

DESCRIPTION

Title of Invention

REFRIGERATOR

Technical Field

5 **[0001]**

The present invention relates to a refrigerator configured to control the shape of frost adhered to a cooler or the thickness of a frost layer to improve performance when frost is formed, thereby achieving energy saving.

10 Background Art

[0002]

15 In some refrigerators of the related art, a fin used in a cooler is surface-treated for improving performance when frost is formed. However, since the shape of the periphery of the cooler fails to match the improvement of the performance when the frost is formed, the performance in a state in which the frost is not much formed remains unimproved (for example, see Patent Literature 1).

20 The frost formation on the cooler hinders heat exchange between a refrigerant and the air. Therefore, when the amount of frost formation is increased, heat resistance of the cooler is increased, and heat exchange performance is lowered, whereby deterioration of cooling efficiency is resulted.

25 In addition, when the amount of frost formation is increased, flowing resistance of air flowing in the periphery of the cooler is increased due to an action of a

refrigerator fan. Therefore, the air volume is reduced, and a refrigerator body cannot maintain a specified cooling capability, whereby the inside temperature rises.

In this event, there arises a problem in terms of quality maintenance of foodstuffs, and hence the refrigerator is provided with defrosting means. The defrosting means is provided in a heat insulating box for the purpose of delaying the reduction of the air volume, a depressed portion is provided between the cooler and the heat insulating box, so that a certain amount of frost can be accumulated therein. In the case of a refrigerator in the range of 500 liters, a capacity which accommodates an amount of frost formation of the order of 500 cc while maintaining the inside temperature is required.

[Cited References]

[Patent Literature]

[0003]

[Patent Literature 1] JP-A-2001-317854 (p. 1, Fig. 1)

Summary of Invention

Technical Problem

[0004]

In the refrigerator of the related art described in Patent Literature 1, the fin used in the cooler is surface-treated for improving the performance demonstrated when frost is formed. However, since the shape of the periphery of the cooler fails to match the improvement of the performance when the frost is formed, the performance in the

state in which the frost is not much formed remains unimproved.

[0005]

5 In order to solve the above-described problem, it is an object of the present invention to provide a refrigerator in which a neat frost layer is formed, an air duct pressure loss is reduced, performance when frost is formed is improved, and energy saving is achieved.

Solution to Problems

10 **[0006]**

A refrigerator comprising:

a refrigeration cycle which is configured in such a way that a refrigerator body constituted by a heat insulating box filled with a heat insulator and provided with an opening is connected with a compressor, a condenser, 15 an expanding device, and a cooler by a pipe and a refrigerant is made to circulate in the pipe, and

blowing means that blows out a cold air generated in said cooler, wherein

20 an almost entire surface of a fin or a heat transfer tube of the cooler is formed with a plurality of pores.

Advantageous Effect of the Invention

[0007]

25 In the refrigerator according to the invention, since a number of the pores are provided over the nearly entire surface of the fin or the heat transfer tube of the cooler in the freezing cycle. Therefore, the surface of the fin or

the heat transfer tube hardly allows water droplets formed thereon due to condensation of water content in air to coalesce and hence become large sized water droplets, and the size of the water droplets when being frozen is reduced.

5 Consequently, a neat frost layer is formed, and an air duct pressure loss is reduced, whereby performance when the frost is formed may be improved.

Brief Description of Drawings

[0008]

10 Fig. 1 is a front view showing an appearance of a refrigerator according to Embodiment 1 in the present invention.

Fig. 2 is a side cross-sectional view of the same refrigerator.

15 Fig. 3 is a refrigerant circuit drawing of a freezing cycle of the same refrigerator.

Fig. 4 is an explanatory drawing relating to generation, growth, coalescence, and freezing of water droplets on an untreated cooling surface of a cooler in the same

20 refrigerator.

Fig. 5. is an explanatory drawing relating to generation of water droplets (condensed liquid droplets) on the untreated cooling surface of the cooler in the same refrigerator.

Fig. 6 is another explanatory drawing relating to generation, growth, coalescence, freezing of water droplets on the
25 cooling surface of the cooler in the same refrigerator.

