

DESCRIPTION

TITLE

RADIATION COOLING STRUCTURE AND METHOD FOR MANUFACTURING SAME

5

TECHNICAL FIELD

[0001]

The present invention relates to a radiation cooling structure and a method for manufacturing the same.

10

BACKGROUND ART

[0002]

A radiation cooling structure including a reflective layer and a resin layer for infrared radiation provided on the reflective layer is known. For example, Patent Document 1 discloses a radiation cooling structure including a reflective layer made of silver or a silver alloy and a resin layer made of a vinyl chloride resin or a vinylidene chloride resin.

15

CITATION LIST

PATENT DOCUMENTS

20 [0003]

Patent Document 1: Japanese Patent No. 6890724

SUMMARY OF THE INVENTION

[0004]

25 The present invention is directed to a radiation cooling structure comprising: a

reflective layer and a transparent protective layer provided on the reflective layer, wherein an uneven surface with a plurality of raised portions each different in size is formed on the protective layer.

[0005]

5 The present invention is directed to a method for manufacturing a radiation cooling structure comprising: a reflective layer and a transparent protective layer provided on the reflective layer, where an uneven surface with a plurality of raised portions each different in size is formed on the protective layer, wherein the plurality of raised portions are solidified products obtained by forming a plurality of droplets of a liquid resin on the protective layer and
10 then solidifying the plurality of droplets.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006]

FIG. 1A shows a structure of a radiation cooling sheet according to an embodiment.

15 FIG. 1B is a cross-sectional view of the radiation cooling sheet according to the embodiment.

FIG. 2 is a cross-sectional view of a first variation of the radiation cooling sheet according to the embodiment.

20 FIG. 3 is a cross-sectional view of a second variation of the radiation cooling sheet according to the embodiment.

FIG. 4 is a photomicrograph of an uneven surface formed by repeating multiple times the operation of forming and solidifying droplets of liquid resin coating material.

DESCRIPTION OF EMBODIMENTS

25 [0007]

Embodiments will be described in detail below.

[0008]

FIGS. 1A and 1B show a radiation cooling sheet 10 according to an embodiment. The radiation cooling sheet 10 is used by being attached to the surface of a cooling object, examples
5 of which include building materials such as building materials for residences and building materials for factories and warehouses; containers such as installation containers, transportation containers, and portable containers; and automobile-related parts such as interior components, air conditioning systems, fuel systems, and battery systems. Then, when being exposed to sunlight, the radiation cooling sheet 10 blocks heat and cools the cooling object located inside
10 it. In the following description, the side which is exposed to sunlight refers to the "upper" side and the side on which the cooling object is provided refers to the "lower" side.

[0009]

The radiation cooling sheet 10 according to the embodiment includes a base material layer 11, an anchor coat layer 12 directly above the base material layer 11, a reflective layer 13
15 directly above the anchor coat layer 12, and a transparent protective layer 14 directly above the reflective layer 13. On the surface of the protective layer 14, an uneven surface 16 with a plurality of transparent raised portions 15 each different in size is formed.

[0010]

The radiation cooling sheet 10 according to the embodiment has a radiation cooling
20 structure consisting of the reflective layer 13, the protective layer 14, and the uneven surface 16 on top. If the radiation cooling sheet 10 is exposed to sunlight, the light is incident on the uneven surface 16 on top, is transmitted through the transparent protective layer 14, and then reaches and is reflected by the reflective layer 13. The light reflected by the reflective layer 13 is transmitted through the protective layer 14 again and is emitted through the uneven surface
25 16 on top. In this process, when the wavelength of light is within the wavelength band of "the

atmospheric window" (7 to 14 μm) in which electromagnetic wave radiation is hardly absorbed by the atmosphere, the cooling object is cooled so that its surface temperature is lowered by efficiently releasing heat to the atmosphere via the radiation cooling sheet 10.

