

METHOD OF MANUFACTURING AN INJECTION-MOLDED ARTICLE

TECHNICAL FIELD

The present invention relates to a method of manufacturing an injection-molded article using a liquid crystalline resin composition.

BACKGROUND ART

A group of plastics called engineering plastics exhibit high strength, and can be used in place of metal components. Among these, a group of plastics called liquid crystalline resins maintains a crystalline structure when molten. Due to the crystalline structure, high strength is one of the characteristics of liquid crystalline resins. Furthermore, liquid crystalline resins have little volumetric change between molten and solidifying states due to low change in the crystalline structure when solidifying. As a result, there is an advantage in liquid crystalline resins in having low mold shrinkage and excelling in dimensional accuracy of molded articles.

Capitalizing on the above such advantages of high strength and the dimensional accuracy being superior, liquid crystalline resin compositions have been adapted to be used in precision equipment components. However, in a case of precision equipment and optical equipment, a small amount of foreign particles, dust, etc. will affect equipment performance. As a result, for components used in precision

equipment and optical equipment, e.g., components for camera modules and the like, ultrasonic cleaning is performed using water or the like to remove small foreign particles, oil content, dust, etc. adhering to the surface of the components. However, for molded articles made by molding a liquid crystalline resin composition, the molecular orientation is particularly high in the surface portion, and thus the surface relatively easily fibrillates. As a result, if the surface of a molded article peels off, it will become a main contributor to fallen debris (foreign particles). Therefore, since the generation of foreign particles and the like is a problem, it is very difficult to ultrasonically clean molded articles made by molding a liquid crystalline resin composition.

The above-mentioned generation of foreign particles and the like occurs due to the molecular orientation being particularly high in the surface of the molded article as mentioned in the foregoing. Therefore, as a resin molded article with improved surface characteristics, a resin molded article containing liquid crystalline polymer and fiber filler has been disclosed that is characterized in having a flat surface for which a difference in the surface roughness Ra value obtained by a specific surface tape-peeling test is 0.4 μm or less (Patent Document 1).

According to the method described in Patent Document 1, it is useful for components of electric and electronic equipment or optical equipment, and makes it to prevent surface particle (foreign particle) generation. When using the technology

described in Patent Document 1 in this way, an improvement in the surface characteristics is possible.

However, as described in the Examples of Patent Document 1, foreign particle generation according to Patent Document 1 indicates foreign particles generating when cleaning a surface by gently stirring in purified water for 1 minute. Therefore, with the improvement in surface characteristics according to the method described in Patent Document 1, a result is not achieved that satisfies fibrillation suppression during ultrasonic cleaning. In other words, with the above-mentioned method described in Patent Document 1, an extraordinarily great amount of foreign particles will generate when exposing the resin molded article to severe conditions such as those of ultrasonic cleaning or the like.

In addition, with Patent Document 1, it is established that a higher mold temperature when molding is more preferable in order to suppress the generation of the above-mentioned foreign particles and the like. Actually, molding was performed at conditions with a mold temperature of 130°C in the Examples of Patent Document 1. In the case of the condition of the mold temperature being set to a temperature exceeding 100°C, temperature regulation cannot be done using water, and thus temperature regulation must be performed using oil. As a result, from the point of view of facilitating the production of injection molded articles, it has been desired to mold under conditions of a mold temperature no higher than 100°C.

Furthermore, since the molecular orientation is particularly high at the surface portion of injection molded articles, surface fibrillation tends to occur and tends to fuzz if ultrasonic cleaning or the like is performed. As a result, a technology for surface characteristic improvement has been demanded that can be applied to injection molded articles.

In addition, the above such fuzz in the surface and the above such peeling of the molded article surface harm the appearance of the injection molded article. As a result, it has also been demanded to provide a superior external appearance to injection molded articles made by injection molding a liquid crystalline resin composition.

Patent Document 1: Japanese Unexamined Patent Application
Publication No. 2008-239950

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

The present invention has been made in order to solve the aforementioned such problems, and an object thereof is to provide a molding technology for obtaining a molded article from a liquid crystal resin composition to have a superior appearance, in which fibrillation of the surface of the injection-molded article is suppressed even if ultrasonically cleaned. In particular, it is to provide a molding technology practicable even at conditions of a mold temperature of no higher than 100°C.