Fig. 7 is another explanatory drawing relating to generation of water droplets (condensed liquid droplets) on the cooling surface of the cooler in the same refrigerator.

Fig. 8 is still another explanatory drawing relating to generation of water droplets (condensed liquid droplets) on the cooling surface of the cooler in the same refrigerator.

Fig. 9 is a perspective view showing a configuration of the cooler in the same refrigerator.

Fig. 10 is a perspective view showing a state in which the surface of the cooler in the same refrigerator is in an enlarged scale.

Fig. 11 is a perspective view showing the cooler and the periphery thereof in the same refrigerator.

Description of Embodiments

[0009]

Embodiment 1

Fig. 1 is a front view showing an appearance of a refrigerator according to Embodiment 1 in the present invention, Fig. 2 is a side cross-sectional view of the same refrigerator, and Fig. 3 is a refrigerant circuit drawing of a freezing cycle of the same refrigerator.

In Fig. 1 and Fig. 2, a refrigerator body 1 is constituted by a heat insulating box filled with a heat insulator and provided with an opening.

The refrigerator body 1 is provided with a refrigerating compartment 2, an ice making compartment 3, a switchable compartment 4 which allows temperature setting to

be changed, a freezing compartment 5, and a vegetable compartment 6 from the top. The respective compartments include a refrigerating compartment door 7 (a double doors 7A and 7B in the drawing), an ice making compartment door 8, a switchable compartment door 9, a freezing compartment door 10, and a vegetable compartment door 11 which allow a user to open and close the openings of the respective compartments.

A compressor 21 is disposed in the refrigerator body 1 at the lower rear portion thereof. A cooler 22 is disposed on the back surface of the freezing compartment 5, and a refrigerator fan 23 is disposed above the cooler 22. A defrosting heater 12 is disposed below the cooler 22.

[0010]

In Fig. 3, the compressor 21, a condenser 25, a restrictor 24, and the cooler 22 are connected via piping, and constitute a refrigerant circuit of a freezing cycle. Cold air generated by the cooler 22 by an action of the freezing cycle is circulated within the refrigerator by the refrigerator fan 23.

In the refrigerant circuit of the freezing cycle, a refrigerant compressed by the compressor 21 and turned into a high-temperature high-pressure state is condensed by the condenser 25, becomes a low-temperature low-pressure refrigerant in the restrictor 24, is evaporated by an action of the refrigerator fan 23 in the cooler 22, and then returns back to the compressor 21 again.

For example, when the evaporation temperature of the refrigerant is about -30°C , the surface temperatures of the piping of the cooler 22 and a fin are 0°C or lower, which are lower than the ambient air temperature and are below the freezing point, so that water vapor in the air is accumulated in the periphery of the cooler 22 as frost, that is, frost formation is resulted.

[0011]

The frost formation on the cooler 22 hinders heat exchange between the refrigerant and the air. When the amount of frost formation is increased, heat resistance of the cooler 22 is increased, heat exchange performance is lowered, and cooling efficiency is deteriorated.

In addition, when the amount of frost formation is increased, flowing resistance of air flowing in the periphery of the cooler 22 due to the action of an refrigerator fan 23 is increased, the air volume is reduced, the refrigerator body 1 cannot maintain a specific cooling capability, whereby the inside temperature rises.

[0012]

In this event, there arises a problem in terms of quality maintenance of foodstuffs, and hence the refrigerator 1 is provided with a defrosting device. The defrosting heater 12 shown in Fig. 2 corresponds to the defrosting device.

The defrosting heater 12 is provided in the heat insulating box 32 for the purpose of delaying reduction of

the air volume, a depressed portion 31 is provided between the cooler 22 and the heat insulating box 32, so that a certain amount of frost can be accumulated therein.

In the case of a refrigerator in the range of 500
5 liters, a capacity which accommodates an amount of frost formation on the order of 550 cc while maintaining the inside temperature is required.