[0011]

5 The radiation cooling structure of the radiation cooling sheet 10 according to the embodiment enables high radiation cooling performance because the uneven surface 16 on the protective layer 14 exhibits the lens effect to accelerate heat dissipation. It also enables high antiglare performance because the light reflected by the reflective layer 13 is diffusely reflected by the uneven surface 16.

10 [0012]

For the antiglare performance of the radiation cooling sheet 10 according to the embodiment, the specular glossiness Gs at 20° is suitably 600% or less, more suitably 300% or less, and still more suitably 100% or less. The specular glossiness Gs at 60° is suitably 350% or less, more suitably 150% or less, and still more suitably 70% or less. The specular glossiness
15 Gs at 85° is suitably 35% or less, more suitably 20% or less, and still more suitably 10% or less. These specular glossinesses are measured according to JIS Z8741:1997.

[0013]

In the whole wavelength range (300 nm to 2500 nm) of the radiation cooling sheet 10 according to the embodiment, the sunlight reflectance is suitably 90% or less, and more suitably
20 84% or less. This sunlight reflectance in the whole wavelength range is determined according to JIS K5602:2008 (the same applies to the following description).

[0014]

The base material layer 11 is a resin film, for example. Examples of the resin for the base material layer 11 include a polyester resin, a polycarbonate resin, and the like. The
25 thickness of the base material layer 11 is, for example, 10 μm or more and 300 μm or less.

[0015]

The anchor coat layer 12 is a cured product of a resin adhesive, for example. Examples of the resin adhesive for the anchor coat layer 12 include a urethane-based adhesive, an epoxy-based adhesive, and the like.

5 [0016]

The reflective layer 13 is a metal film, for example. Examples of the metal for the reflective layer 13 include silver, silver alloy, aluminum, aluminum alloy, and the like. Among these examples, the metal for the reflective layer 13 is suitably silver and silver alloy, and more suitably silver, from the viewpoint of enabling high radiation cooling performance. The sunlight
10 reflectance of the reflective layer 13 in the whole wavelength range is suitably 90% or more. The thickness of the reflective layer 13 is, for example, 50nm or more and 300nm or less.

[0017]

The reflective layer 13 can be formed by coating the base material layer 11 with a resin adhesive and then curing the resin adhesive, thereby forming the anchor coat layer 12; and
15 afterward forming a metal film on the anchor coat layer 12. Examples of the film forming method include a dry film forming method such as vapor deposition, sputtering, ion plating, and the like; and a wet film forming method using a silver mirror reaction.

[0018]

If the reflective layer 13 has high stickiness or adhesiveness to the base material layer
20 11 and also the reflective layer 13 has superior formability, the reflective layer 13 may be formed directly above the base material layer 11 as shown in FIG. 2. For example, assume that the reflective layer 13 is formed by treating silver using a silver mirror reaction. Then, if the base material layer 11 is a polycarbonate resin film, the reflective layer 13 has high stickiness or adhesiveness to the base material layer 11, and also the base material layer 11 has high
25 wettability and the reflective layer 13 has superior formability. Thus, the reflective layer 13 can

be provided directly above the base material layer 11. In contrast, if the base material layer 11 is a polyester resin film, the base material layer 11 has high wettability and the reflective layer 13 has superior formability, but the reflective layer 13 has lower stickiness or adhesiveness to the base material layer 11. Thus, the reflective layer 13 is suitably provided above the base material layer 11 with the anchor coat layer 12 sandwiched therebetween.