Means for Solving the Problems

The present inventors carried out diligent research in order to solve the above-mentioned problems. As a result, in injection molding of a liquid crystalline resin composition, it was found that the above-mentioned problems could be solved by using a mold in which a heat-insulating layer is formed on a mold inner surface, and injection molding under molding conditions satisfying a specific relational formula, in which t_1 is the thickness of the heat-insulating layer, S is the injection speed, t_2 is the thickness of the injection molded article, and T is the mold temperature. More specifically, the present invention provides the following.

According to a first aspect of the invention, in a method of manufacturing an injection-molded article by injection molding of a liquid crystal resin composition, injection molding is performed using a mold having a heat-insulating layer formed on a mold inner surface, and under molding conditions that satisfy the following formula (I), in which t_1 is thickness of the heat-insulating layer (μm), S is injection molding speed (mm/sec), t_2 is thickness of the injection-molded article (mm), and T is mold temperature ($^{\circ}\text{C}$).

$$(t_1 \times S) / t_2 + T \geq 1000 \cdots (I)$$

According to a second aspect, in the method of manufacturing an injection molded article as described in the first aspect, injection molding is performed under molding conditions that satisfy the following formula (II).

$$(t_1 \times S) / t_2 + T \geq 2000 \cdots (II)$$

According to a third aspect, in the method of manufacturing an injection molded article as described in the first or second aspect, the heat-insulating layer has a thermal conductivity of no more than 5 W/(mK).

According to a fourth aspect, in the method of manufacturing an injection molded article as described in any one of the first to third aspects, the heat-insulating layer includes a polyimide resin.

According to a fifth aspect, in the method of manufacturing an injection molded article as described in any one of the first to fourth aspects, the mold temperature is no greater than 100°C.

Effects of the Invention

The injection molded articles obtained by the manufacturing method of the present invention do not generate fallen debris (foreign particles) from peeling of the molded article surface, even if ultrasonically cleaned. As a result, the injection molded articles to be used in precision equipment, optical equipment and the like manufactured by the manufacturing method of the present invention can be subjected to ultrasonic cleaning easily, and thus the cleaning operation during component manufacturing can be performed more efficiently.

The injection molded articles obtained by the manufacturing method of the present invention have a superior appearance. In particular, the surface of the injection molded articles obtained by the manufacturing method of the present

invention will not easily peel off; therefore, the attractive appearance tends to be maintained over a long period of time.

The manufacturing method of the present invention can be performed under conditions in which the mold temperature is no higher than 100°C. Due to this, temperature regulation of the mold upon obtaining an injection molded article can be performed not with oil, but with water. As a result, a superior injection molded article can be obtained easily.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view showing multi-layered structures of injection molded articles obtained according to the production method of the present invention;

FIG. 2 is a view showing multi-layered structures of injection molded articles obtained according to the production method of the conventional technology; and

FIG. 3 is a view showing a multi-layered structure of an injection molded article produced at conditions satisfying the formula (II).

PREFERRED MODE FOR CARRYING OUT THE INVENTION

Although embodiments of the present invention will be explained in detail hereinafter, the present invention is not to be at all limited to the following embodiment, and can be implemented by including suitable modifications within the scope of the object of the present invention.

In the injection molding of a liquid crystalline resin

composition, the present invention is characterized in using a mold in which a heat-insulating layer is formed on a mold inner surface, and in injection molding at molding conditions satisfying a certain relational formula, in which t_1 is the thickness of the heat-insulating layer (μm), S is the injection molding speed (mm/sec), t_2 is the thickness of the injection-molded article (mm), and T is the mold temperature ($^{\circ}\text{C}$). Hereinafter, the present invention will be explained in the order of a liquid crystalline resin composition, and a method of manufacturing an injection molded article.

Liquid Crystalline Resin Composition

The method of manufacturing an injection molded article of the present invention can be applied to all liquid crystalline resin compositions containing a liquid crystalline resin.