Fig. 11 is a perspective view of the cooler in the refrigerator and the periphery thereof according to
10 Embodiment 1. In a case where the cooler 22 is not surface treated, and a pitch of the fins provided on the cooler 22 is 5 mm, the maximum amount of frost formation which can be held without causing clogging on the lower portion of the cooler 22 is the sum of the cross-sectional surface area of
15 the cooler 22 multiplied by 5 mm and the capacity of the depressed portion 31. For example, in a case where a width (L) of the cooler 22 is 40cm and a depth (W) is 7.5 cm, the amount of frost formation which can be held by the cooler 22 is about 400 cc. Therefore, a capacity of 150 cc is
20 required for the depressed portion 31.

[0013]

The frost accumulated on the surface of the cooler 22 is a porous layer including ice and air. A process of formation of the frost in the periphery of the cooler will
25 be described below with reference to Fig. 4 and Fig. 5.

When the air is cooled by a cooling surface (the surface of the cooler) and is cooled to a dew point

(saturation temperature) or lower, mist is generated in the vicinity of the cooling surface, which is deposited on the cooling surface as water droplets (condensed liquid droplets) and adhered thereto.

5 When the water droplets are generated on the cooling surface, they serve as nucleuses and are gradually grown in size. In this case, as shown in Fig. 4, if the cooling surface is not specifically treated, the water droplets are generated arbitrarily here and there on the cooling surface
10 (see the drawing (a) in Fig. 4).

 Therefore, there exist short distances and long distances among the water droplets. When the water droplets are grown into sizes which cause the adjacent droplets to come in contact with each other, these water droplets
15 coalesce and become a large water droplet (see the drawings (b) and (c) in Fig. 4).

[0014]

 However, since there exist the short distances and the long distances among the water droplets on the cooling
20 surface, the water droplets at the short distance are likely to coalesce and hence generate the large water droplet.

 The water droplets are further cooled on the cooling surface and hence are frozen to be ice droplets. Then needle-like frost is generated from the ice droplets,
25 thereby forming a frost layer (see the drawing (d) in Fig. 4). In this case, assuming that the amount of frost formation is the same, if the sizes of the ice droplets (or

the water droplets immediately before freezing) are large, a surface of the formed frost layer becomes more irregular correspondingly, and the maximum thickness of the frost layer becomes large.

5 Since draft resistance of the cooler 22 is determined by the maximum frost layer thickness, the draft resistance of the cooler made up of untreated fins is large, so that the air volume of the refrigerator fan 23 which is delivered to the cooler 22 being operated as the cooler is reduced,
10 and cooling performance is more likely to be deteriorated.

[0015]

 In contrast as shown in Fig. 5, when pores (minute holes) exist on the surface of the cooling surface, water droplets are likely to be formed from the pores as nucleuses
15 (detailed description will be given later). When the pores are arranged uniformly on the cooling surface, the water droplets are formed substantially at the same distance (see the drawing (a) in Fig. 5), the coalescence of the water droplets are unlikely to occur, and small water droplets are
20 formed (see the drawings (b) and (c) in Fig. 5).

 The water droplets are further cooled on the cooling surface and hence are frozen to be ice droplets. Then needle-like frost is generated from the ice droplets, thereby forming a frost layer (see the drawing (d) in Fig.
25 5). In this case, assuming that the amount of frost formation is the same, if the sizes of the ice droplets (or the water droplets immediately before freezing) are small, a

surface of the formed frost layer becomes less irregular correspondingly, and the maximum thickness of the frost layer becomes small.

[0016]

5 Since the draft resistance of the cooler 22 is determined by the maximum frost layer thickness, the draft resistance of the cooler 22 made up of fins 43 each having a number of the pores on the cooling surfaces is small, so that reduction of the blowing air volume of the refrigerator
10 fan 23 which is delivered to the cooler 22 being operated is prevented, and the cooling performance of the cooler 22 is less likely to be deteriorated and hence energy is saved more than the case where the fins 45 is not treated.

 In this manner, when the fins 43 (cooling surfaces) of
15 the cooler 22 having a number of the pores is used, water droplets, and by extension, ice droplets having uniform size and shape are formed neatly, and hence the frost layer having less surface irregularity and small maximum thickness is formed, whereby the cooler 22 having a small air duct
20 pressure loss and less lowering of the cooling performance, and contributing to the energy saving is achieved.