[0019]

The protective layer 14 is made of a resin, for example. Examples of the resin for the protective layer 14 include an acryl-based resin, a urethane resin, a urethane acrylic resin, and a polyester resin. Here, the "acrylic-based resin" in this application refers to a polymer resin obtained by polyaddition of acrylic acid, methacrylic acid, and the derivatives thereof (for example, acrylamide, acrylonitrile, and the like) as monomers. Specific examples of the acrylic-based resin include a polyacrylic acid acrylic resin, a polymethacrylic acid resin, a polymethyl methacrylate resin, and the like. Among these examples, the resin for the protective layer 14 is suitably a urethane acrylic resin and a polyester resin from the viewpoint of enabling high radiation cooling performance. The total luminous transmittance of the resin for the protective layer 14 is suitably 85% or more, and more suitably 90% or more, from the viewpoint of enabling high radiation cooling performance. This total luminous transmittance is measured according to JIS K7361-1:1997 (the same applies to the following description). The thickness of the protective layer 14 is, for example, 10 μm or more and 100 μm or less, and from the viewpoint of reducing heat accumulation, the thickness is suitably 60 μm or less, and more suitably 40 μm or less.

[0020]

The protective layer 14 may be a solidified product of a resin coating material coated on the reflective layer 13. Examples of the resin coating material include an ultraviolet curable resin coating material, a thermosetting resin coating material, a thermoplastic resin solution,

and the like.

[0021]

The protective layer 14 may be a resin film. In this case, the protective layer 14 consisting of the resin film is suitably provided above the reflective layer 13 with an adhesive layer 17 sandwiched therebetween as shown in FIG. 3. The adhesive layer 17 is a cured product of a resin adhesive, for example. Examples of the resin adhesive for the adhesive layer 17 include a urethane-based adhesive.

[0022]

The raised portion 15 is made of a resin, for example. The resin for the raised portion 15 may be the same as the resin for the protective layer 14, but is suitably different from the resin for the protective layer 14 from the viewpoint of enabling high radiation cooling performance. Examples of the resin for the raised portion 15 include an acrylic-based resin, a urethane resin, a urethane acrylic resin, and the like. From the same viewpoint, among these examples, the resin for the raised portion 15 is suitably an acrylic-based resin, and more suitably a polyacrylic acid acrylic resin. From the same viewpoint, the total luminous transmittance of the resin for the raised portion 15 is suitably 85% or more, and more suitably 90% or more. When the resin for the raised portion 15 is different from the resin for the protective layer 14, the total luminous transmittance of the resin for the raised portion 15 is suitably higher than the total luminous transmittance of the resin for the protective layer 14.

[0023]

The shape of the raised portion 15 is suitably a hemisphere or a semi-ellipsoid. The outer diameter of the raised portion 15, where the outer diameter is defined as the average value of the major axis and the minor axis of an ellipse that approximates the shape of the raised portion 15 in plan view, is suitably 1 μm or more and 100 μm or less, more suitably 5 μm or more and 80 μm or less, and still more suitably 10 μm or more and 25 μm or less, from the

viewpoint of enabling high radiation cooling performance and high antiglare performance. From the same viewpoint, the aspect ratio (major axis/minor axis) of the raised portion 15 is suitably 4 or less, more suitably 2 or less, and still more suitably 1.5 or less. From the same viewpoint, the height of the raised portion 15 is suitably 1 μm or more and 100 μm or less, more
5 suitably 5 μm or more and 50 μm or less, and still more suitably 10 μm or more and 15 μm or less.

[0024]

The plurality of raised portions 15 each different in size are provided on the surface of the protective layer 14 in order to form the uneven surface 16. The median of the distribution
10 of outer diameters of the plurality of raised portions 15 forming the uneven surface 16 is suitably 5 μm or more and 15 μm or less, and more suitably 8 μm or more and 12 μm or less, from the viewpoint of enabling high radiation cooling performance and high antiglare performance. From the same viewpoint, the first quartile is suitably 3 μm or more and 12 μm or less, and more suitably 6 μm or more and 9 μm or less. From the same viewpoint, the third quartile is
15 suitably 15 μm or more and 25 μm or less, and more suitably 18 μm or more and 22 μm or less. From the same viewpoint, the interquartile range is suitably 8 μm or more and 20 μm or less, and more suitably 10 μm or more and 15 μm or less. The distribution of outer diameters of the raised portions 15 is determined by observing the uneven surface 16 on top with a laser microscope and analyzing an image of the uneven surface 16 using image analysis software.
20 Specifically, the surface of the protective layer 14 is defined as a reference surface, and portions above the reference surface are defined as the raised portions 15. Then, the outer diameter of each of the plurality of raised portions 15 forming the uneven surface 16 is measured (where the outer diameter is defined as the average value of the major axis and the minor axis of an ellipse that approximates the shape of the raised portion 15 in plan view), and the distribution
25 of those outer diameters is output. At this time, portions with the aspect ratio of 2 or less and