Liquid Crystalline Resin

Liquid crystalline resin indicates a melt processable polymer having a property of being able to form an optically anisotropic molten phase. The property of the anisotropic molten phase can be confirmed by a common method employing an orthogonal polarizer. More specifically, confirmation of the anisotropic molten phase can be performed using a Leitz polarizing microscope by observing a molten sample placed on a Leitz hot stage at a magnification of 40 times under a nitrogen atmosphere. When a liquid crystalline resin that can be employed in the present invention is examined between an orthogonal polarizer, polarized light normally penetrates even if in a molten stationary state, for example, and thus

exhibits anisotropy optically.

Although the above such liquid crystalline resin is not particularly limited, it is preferably an aromatic polyester or aromatic polyester amide, and a polyester partly containing aromatic polyester or aromatic polyester amide in the same molecular chain is also in the scope thereof. When these are melted at 0.1% by weight concentration in pentafluorophenol at 60°C, it is preferable to use a polyester having a inherent viscosity (I.V.) of at least about 2.0 dl/g, and more preferably 2.0 to 10.0 dl/g.

Particularly preferable as the aromatic polyester or aromatic polyester amide for liquid crystalline resins that can be employed in the present invention are an aromatic polyester, or aromatic polyester amide having at least one compound selected from the group of aromatic hydroxycarboxylic acid, aromatic hydroxylamine and aromatic diamine as a constituent component.

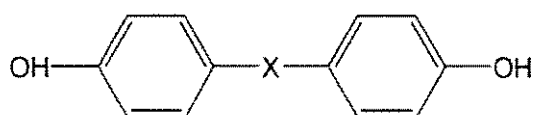
More specifically,

- (1) polyesters mainly composed of at least one of aromatic hydroxycarboxylic acid and derivatives thereof;
- (2) polyesters mainly composed of (a) at least one of aromatic hydroxycarboxylic acid and derivatives thereof, (b) at least one of aromatic dicarboxylic acid, alicyclic dicarboxylic acid and derivatives thereof; and (c) at least one of aliphatic diol, alicyclic diol, aliphatic diol and derivatives thereof;
- (3) polyester amides mainly composed of (a) at least one of aromatic hydroxycarboxylic acid and derivatives thereof, (b)

at least one of aromatic hydroxylamine, aromatic diamine and derivatives thereof, and (c) at least one of aromatic dicarboxylic acid, alicyclic dicarboxylic acid and derivatives thereof;

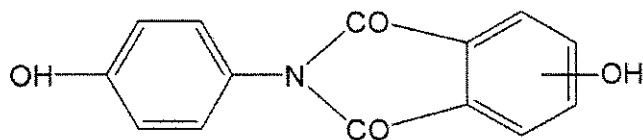
(4) polyester amides mainly composed of (a) at least one of aromatic hydroxycarboxylic acid and derivatives thereof, (b) at least one of aromatic hydroxylamine, aromatic diamine and derivatives thereof, (c) at least one of aromatic dicarboxylic acid, alicyclic dicarboxylic acid and derivatives thereof, and (d) at least one aromatic diol, alicyclic diol, aliphatic diol and derivatives thereof; etc. can be exemplified, and a molecular weight modifier may be further used together with the above-mentioned constituent components as necessary.

As preferred examples of specific compounds configuring the liquid crystalline resins that can be employed in the present invention, aromatic hydroxycarboxylic acids such as p-hydroxybenzoic acid, 6-hydroxy-2-napthoic acid, aromatic diols such as 2,6-naphthalenediol, 1,4-dihydroxynaphthalene, 4,4'-dihydroxybiphenyl, hydroquinone, resorcin, and compounds represented by the following general formula (A) and the following general formula (B); aromatic dicarboxylic acids such as terephthalic acid, isophthalic acid, 4,4'-diphenyldicarboxylic acid, 2,6-naphthalenedicarboxylic acid, and compounds represented by the following general formula (C); and aromatic amines such as p-aminophenol and p-phenylenediamine can be exemplified.

