C)

5 minutes later: 22°C (+7°C)

20 10 minutes later: 24°C (+9°C)

A sufficient warm sensation was obtained at a  
sensible temperature of 17°C→27°C (+10°C).

The temperature felt: Rating A

**[0060]**

25 Working Example 2

A: Integrated emissivity of an alumite-treated Al-  
Si-Fe-based aluminum alloy plate (thickness: 2 mm, oxide  
coating: 20  $\mu$ m): 0.87

B: Integrated emissivity of a polyester synthetic  
30 fiber fabric: 0.71

Integrated emissivity of the overlapping region of  
both spectral emission spectra: 0.71 (i.e., the  
overlapping shared region is 71% of black body radiation)

These spectral emission spectra are shown in Fig. 8.  
35 When the side of the material including a far-infrared

radiating substance A is set at 40°C and the side of the material including a far-infrared radiating substance B is set at 15°C, changes in surface temperature at the side of the material including a far-infrared radiating substance B after removing the screen between the two were as follows:

1 minute later: 16°C (+1°C)

3 minutes later: 18°C (+3°C)

5 minutes later: 20°C (+5°C)

10 minutes later: 22°C (+7°C)

A satisfactory warm sensation was obtained at a sensible temperature of 17°C→25°C (+8°C).

The temperature felt: Rating A

[0061]

Working Example 3

A: Integrated emissivity of an alumite-treated Al-Si-Fe-based aluminum alloy plate (thickness: 2 mm, oxide coating: 20 μm): 0.87

B: Integrated emissivity of an alumina sintered substrate (thickness: 0.6 mm): 0.72

Integrated emissivity of the overlapping region of both spectral emission spectra: 0.69

These spectral emission spectra are shown in Fig. 9. When the side of the material including a far-infrared radiating substance A is set at 40°C and the side of the material including a far-infrared radiating substance B is set at 15°C, changes in surface temperature at the side of the material including a far-infrared radiating substance B after removing the screen between the two were as follows:

1 minute later: 16°C (+1°C)

3 minutes later: 18°C (+3°C)

5 minutes later: 20°C (+5°C)

10 minutes later: 22°C (+7°C)

A satisfactory warm sensation was obtained at a

sensible temperature of  $17^{\circ}\text{C} \rightarrow 25^{\circ}\text{C}$  ( $+8^{\circ}\text{C}$ ).

The temperature felt: Rating A

[0062]

Working Example 4

5           A: Integrated emissivity of an alumite-treated ordinary (2S) aluminum plate (thickness: 2 mm, oxide coating: 20  $\mu\text{m}$ ): 0.77

          B: Integrated emissivity of a polyethylene sheet (thickness: 1 mm) into which a far-infrared radiating ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder was added to 10% : 0.83

10           These spectral emission spectra are shown in Fig. 10. When the side of the material including a far-infrared radiating substance A is set at  $40^{\circ}\text{C}$  and the side of the material including a far-infrared radiating substance B is set at  $15^{\circ}\text{C}$ , changes in surface temperature at the side of the material including a far-infrared radiating substance B after removing the screen between the two were as follows:

          1 minute later:  $16^{\circ}\text{C}$  ( $+1^{\circ}\text{C}$ )  
20           3 minutes later:  $19^{\circ}\text{C}$  ( $+4^{\circ}\text{C}$ )  
          5 minutes later:  $20^{\circ}\text{C}$  ( $+6^{\circ}\text{C}$ )  
          10 minutes later:  $23^{\circ}\text{C}$  ( $+8^{\circ}\text{C}$ )

A sufficient warm sensation was obtained at a sensible temperature of  $17^{\circ}\text{C} \rightarrow 25^{\circ}\text{C}$  ( $+9^{\circ}\text{C}$ ).

25           The temperature felt: Rating A

[0063]

Working Example 5

          A: Integrated emissivity of a far-infrared radiating ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based)-coated stainless plate (SUS304) (thickness: 2 mm): 0.80

30           B: Integrated emissivity of a polyethylene sheet (thickness: 1 mm) into which a far-infrared radiating ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder was added to 10 wt%: 0.83

35           Integrated emissivity of the overlapping region of both spectral emission spectra: 0.79 (i.e., the

overlapping shared region is 79% of black body radiation)

These spectral emission spectra are shown in Fig.