the outer diameter of 2 μm or more are treated as the raised portions 15, and portions with the outer diameter of less than 2 μm are removed as noise. If some raised portions 15 are combined together, they are processed for separation.

[0025]

5 The uneven surface 16 is suitably provided with a plurality of small raised portions 15 from the viewpoint of accelerating heat dissipation with a larger surface area, as well as diffusely reflecting the light reflected by the reflective layer 13 and then emitting the light to the outside.

[0026]

10 The percentage of the area occupied by the plurality of raised portions 15 on the uneven surface 16 is suitably 10% or more, more suitably 15% or more, and still more suitably 30% or more, from the viewpoint of enabling high radiation cooling performance and high antiglare performance. This percentage of the occupied area is also determined by observing the uneven surface 16 on top with a laser microscope and analyzing an image of the uneven surface 16
15 using image analysis software. Specifically, the surface of the protective layer 14 is defined as a reference surface, and portions above the reference surface are defined as the raised portions 15; and then the portion of the reference surface and the portion of the raised portions 15 are edited into a binary format, and the percentage of the area occupied by the raised portions 15 with respect to the whole portion is calculated and output.

20 [0027]

 The arithmetic mean height S_a of the uneven surface 16 is suitably 1 μm or more and 10 μm or less, more suitably 1.5 μm or more and 4 μm or less, and still more suitably 2 μm or more and 3 μm or less, from the viewpoint of enabling high radiation cooling performance and high antiglare performance. This arithmetic mean height S_a is measured according to ISO
25 25178 using a laser microscope (for example, VK-X150/KV-X100 by KEYENCE

CORPORATION). From the same viewpoint, the plurality of raised portions 15 forming the uneven surface 16 are suitably provided at random on the protective layer 14.

[0028]

The plurality of raised portions 15 forming the uneven surface 16 may be solidified products obtained by applying spray coating or inkjet coating on the protective layer 14 to form thereon a plurality of droplets of liquid resin coating material and then solidifying those droplets. The contact angle of the droplet on the protective layer 14 according to the half-angle ($\theta/2$) method is, for example, 5° or more and 90° or less.

[0029]

The plurality of raised portions 15 are suitably formed by repeating multiple times the operation of forming and solidifying droplets of liquid resin coating material. In this case, as shown in FIG. 4, for example, on a solidified product 151 of a droplet formed by the first operation, a solidified product 152 of another droplet formed by the second operation is placed; on the solidified product 152, a solidified product 153 of still another droplet formed by the third operation is placed; then the operation is still repeated; and finally the solidified products 151, 152, 153, . . . are stacked to form the raised portion 15. This raised portion 15 provides more opportunities to convert the wavelength of light and more occasions to refract the light at the interface between the solidified products 151, 152, 153, . . . of the droplets, thus enabling higher antiglare performance and higher heat shielding performance. From the viewpoint of productivity, the operation of forming and solidifying a droplet of liquid resin coating material is repeated suitably 15 times or fewer, and more suitably 10 times or fewer.

[0030]

Examples of the resin coating material include an ultraviolet curable resin coating material, a thermosetting resin coating material, a thermoplastic resin solution, and the like. If an ultraviolet curing resin coating material is used, the plurality of raised portions 15 can be

easily formed through a simple operation. If a water-based thermosetting resin coating material that is curable at a room temperature is used, a drying operation after coating is suitably performed at a low temperature from the viewpoint of less combining the droplets together before forming the raised portions 15. This drying temperature is suitably 50°C or lower, and more suitably 30°C or lower. From the same viewpoint, a drying operation after coating is suitably performed at a low humidity. This drying humidity is suitably 70% or less, and more suitably 50% or less.