[0017]

 Referring now to Fig. 6 to Fig. 8, the fact that if the pores (minute holes) exist on the surface of the fins 43
25 (cooling surfaces) of the cooler 22, the water droplets are formed with these pores as the nucleuses.

Air is cooled by the cooling surface, and becomes supersaturated air in the vicinity of the cooling surface, thereby assuming mist including minute liquid droplets mixed in aerial current.

5 Part of the mist is flowed by the aerial current, is discharged from a portion in the vicinity of the cooling surface, and remaining part is condensed as water droplets on the cooling surface.

10 In this case, positions where initial water droplets (condensed liquid droplets) are formed are determined depending on part-to-part difference in the state of the cooling surface at the micro level (minute irregularity or the like). In contrast, in the untreated case as shown in Fig. 6, the positions where the initial droplets (condensed
15 liquid droplets) are formed are unknown.

 Therefore, since the positions where the water droplets are formed are not specified in the untreated case, water droplets are generated at random and the distances among the water droplets are not uniform, the coalescence in
20 association of the growth of the water droplets is likely to occur, and hence large droplets are likely to be generated.

[0018]

 In contrast, when the pores exist on the cooling surface as shown in Fig. 7, the initial droplets (condensed
25 liquid droplets) are likely to be formed at positions of ridge lines of the pores. When the size of the pore is smaller than, or not sufficiently larger than the sizes of

the water droplets or the amplitude of the vibrations of water vapor, the water droplets are formed on the ridge lines on the top of the pores.

Therefore, if a number of the pores are arranged at regular intervals on the cooling surface, the positions of the water droplets are specified at the regular intervals, and hence a number of small water droplets having the uniform size are formed in the process of growing by coalescence of the water droplets.

As shown in Fig. 8, when the size of the pores is sufficiently larger than the sizes of the water droplets or the amplitude of the vibrations of the water vapor, water content in air is generated on the ridge lines on the top of the holes and the interiors of the holes. In this case as well, if a number of the pores are arranged at regular intervals on the cooling surface, the positions of the water droplets are specified at the regular intervals, and hence a number of small water droplets having the uniform size are formed in the process of growing by coalescence of the water droplets.

[0019]

However, it is necessary to generate small water droplets in comparison with the water droplets formed on the untreated cooling surface, and if the distance among the pores is too far, water droplets may be formed also on the untreated cooling surface between the pores by condensation, so that large sized water droplets are formed. Therefore,

the distance among the pores should be small to some extent. In anodization treatment described later, the distance among the pores is on the order of 20 nm. However, pore-to-pore distance on the order of 100 nm at the maximum is not too large for forming the initial water droplets, and the most effective result is expected.

The same can be said to the size of the pores (an equivalent diameter or the length of a smallest side). Generation of the small water droplets is possible as long as the size does not exceeds values on the order of 0.1 mm (100 μ m) and, if the pores have sizes on the order of 100 nm at the maximum, they are not too large for forming the initial water droplets, and the most effective result is expected.

[0020]

Fig. 9 is a perspective view showing a configuration of the cooler in the refrigerator in Embodiment 1.

In Fig. 9, the cooler 22 is of a fin tube type including fins 45 and heat transfer tubes 46, and the fins 45 are treated so as to have a number of pores 51a.

Although the fins 45 are formed of aluminum and the heat transfer tubes are formed of copper in many cases, the invention is not limited thereto, and any materials may be employed as long as it has a high coefficient of thermal conductivity. For example, by employing a heat exchanger having heat transfer tubes formed of aluminum, which is the same material as that of the fins, and being formed with the

pores both on surfaces of the fins and surfaces of the heat transfer tubes, a higher energy saving effect is expected.

[0021]

5 The type of the cooler is not limited to the type described above and, for example, a heat exchanger in which heat transfer performance is improved by using flat heat transfer tubes without providing the fins may be employed and, in this case, a treatment for forming a number of pores is applied to the outer surfaces of the heat transfer tubes.
10 The cooler of this type is manufactured using aluminum in many cases.