11. When the side of the material including a far-infrared radiating substance A is set at 40°C and the side of the material including a far-infrared radiating substance B is set at 15°C, changes in surface temperature at the side of the material including a far-infrared radiating substance B after removing the screen between the two were as follows:

1 minute later: 16°C (+1°C)

3 minutes later: 19°C (+4°C)

5 minutes later: 20°C (+5°C)

10 minutes later: 23°C (+8°C)

A sufficient warm sensation was obtained at a sensible temperature of 17°C→26°C (+9°C).

The temperature felt: Rating A

**[0064]**

Working Example 6

A: Integrated emissivity of anode oxidation treated Al-Si-Fe-based aluminum alloy plate (thickness: 2 mm): 0.87

B: Integrated emissivity of a synthetic fiber fabric into which a far-infrared radiating ceramics ( $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ -based) powder was kneaded to 10 wt% and spun: 0.93

Integrated emissivity of the overlapping region of both spectral emission spectra: 0.87 (i.e., the overlapping shared region is 87% of black body radiation)

These spectral emission spectra are shown in Fig. 7. When side A is set at 12°C and side B is set at 32°C, changes in surface temperature at side B after removing the screen between the two were as follows:

1 minute later: 32°C (-1°C)

3 minutes later: 30°C (-2°C)

5 minutes later: 29°C (-3°C)

10 minutes later: 28°C (-4°C)

A sufficient cool sensation and comfortable sensation were obtained at a sensible temperature of  $33^{\circ}\text{C} \rightarrow 28^{\circ}\text{C}$  ( $-5^{\circ}\text{C}$ ).

The temperature felt: Rating A

5     **[0065]**

Working Example 7

A: Integrated emissivity of a silicon nitride ( $\text{Si}_3\text{N}_4$ )/silicon carbide ( $\text{SiC}$ ) composite ceramics plate (thickness: 3 mm): 0.82

10     B: Integrated emissivity of a low-density polyethylene sheet (thickness: 1 mm): 0.76

Integrated emissivity of the overlapping region of both spectral emission spectra: 0.73 (i.e., the overlapping shared region is 73% of black body radiation)

15     These spectral emission spectra are shown in Fig.

12. When side A is set at  $12^{\circ}\text{C}$  and side B is set at  $32^{\circ}\text{C}$ , changes in surface temperature at side B after removing the screen between the two were as follows:

1 minute later:  $31.5^{\circ}\text{C}$  ( $-0.5^{\circ}\text{C}$ )

20     3 minutes later:  $31^{\circ}\text{C}$  ( $-1^{\circ}\text{C}$ )

5 minutes later:  $30^{\circ}\text{C}$  ( $-2^{\circ}\text{C}$ )

10 minutes later:  $29^{\circ}\text{C}$  ( $-3^{\circ}\text{C}$ )

A satisfactory comfortable sensation was obtained at a sensible temperature of  $33^{\circ}\text{C} \rightarrow 29^{\circ}\text{C}$  ( $-4^{\circ}\text{C}$ ).

25     The temperature felt: Rating A

**[0066]**

Comparative Example 1

A: Integrated emissivity of an alumite treated Al-Si-Fe-based aluminum alloy plate (thickness: 2 mm): 0.87

30     B: Integrated emissivity of a polyethylene sheet (thickness: 1 mm): 0.36

Integrated emissivity of the overlapping region of both spectral emission spectra: 0.36 (i.e., the overlapping shared region is 36% of black body radiation)

35     These spectral emission spectra are shown in Fig.

14. When the side of the material including a far-

infrared radiating substance A is set at 40°C and the side of the material including a far-infrared radiating substance B is set at 15°C, changes in surface temperature at the side of the material including a far-infrared radiating substance B after removing the screen between the two were as follows:

1 minute later: 15°C (+0°C)  
3 minutes later: 16°C (+1°C)  
5 minutes later: 18°C (+3°C)  
10 minutes later: 19°C (+4°C)  
Little warm sensation was obtained at a sensible temperature of 17°C→21°C (+4°C).