[0031]

The radiation cooling sheet 10 according to the embodiment includes a sticky layer 18 directly below the base material layer 11 and the peeling layer 19 directly on the sticky layer 18.

[0032]

The sticky layer 18 is made of a resin-based adhesive, for example. Examples of the resin-based adhesive for the sticky layer 18 include an acrylic-resin-based adhesive. The peeling layer 19 is release paper, for example.

[0033]

The radiation cooling sheet 10 according to the embodiment with the peeling layer 19 being peeled off is used by being attached to the surface of the cooling object with the sticky layer 18 sandwiched therebetween.

[0034]

In the above embodiment, the radiation cooling sheet 10 is attached to the cooling object, but the present disclosure is not particularly limited thereto. The radiation cooling structure of the radiation cooling sheet 10 according to the embodiment can be applied to clothing such as hats, clothes, and the like using a base material made of fabric, for example.

[Examples]

[0035]

[Test Evaluation 1]

(Test Piece)

<Example 1>

5 A silver thin film as a reflective layer was formed by applying a silver mirror coating to the surface of a rectangular polycarbonate plate with 52 mm in length, 84 mm in width, and 2 mm in thickness. The sunlight reflectance of the reflective layer in the whole wavelength range was 97%. The thickness of the reflective layer was 100 nm.

[0036]

10 Next, a protective layer was formed by applying a coating material made of a urethane acrylic resin onto the reflective layer and then curing this coating material. The protective layer was put on a polycarbonate plate having a total luminous transmittance of about 90%, and then the total luminous transmittance of this product was measured and the result was 91%. The thickness of the protective layer was 58 μm .

15 [0037]

 Then, spray coating was applied on the protective layer so that a plurality of droplets of a liquid uncured ultraviolet curable acrylic resin coating material were formed on the protective layer; then those plurality of droplets were exposed to ultraviolet rays and cured, thereby being solidified so that a plurality of raised portions were formed; and accordingly,
20 those plurality of raised portions formed the uneven surface on the protective layer. The operation of forming and solidifying the droplets of the liquid uncured ultraviolet curable acrylic resin coating material was repeated twice. The total luminous transmittance of the ultraviolet curable acrylic resin for the raised portions was 93%. The average size of 50 raised portions selected at random was determined, where the outer diameter of the raised portion was
25 23 μm ; the height of the raised portion was 12 μm ; and the ratio of the height to the outer

diameter of the raised portion was 0.9. The percentage of the area occupied by the raised portions on the uneven surface was 19%. The arithmetic mean height Sa of the uneven surface was 1.8 μm .

[0038]

5 The test piece produced as described above was defined as Example 1.

[0039]

<Example 2>

The test piece produced in the same way of Example 1 except that the operation of forming and solidifying the droplets of the liquid uncured ultraviolet curable acrylic resin
10 coating material was repeated three times was defined as Example 2.

[0040]

The average size of 50 raised portions selected at random was determined, where the outer diameter of the raised portion was 13 μm ; the height of the raised portion was 13 μm ; and the ratio of the height to the outer diameter of the raised portion was 1.2. The percentage of the
15 area occupied by the raised portions on the uneven surface was 36%. The arithmetic mean height Sa of the uneven surface was 2.4 μm .

[0041]

<Comparative Example 1>

A commercially available radiation cooling sheet of which a silver thin film was
20 covered with a vinyl chloride resin layer was attached to the surface of a polycarbonate plate. This product was defined as Comparative Example 1.

[0042]

(Test Method)

<Radiation Cooling Performance>

25 For each test piece of Examples 1 and 2 and Comparative Example 1, a thermocouple

was attached to each of the back surface on the polycarbonate plate side and the light-exposed surface on the opposite side. The test piece was placed 280 mm apart from a floodlight of 500W so that the light-exposed surface faced the floodlight. The test piece was exposed to light from the floodlight. The average temperature of each of the light-exposed surface and the back surface between 15 and 20 minutes after the start of light exposure was determined.