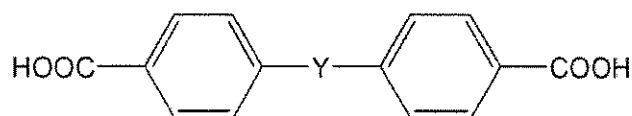


... (A)

(X: is a group selected from an alkylene (C_1 to C_4), alkydene, $-O-$, $-SO-$, $-SO_2-$, $-S-$ and $-CO-$.)



... (B)



... (C)

(Y: is a group selected from $-(CH_2)_n-$ ($n=1$ to 4) and $-O(CH_2)_nO-$ ($n=1$ to 4).)

Other Components

A composition imparted with a desired property by adding other resins, a nucleating agent, carbon black, pigment such as an inorganic calcined pigment, or an added agent such as an antioxidant, a stabilizer, a plasticizer, a lubricant, a mold release agent, a fire retardant, or the like to the liquid crystalline resin composition used in the present invention, in ranges not inhibiting the effects of the present invention, is also included in the liquid crystalline resin composition used in the present invention.

Method of Manufacturing Injection Molded Article

In the injection molding of the above-mentioned liquid crystalline resin composition, the method of manufacturing an injection molded article of the present invention uses a mold in which a heat-insulating layer is formed on a mold inner

surface, and performs injection molding at molding conditions satisfy the following formula (I), in which t_1 is the thickness of the heat-insulating layer (μm), S is the injection molding speed (mm/sec), t_2 is the thickness of the injection-molded article (mm), and T is the mold temperature ($^{\circ}\text{C}$).

$$(t_1 \times S) / t_2 + T \geq 1000 \cdots (I)$$

Mold

In the method of manufacturing an injection molded article of the present invention, a mold is used in which a heat-insulating layer is formed on an inner surface of the mold (surface on the inside of the mold). Due to the heat-insulating layer formed on the surface inside of the mold, it is difficult for the liquid crystalline resin composition streamed into the mold to solidify in the vicinity of the mold surface. As a result, the molecules contained in the resin composition prior to solidification contacting the resin composition that has solidified at the mold surface are drawn to the resin composition after solidification thereof, whereby it is possible to suppress the molecular orientation from increasing at the molded article surface.

So long as the heat-insulating layer formed on the inner surface of the mold acts to delay the solidification of the liquid crystalline resin composition at the mold surface, the materials and the like thereof are not particularly limited. In addition, a mold on which a heat-insulating layer is formed on a portion of the mold inner surface is also included as the

"mold in which a heat-insulating layer is formed in a mold inner surface. In the method of manufacturing an injection molded article of the present invention, it is necessary to form at least on the entirety of a mold inner surface portion corresponding to the portion of the molded article at which favorable appearance characteristics are desired, and it is preferable to form over the entirety of the mold inner surface.

The thickness (t_1) of the heat-insulating layer is not particularly limited if adjusted so as to satisfy the above formula (I) as described above. The thickness of the heat-insulating layer formed on the above-mentioned mold inner surface may be uniform, and may be contain a part of different thickness. In the case of the thickness of the heat-insulating layer not being uniform, the average thickness is defined as t_1 .

In addition, the thermal conductivity of the heat-insulating layer formed on the mold inner surface is particularly preferably no more than 5 W/(mK). By adjusting the thermal conductivity of the heat-insulating layer to the above-mentioned range, even if the injection molded article is molded at a mold temperature of 100°C or less, the molded article surface will not peel off while performing ultrasonic cleaning or the like, and thus an injection molded article having a superior appearance is more easily obtained. It should be noted that the above-mentioned thermal conductivity indicates the thermal conductivity measured by the method described in the Examples.

In addition, since a liquid crystalline resin composition of high temperature is poured into the mold during injection molding, the heat-insulating layer must have a heat-resisting property so as to withstand the high temperatures during molding.