 In terms of the strength of the cooler 22, the pores 51a are preferably formed so as not to penetrate through the surfaces of the fins. However, the pores 51a penetrating
15 through the fins may also be employed, and in this case as well, the effects of forming small water droplets are the same.

[0022]

 As a method of forming pores 51a on the surface of the
20 fin 45 as the cooling surfaces of the cooler 22, for example, anodization (anodic oxidization) is exemplified. Fig. 10 is a perspective view showing a state in which the surface of the fin of the cooler, which is applied with the anodization, is in an enlarged scale.

25 The anodization (anodic oxidization) is capable of forming the pores simultaneously on both surfaces of the fin.

By performing DC electrolysis in an environment, for example, in acid solution such as sulfuric acid, oxalic acid, phosphoric acid, chromic acid, or in alkali solution such as sodium acid phosphate with the fins (aluminum) used as an anode, aluminum ions (Al^{3+}) dissolved from the fin (aluminum) and water (H_2O) react and a film (anodic oxide film) of aluminum oxide (alumina) is generated on the aluminum as a base metal.

[0023]

An anodization film 50 includes a porous layer 51 formed with the pores 51a extending perpendicularly, and a barrier layer 52 formed at a bottom wall portion which is in contact with a base metal 53, and has, so called a hexagonal cell structure. When forming the pores 51a, since the thickness of the barrier layer 52 is basically constant, control of the depth of the pores 51a is achieved practically controlling the thickness of the film.

Since the speed of formation and the thickness of the anodization film 50 depend on interpolar current or potential to be supplied and the duration of the anodization, the interpolar current or the potential to be supplied and the duration of the anodization are controlled when forming the pores 51a having a predetermined thickness.

Also, since the number of the pores per unit surface area (density) and the diameter of the pores depend on the interpolar potential, the interpolar potential is controlled

in order to form the pores of a predetermined number and diameter.

[0024]

Also, a mold (metal mold or the like) having
5 projections formed at intervals corresponding to the
intervals of the pores 51a is pressed against the surface of
aluminum, which becomes the fins 45, to form regular
depressions on the surface. By performing the anodization
thereafter, the pores 51a are formed around the depressions
10 as centers thereof, and a regular array of the pores 51a is
achieved, so that high level of control can be performed in
terms of the density.

In addition, in order to avoid the pores 51a formed by
the anodization from reacting with water content in air and
15 being clogged thereby, an operation to remove water content
contained in the film by heating the fins 45 with warm wind
at a temperature on the order of 100 to 200°C immediately
after the formation of the pores and to transform the film
into a stable oxide is performed.

20 The heat transfer tubes 46 are inserted through the
plurality of through holes of the fins 45 formed in the
manner described above to form the cooler 22 as the heat
exchanger.

[0025]

25 In the holes having a minute diameter such as the
pores 51a, a large amount of energy is required for water to
freeze. Therefore, the degree of supercooling of water

increases with decrease of the hole diameter. In other words, the frost formation is delayed correspondingly, and the intervals of defrosting may be elongated, so that the energy saving is achieved.

5 With the pores 51a having a larger depth, the quantity of water held in the holes is increased, and hence frost formation delaying effect and the energy saving effect are enhanced. When the depth of the pores 51a is, for example, 10 μm or more, a sufficient water capacity is obtained, and
10 the energy saving effect is enhanced.

[0026]

 In Embodiment 1, the material of the fins 45 of the cooler 22 is aluminum in the description. However, the material is not limited to aluminum. For example, it is
15 also possible to use so-called valve metal as the material of the fins 45, and form the pores 51a on the surfaces thereof by anodization.

 The valve metal is a generic designation of metals which allows formation of an oxide film which exhibits
20 electrolytic rectification by anodic oxidation, such as aluminum, tantalum, niobium, titanium, hafnium, zirconium, zinc, tungsten, bismuth, antimony.

 Among these metals, those which can be used practically as the fins 45 include, for example, aluminum,
25 titanium, zirconium, niobium, and tantalum. With these types of metals as well, the same effects as aluminum are achieved.