[0043]

<Antiglare Performance>

For each test piece of Examples 1 and 2 and Comparative Example 1, the specular glossiness Gs at 60° and the specular glossiness Gs at 85° were measured according to JIS Z8741:1997.

[0044]

<Sunlight Reflectance>

For each test piece of Example 1 and Comparative Example 1, the sunlight reflectance in the whole wavelength range was determined.

[0045]

(Test Results)

The test results are shown in Table 1. Table 1 shows that the temperature of the back surface of both Examples 1 and 2 is lower by about 2°C than Comparative Example 1. That is, Examples 1 and 2 exhibit higher heat shielding performance than Comparative Example 1. In contrast, comparison between Example 1 and Comparative Example 1 shows that the latter exhibits a higher sunlight reflectance in the whole wavelength range than the former. That is, Comparative Example 1 assumingly exhibits higher heat shielding performance by reflection than Example 1. Accordingly, Examples 1 and 2 exhibit high radiation cooling performance.

[0046]

[Table 1]

		Example 1	Example 2	Comparative Example 1
Reflective layer	Sunlight reflectance (%)	97	97	-
	Thickness (nm)	100	100	-
Protective layer	Total luminous transmittance (%)	91	91	-
	Thickness (μm)	58	58	-
Raised portion	Total luminous transmittance (%)	93	93	-
	Outer diameter (μm)	23	13	-
	Height (μm)	12	13	-
	Height/Outer diameter	0.9	1.2	-
	Percentage of occupied area (%)	19	36	-
Uneven surface	Arithmetic mean height Sa (μm)	1.8	2.4	-
Radiation cooling performance (°C)	Back surface	33.9	33.6	36.4
	Light-exposed surface	42.0	41.1	42.9
Antiglare performance (%)	Specular glossiness Gs at 60°	91.4	67.0	45.3
	Specular glossiness Gs at 85°	10.2	3.7	9.8
Sunlight reflectance (%)		82.0	-	84.5

[0047]

5 [Test Evaluation 2]

(Test Piece: Example 3)

A commercially available material including a base material, a silver thin film as a reflective layer formed on the base material, and a protective layer stacked on the reflective layer was used, where the protective layer was a polyester resin film and was 25 μm in thickness.

10 Then, spray coating was applied on the protective layer so that a plurality of droplets of a liquid uncured water-based urethan resin coating material that was curable at a room temperature were formed on the protective layer; then those plurality of droplets were held at a room temperature and cured, thereby being solidified so that a plurality of raised portions were formed; and accordingly, those plurality of raised portions formed the uneven surface on the protective layer.

15 The test piece produced in this manner was defined as Example 3.

[0048]

(Test Method and Results)

For Example 3, the following test was conducted. The results are shown in Table 2.

[0049]

<Outer Diameter Distribution and Occupied Area Percentage of Raised Portions>

For the test piece of Example 3, an image of the uneven surface on top observed at a
5 magnification of 500 times with a laser microscope (VK-X50 by KEYENCE CORPORATION)
was analyzed with image analysis software (Image-J).

[0050]

Specifically, the surface of the protective layer was defined as a reference surface, and
portions above the reference surface were defined as raised portions. Then, the outer diameter
10 of each of the plurality of raised portions forming the uneven surface was measured, and the
distribution of those outer diameters was output. At this time, the outer diameter was defined
as the average value of the major axis and the minor axis of an ellipse that approximates the
shape of the raised portion. Portions with the aspect ratio (major axis/minor axis) of 2 or less
and the outer diameter of 2 μm or more were treated as the raised portions, and portions with
15 the outer diameter of less than 2 μm were removed as noise. Raised portions combined together
were processed for separation. The resultant distribution of the outer diameters of the raised
portions was statistically processed to determine the median, the first quartile, the third quartile,
and the interquartile range of the outer diameters of the raised portions.