The heat-insulating layer formed on the inner surface of the mold to be used in the method of manufacturing an injection molded article of the present invention preferably contains polyimide resin. This is because the polyimide resin has the above-mentioned thermal conductivity of no more than 5 W/(mK), and has a heat-resisting property to adequately withstand the high temperatures during injection molding. As specific examples of polyimide resins that can be used, a pyromellitic acid (PMDA)-based polyimide, biphenyltetracarboxylic acid-based polyimide, polyamide-imide using trimellitic acid, bismaleimide-based resin (bismaleimide/triazine-based or the like), benzophenonetetracarboxylic acid-based polyimide, acetylene-terminated polyimide, a thermoplastic polyimide, and the like can be exemplified. It should be noted that a heat-insulating layer composed of a polyimide resin is particularly preferable. As preferable materials other than polyimide resin, for example, a tetrafluoroethylene resin or the like can be exemplified.

The method of forming the heat-insulating layer on the inner surface of the mold is not particularly limited. For example, forming the heat-insulating layer on the inner

surface of the mold by the following method is preferable.

A method of forming a heat-insulating layer such as a polyimide film by coating a solution of a polymer precursor such as a polyimide precursor that can form a polymeric heat-insulating layer onto the mold surface, heating the solvent to evaporate, and then polymerizing by superheating; a method of vapor deposition polymerizing a monomer for a heat resistant polymer, e.g., pyromellitic anhydride and 4,4-diaminodiphenyl ether; or on a mold of planar shape, a method of forming heat-insulating layer adhered on a desired portion of a mold using a suitable fastening technique employing a polymeric heat-insulating film or a polymeric heat-insulating film of adhesive-tape form can be exemplified. In addition, it is also possible to form a polyimide film, and further form a chrome (Cr) film or titanium nitride (TiN) film as a metallic skin layer on this surface.

Molding Conditions

The method of manufacturing an injection molded article of the present invention is characterized in performing injection molding under molding conditions that satisfy the relational formula of the following formula (I), in which t_1 is the thickness of the heat-insulating layer (μm), S is the injection molding speed (mm/sec), t_2 is the thickness of the injection-molded article (mm), and T is the mold temperature ($^{\circ}\text{C}$).

$$(t_1 \times S) / t_2 + T \geq 1000 \cdots (I)$$

By manufacturing the injection molded article under the

above such conditions, the boundary between the outer layer and skin layer in the injection molded article obtained will not exist in at least a portion of the injection molded article, as described below. Surface peeling of the injection molded article is caused by peeling of the outer layer further formed on the skin layer; however, in the present invention, an injection molded article that does not have this outer layer in at least a portion of the injection molded article is obtained. As a result, it is possible to obtain a high-quality injection molded article superior in the appearance and without peeling of the surface even if ultrasonically cleaned.

The injection molded article obtained by the method of manufacturing of the present invention is characterized by eliminating the boundary between the outer layer and the skin layer of the injection molded article at least in one part thereof. As a result of such an injection molded article being obtained, the effect of suppressing surface peeling of the injection molded article is remarkably raised. The injection molded article having superior appearance for which peeling of the molded article surface is extremely reduced in this way is assumed to be obtained by preventing the liquid crystalline resin composition poured into the mold from immediately solidifying, and suppressing the molecules in the resin composition prior to solidification from being drawn by the solidified resin composition, and the molecular orientation from increasing at the molded article surface.

The heat-insulating layer has a function of suppressing

the resin composition from immediately solidifying at the mold surface when the liquid crystalline resin composition in the molten state is poured to the mold as described in the foregoing.

By improving the injection speed, the time for the resin composition to be filled into the mold shortens. In other words, the filling of the liquid crystalline resin composition into the mold can be completed at a stage at which solidifying of the liquid crystalline resin compositions has not progressed too much. As a result, it is possible to suppress the molecules of a portion prior to solidifying from being drawn by the hardened resin composition, and the molecular orientation from increasing at the molded article surface.

A long time is required to fill the liquid crystalline resin composition into the mold when the thickness of the injection molded article is excessively thick. As a result, when the thickness of the injection molded article is excessively thick, a phenomenon tends to occur whereby molecules of a portion prior to solidifying are drawn by the solidified resin composition and the molecular orientation at the molded article surface increases.

By setting the mold temperature T to be high, it is possible to delay the solidifying of the liquid crystalline resin composition in the vicinity of the inside surface of the mold in particular. As a result, it is possible to suppress a phenomenon whereby molecules of a portion prior to solidifying are drawn by the solidified resin composition and the

molecular orientation at the molded article surface increases.