[0027]

The fins 45 after having been subjected to the anodization treatment may have either a hydrophilic property or a water repellent property. In general, they have the hydrophilic property (contact angle: smaller than 50°) immediately after the treatment, and have the water repellent property (contact angle: at least 50°) after elapse of time.

However, since the sizes of liquid droplets or ice droplets formed on the surfaces of the fins 45 are determined by the size and interval of the pores 51a, the effects are almost the same irrespective of whether the fins 45 have the hydrophilic property or the water repellent property, and the same effects are achieved. In other words, the method on the basis of the anodization treatment is able to maintain the energy saving effect virtually unchanged with time.

Since the pores 51a are necessary, application of sealing treatment in general anodization has a reverse effect.

[0028]

By using the cooler 22 surface treated as described above in order to improve the performance demonstrated when the frost is formed, the amount of frost formation which results in clogging is different.

For example, in a case where the cooler 22 has a width (L) of 40 cm, a depth (W) of 7.5 cm, a height (T) of 20 cm,

and a fin pitch of 5 mm, the maximum amount of frost formation which can be held without causing the clogging of the cooler 22 when the surface treatment described above is applied is at least twice an amount in the untreated case, that is, at least 800 cc.

Therefore, 50cc is sufficient as the capacity of the depressed portion 31. Although the capacity of the depressed portion 31 in this case is smaller than 1% with respect to that of the cooler 22, if it is 0.5% or more, it is sufficient as the capacity of the depressed portion 31.

[0029]

The cooler 22 used as an evaporator of the freezing cycle of the refrigerator in Embodiment 1 achieves the energy saving by the provision of a number of the pores 51a over the substantially entire surfaces of the fins 45 or the heat transfer tubes 46 to resist water droplets formed by the condensation of the water content in the air on the surfaces from coalescing and hence becoming large sized water droplets, thereby downsizing of the water droplets when being frozen, forming the neat frost layer to reduce the air duct pressure loss, improving the performance demonstrated when the frost is formed, and reducing the size of the depressed portion 31 to be formed between the cooler 22 and the heat insulating box 32.

The method of providing the pores 51a is not limited to the anodization treatment, and boehmite treatment is also applicable. The method of obtaining the hydrophilic

property may use a coating compound including a hydrophilic coating compound and a water repellent coating compound blended together.

Reference Sign List

5 [0030]

1: refrigerator body, 2: refrigerating compartment, 3: ice making compartment, 4: switchable compartment, 5: freezing compartment, 6: vegetable compartment, 7: refrigerating compartment door, 8: ice making compartment door, 9: switchable compartment door, 10: freezing compartment door, 11: vegetable compartment door, 12: defrosting heater, 21: compressor, 22: cooler, 23: refrigerator fan, 24: restrictor, 25: condenser, 31: depressed portion, 32: heat insulating box, 45: fin, 46: heat transfer tube, 50: anodization film, 51: porous layer, 51a: pore, 52: barrier layer, 53: base metal

CLAIMS

1. A refrigerator comprising:

a refrigeration cycle which is configured in such a way that a refrigerator body constituted by a heat
5 insulating box filled with a heat insulator and provided with an opening is connected with a compressor, a condenser, an expanding device, and a cooler by a pipe and a refrigerant is made to circulate in the pipe, and

blowing means that blows out a cold air generated in
10 said cooler, wherein

an almost entire surface of a fin or a heat transfer tube of the cooler is formed with a plurality of pores.

2. The refrigerator of claim 1, wherein the capacity of a
15 depressed portion provided between the cooler and the heat insulating box is 1% to 0.5% of the capacity of the cooler.

3. The refrigerator of claim 1 or 2, wherein the pores
20 are arranged at a distance of 20 to 100 nm from the adjacent pores.

4. The refrigerator of any one of claims 1 to 3, an
equivalent diameter or a shortest side length of the pore is
100 nm to 0.1 mm.

5. The refrigerator of any one of claims 1 to 4, wherein the pores are formed by applying anodization treatment on the fin or the heat transfer tube.