[0051]

20 The portion of the reference surface and the portion of the raised portions were edited
into a binary format, and the percentage of the area occupied by the raised portions with respect
to the whole portion was calculated and output.

[0052]

<Antiglare Performance>

25 For the test piece of Example 3, the specular glossiness G_s at 20° , the specular

glossiness Gs at 60°, and the specular glossiness Gs at 85° were measured according to JIS Z8741:1997.

[0053]

[Table 2]

		Example 3
Outer diameter distribution of raised portions (μm)	Median	11.8
	First quartile	7.3
	Third quartile	20.2
	Interquartile range	12.9
Occupied area percentage of raised portions (%)		30
Antiglare performance (%)	Specular glossiness Gs at 20°	576
	Specular glossiness Gs at 60°	313
	Specular glossiness Gs at 85°	32.5

5

[0054]

[Test Evaluation 3]

(Test Piece)

<Example 4>

10 The test piece produced in the same way of Example 3 except that the operation of forming and solidifying the plurality of droplets of the liquid uncured water-based urethan resin coating material that was curable at a room temperature was repeated three times was defined as Example 4.

[0055]

15 The percentage of the area occupied by the raised portions on the uneven surface, that is, the percentage of the area occupied by the portion made of coating material on the uneven surface was 73.3%. The arithmetic mean height Sa of the uneven surface was 2.3 μm.

[0056]

<Example 5>

20 The test piece produced in the same way of Example 4 except that the operation of forming and solidifying the plurality of droplets of the liquid uncured water-based urethan resin

coating material that was curable at a room temperature was repeated six times was defined as Example 5.

[0057]

5 The percentage of the area occupied by the raised portions on the uneven surface, that is, the percentage of the area occupied by the portion made of coating material on the uneven surface was 92.3%. The arithmetic mean height S_a of the uneven surface was 3.8 μm .

[0058]

<Example 6>

10 The test piece produced in the same way of Example 4 except that the operation of forming and solidifying the plurality of droplets of the liquid uncured water-based urethan resin coating material that was curable at a room temperature was repeated nine times was defined as Example 6.

[0059]

15 The percentage of the area occupied by the raised portions on the uneven surface, that is, the percentage of the area occupied by the portion made of coating material on the uneven surface was 100%. The arithmetic mean height S_a of the uneven surface was 5.4 μm .

[0060]

<Comparative Example 2>

20 A commercially available material including a base material, a silver thin film as a reflective layer formed on the base material, and a protective layer stacked on the reflective layer, where the protective layer was a polyester resin film and was 25 μm in thickness, was defined as the test piece of Comparative Example 2. The percentage of the area occupied by the portion made of coating material was 0%.

[0061]

25 <Comparative Example 3>

The test piece produced in the same way of Example 3 except that spray coating was applied on the protective layer so that a liquid uncured water-based urethan resin coating material that was curable at a room temperature was uniformly sprayed on the protective layer, and then was held at a room temperature and cured, thereby being solidified, was defined as Comparative Example 3. The percentage of the area occupied by the portion made of coating material was 100%.

[0062]

(Test Method and Results)

For Examples 4 to 6 and Comparative Examples 2 to 3, the following test was conducted. The results are shown in Table 3.

[0063]

<Radiation Cooling Performance>

Each test piece of Examples 4 to 6 and Comparative Examples 2 to 3 was attached to the surface of a rectangular polycarbonate plate with 55 mm in length, 85 mm in width, and 2 mm in thickness, and also a thermocouple was attached to each of the back surface of the polycarbonate plate and the light-exposed surface of the test piece. The test piece was placed 370 mm apart from a floodlight of 500W so that the light-exposed surface faced the floodlight. The test piece was exposed to light from the floodlight. The average temperature of each of the light-exposed surface of the test piece and the back surface of the polycarbonate plate between 15 and 20 minutes after the start of light exposure was determined.