The characteristic of the present invention is in the aspect of having found that the boundary between the outer layer and skin layer of an injection molded article surface is eliminated by adjusting such that the heat-insulating layer thickness t_1 (μm), injection speed S (mm/sec), mold temperature T ($^{\circ}\text{C}$), and injection molded article thickness t_2 (mm) satisfy the above formula (I).

Then, with the present invention, a superior injection molded article in various forms (particularly in a case of t_2 (mm) being thick as well) can be manufactured by adjusting the injection speed S (mm/sec), heat-insulating layer thickness t_1 (μm), and mold temperature T ($^{\circ}\text{C}$). This is because, if satisfying the above formula (I), the boundary between the outer layer and skin layer of the injection molded article will not exist at least in a portion.

In addition, by injection molding at molding conditions satisfying the following formula (II), it becomes more difficult for surface peeling to occur, and it is possible to obtain an injection molded article having a remarkably superior appearance. More specifically, by performing injection molding at conditions satisfying the following formula (II), it becomes easier for a molded article to be obtained in which a boundary between the outer layer and skin layer is entirely nonexistent. Hereinafter, the manufacturing conditions of the manufacturing method of the present invention will be explained in detail.

$$(t_1 \times S) / t_2 + T \geq 2000 \dots (II)$$

First, the heat-insulating layer thickness t_1 (μm) will be explained. So long as the heat-insulating layer thickness t_1 is adjusted so as to satisfy the above formula (I), this thickness is not particularly limited. Although differing depending on the type of liquid crystalline resin composition used, shape of the injection molded article, and the like, it is preferable to adjust the heat-insulating layer thickness t_1 to 1 μm to 1000 μm in the manufacturing method of the present invention. Adjusting the heat-insulating layer thickness to at least 1 μm is preferable in order for a suitable heat-insulating effect to be achieved, and adjusting to no more than 1000 μm is preferable for the reason of the precision of the molded article. More preferably, the heat-insulating layer thickness t_1 is from 10 μm to 300 μm .

Next, the injection speed S (mm/sec) will be explained. Similarly to the above-mentioned heat-insulating layer thickness t_1 , the injection speed S only needs to be adjusted so as to satisfy the above formula (I). Although differing depending on the type of liquid crystalline resin composition used, shape of the injection molded article, and the like, it is preferable to adjust the injection speed S in the range of 20 mm/sec to 1000 mm/sec in the manufacturing method of the present invention. Adjusting the injection speed to at least 20 mm/sec is preferable due to being able to prevent hesitation, and adjusting the injection speed to no more than 1000 mm/sec is preferable due to being able to prevent jetting.

More preferably, the injection speed is from 50 mm/sec to 500 mm/sec.

Next, the mold temperature T ($^{\circ}\text{C}$) will be explained. Similarly to the above heat-insulating layer thickness t_1 and the like, the mold temperature T only needs to be adjusted so as to satisfy the above formula (I). Although differing depending on the type of liquid crystalline resin composition used, shape of the injection molded article, and the like, it is preferable to adjust the mold temperature T to no higher than 100°C in the manufacturing method of the present invention. By setting the mold temperature to no higher than 100°C , the temperature regulation of the mold can be performed using water, and a high-quality injection molded article can be obtained easily. More preferably, the range of mold temperature is from 50° to 100°C .

By adjusting the above-mentioned heat-insulating layer thickness t_1 , injection speed S , and mold temperature T , it is possible to adjust the injection molded article thickness t_2 in a wide range. More specifically, under the conditions satisfying the above formula (I), it is possible to adjust the injection molded article thickness t_2 to 0.2 mm to 10 mm. Under the conditions satisfying the above formula (II), it is possible to set t_2 to 0.2 mm to 5 mm. Although the above problems tend to arise particularly in the range of the injection molded article thickness t_2 of 0.2 mm to 3 mm, it is possible to easily obtain a high-quality injection molded article having superior appearance without surface peeling by

molding according to the manufacturing method of the present invention.