The temperature felt: Rating C to D

[0067]

Comparative Example 2

A: Integrated emissivity of a black-coated stainless plate (SUS304) (thickness: 2 mm): 0.39

B: Integrated emissivity of a low-density polyethylene sheet (thickness: 1 mm): 0.36

Integrated emissivity of the overlapping region of both spectral emission spectra: 0.32 (i.e., the overlapping shared region is 32% of black body radiation)

These spectral emission spectra are shown in Fig. 15. When the side of the material including a far-infrared radiating substance A is set at 40°C and the side of the material including a far-infrared radiating substance B is set at 15°C, changes in surface temperature at the side of the material including a far-infrared radiating substance B after removing the screen between the two were as follows:

1 minute later: 15.2°C (+0.2°C)  
3 minutes later: 15.5°C (+0.5°C)  
5 minutes later: 16.2°C (+1.2°C)  
10 minutes later: 17.0°C (+2.0°C)  
Little warm sensation was obtained at a sensible

temperature of 17°C→20°C (+3°C).

The temperature felt: Rating D

#### INDUSTRIAL APPLICABILITY

##### [0068]

5 The present invention can be widely used to adjust the  
environments of rooms or spaces in construction or  
architectural fields that provide various rooms and  
facilities in which humans live or are active, rooms for  
storage of articles (for example, warehouse rooms) or  
10 spaces for display (for example, showcases).

#### REFERENCE SIGNS LIST

##### [0069]

110: Heat absorbing device  
113: Floor surface  
15 114: Wall surface  
115, 116: Fin  
115c: Water channel

What is claimed is:

1. An indoor environment adjustment system wherein the cooling surface of a cooling source is exposed in an indoor space and are constructed from a material including a far-infrared radiating substance A, the exposed surface of an indoor surface-forming member in the indoor space is constructed from a material including a far-infrared radiating substance B having a different type of molecule from the far-infrared radiating substance A, the cooling source is a device for cooling the cooling surface by means of a medium flowing in a flow path formed therein, the integrated emissivity of the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B is 0.70 or greater in the wavelength range of 4.5 to 20 $\mu$ m, and with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, an overlapping region in the spectral emission spectrum for wavelengths of 4.5 to 20  $\mu$ m in the operating temperature range of the system is 60% or greater of black-body radiation.

2. The indoor environment adjustment system according to claim 1, wherein with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, the overlapping region in the spectral emission spectrum for wavelengths of 7 to 12  $\mu$ m is 60% or greater of black-body radiation.

3. The indoor environment adjustment system according to claim 1 or 2, wherein with regard to the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B, the overlapping region is 70% or greater of black-body radiation.

4. The indoor environment adjustment system according to any one of claims 1 to 3, wherein the overlapping region is 80% or greater of black-body radiation.

5           5. The indoor environment adjustment system according to any one of claims 1 to 4, wherein the integrated emissivity of the material including the far-infrared radiating substance A and the material including the far-infrared radiating substance B is 0.80 or  
10 greater.

6. The indoor environment adjustment system according to any one of claims 1 to 5, wherein 0.1-100 wt% of the far-infrared radiating substance B is present in the material forming the exposed surface of an indoor  
15 surface-forming member.

7. The indoor environment adjustment system according to any one of claims 1 to 6, wherein 0.1-100 wt% of the far-infrared radiating substance A is present in the material forming the cooling surface of the  
20 cooling source.

8. The indoor environment adjustment system according to any one of claims 1 to 7, wherein the area of the indoor surface-forming member constructed from the material including the far-infrared radiating substance B is at least 0.05 times the total floor area of the space  
25 of which environment is to be adjusted.

9. The indoor environment adjustment system according to any one of claims 1 to 8, wherein the area of the indoor surface-forming member constructed from the material including the far-infrared radiating substance B is at least 0.3 times the total floor area of the space  
30 of which environment is to be adjusted.

10. The indoor environment adjustment system according to any one of claims 1 to 9, wherein the area  
35 of the cooling surfaces including the far-infrared radiating substance B of the cooling source is not greater than 0.5 times the area of the indoor surface-

forming member constructed from the material including the far-infrared radiating substance B.

5        11. The indoor environment adjustment system according to any one of claims 1 to 10, wherein the area of the cooling surfaces including the far-infrared radiating substance B of the cooling source is 0.2-0.5 times the area of the indoor surface-forming member constructed from the material including the far-infrared radiating substance B.

10        12. The indoor environment adjustment system according to any one of claims 1 to 11, wherein the cooling source also serves as a heating source that utilizes the cooling surface as the heating surface by heating the cooling surface by means of a medium flowing  
15 in a flow path formed therein.