[0064]

<Antiglare Performance>

For each test piece of Examples 4 to 6 and Comparative Examples 2 to 3, the specular glossiness Gs at 20°, the specular glossiness Gs at 60°, and the specular glossiness Gs at 85° were measured according to JIS Z8741:1997.

[0065]

[Table 3]

		Example 4	Example 5	Example 6	Comparative Example 2	Comparative Example 3
Number of operation of forming and solidifying droplets (times)		3	6	9	-	-
Percentage of area occupied by portion made of coating material (%)		73.3	92.3	100	0	100
Arithmetic mean height Sa of uneven surface (μm)		2.3	3.8	5.4	-	-
Radiation cooling performance (°C)	Back surface	37.2	37.8	38.0	37.1	39.3
	Light-exposed surface	40.7	40.7	41.4	40.5	41.3
Antiglare performance (%)	Specular glossiness Gs at 20°	95.0	37.8	33.0	1411	1623
	Specular glossiness Gs at 60°	72.1	49.3	44.8	999	955
	Specular glossiness Gs at 85°	6.8	5.3	4.8	138	132

INDUSTRIAL APPLICABILITY

5 [0066]

The present invention is useful in the technical field of radiation cooling structures and the methods of manufacturing the same.

DESCRIPTION OF REFERENCE CHARACTERS

10 [0067]

10 Radiation Cooling Sheet

11 Base Material layer

12 Anchor Coat Layer

13 Reflective layer

15 14 Protective Layer

- 14a Recessed Portion
- 15 Raised Portion
- 151, 152, 153 Solidified Product of Droplet
- 16 Uneven surface
- 5 17 Adhesive Layer
- 18 Sticky Layer
- 19 Peeling Layer

CLAIMS

- [Claim 1] A radiation cooling structure comprising: a reflective layer and a resin-made transparent protective layer provided on the reflective layer, wherein
- an uneven surface with a plurality of resin-made raised portions each different in size is formed on the protective layer, and
- the raised portions have a total luminous transmittance higher than that of the protective layer.
- [Claim 2] The radiation cooling structure of claim 1, wherein
- the plurality of raised portions forming the uneven surface are provided at random on the protective layer.
- [Claim 3] The radiation cooling structure of claim 1, wherein
- a median of a distribution of outer diameters of the plurality of raised portions forming the uneven surface is 5 μm or more and 15 μm or less.
- [Claim 4] The radiation cooling structure of claim 1, wherein
- an arithmetic mean height of the uneven surface is 1 μm or more and 10 μm or less.
- [Claim 5] The radiation cooling structure of claim 1, wherein
- a percentage of an area occupied by the raised portions on the uneven surface is 10% or more.
- [Claim 6] The radiation cooling structure of claim 1, wherein
- the raised portion is a solidified product of droplets of a liquid resin.
- [Claim 7] The radiation cooling structure of claim 6, wherein
- the raised portion is formed by stacking the solidified product of the droplets of the liquid

resin.

[Claim 8] The radiation cooling structure of claim 1, wherein the raised portion is made of an acryl-based resin.

[Claim 9] The radiation cooling structure of claim 1, wherein the protective layer is made of a urethane acrylic resin.

[Claim 10] The radiation cooling structure of claim 1, wherein the reflective layer is made of silver or a silver alloy.

[Claim 11] The radiation cooling structure of claim 1, wherein a specular glossiness at 60° is 350% or less, and a specular glossiness at 85° is 35% or less.

[Claim 12] The radiation cooling structure of claim 1, wherein a sunlight reflectance in a whole wavelength range of 300 nm to 2500 nm is 90% or less.

[Claim 13] A method for manufacturing a radiation cooling structure of claim 1, wherein the plurality of raised portions are solidified products obtained by forming a plurality of droplets of a liquid resin on the protective layer and then solidifying the plurality of droplets.

[Claim 14] The method of claim 13, wherein operation of forming and solidifying the droplets of the liquid resin is repeated multiple times.