Injection Molded Article

When the liquid crystalline resin composition is molded, a multi-layer structure is formed. FIG. 1 shows multi-layered structures (from the central portion to surface portion) of injection molded articles obtained by the manufacturing method of the present invention. As shown in FIG. 1A, a boundary between the outer layer and skin layer does not exist in the injection molded article obtained by the manufacturing method of the present invention at least in a portion of the molded article surface. Therefore, even if performing ultrasonic cleaning or the like on an injection molded article obtained by way of the manufacturing method of the present invention, a portion at which surface peeling occurs is decreased, as shown in FIG. 1B.

In contrast, FIG. 2 shows multi-layered structures (from the central portion to surface portion) of injection molded articles obtained according to a manufacturing method of the conventional technology. As shown in FIG. 2A, an outer layer exists at the entire surface of the injection molded article. Therefore, when performing ultrasonic cleaning or the like on the injection molded article obtained according to the manufacturing method of the conventional technology, surface peeling occurs at the entire surface, as shown in FIG. 2B.

Furthermore, FIG. 3 shows the multi-layered structure (from the central portion to surface portion) of an injection

molded article manufactured under conditions satisfying the above formula (II). As shown in FIG. 3, even among the injection molded articles obtained according to the manufacturing method of the present invention, a boundary between the outer layer and skin layer tends to be entirely nonexistent for the injection molded article manufactured under conditions satisfying the above formula (II). Therefore, even if performing ultrasonic cleaning or the like, an injection molded article is formed for which it is remarkably difficult for surface peeling to occur.

As in the foregoing, the injection molded article obtained by way of the manufacturing method of the present invention has a superior appearance, without peeling of the surface occurring, even if performing ultrasonic cleaning. Furthermore, by setting the mold temperature to no more than 100°C, a high-quality injection molded article can be obtained easily.

EXAMPLES

Hereinafter, the present invention will be explained in further detail based on Examples; however, the present invention is not to be limited by these Examples.

Materials

Liquid crystalline resin 1: "Vectra (registered trademark) E130i", containing glass fiber 30% by mass, melting point 335°C, melt viscosity 40 Pa·s (manufactured by Polyplastics Co., Ltd.)

Heat-insulating layer formation material 1: polyimide resin

tape (manufactured by Sumitomo 3M Limited), thermal conductivity 0.2 W/(mK)

Heat-insulating layer formation material 2: polyimide resin varnish (manufactured by Fine Chemicals Japan), thermal conductivity 0.2 W/(mK)

Heat-insulating layer formation material 3: polyimide resin film (manufactured by DuPont Toray Co., Ltd.), thermal conductivity 0.2 W/(mK)

The thermal conductivities of the above-mentioned polyimide resins were calculated by measuring the coefficient of thermal diffusivity according to the laser flash method, the specific gravity according to the Archimedes method, and the specific heat using a DSC.

Example 1

Using the liquid crystalline resin 1 as a molding material, the heat-insulating layer formation material 1 was pasted on the mold cavity surface of a mold for sheet molding with 20 mm width, 50 mm length, and 0.5 mm thickness, and molding was performed under molding conditions such as the injection speed and the mold temperature in Table 1, whereby an injection molded article was obtained. It should be noted that the conditions other than the molding conditions shown in the table are as follows.

Molding Conditions

Cylinder set temperature: 350°C

Screw rotation speed: 150 rpm

Example 2

Using the liquid crystalline resin 1 as a molding material, the heat-insulating layer formation material 2 was sprayed onto the mold cavity surface of a mold for sheet molding of a 40 mm square with 1 mm thickness, baked for one hour, after which the polyimide surface was polished to adjust to the heat-insulating layer thickness in Table 1, and then molding was performed under molding conditions such as the injection speed and the mold temperature in Table 1, whereby an injection molded article was obtained. It should be noted that the molding conditions other than those shown in Table 1 are the same as Example 1.

Example 3

An injection molded article was manufactured by the same method as Example 2 except for changing the molding conditions to the conditions shown in Table 1. It should be noted that the molding conditions other than those shown in Table 1 are similar to Example 1.

Example 4

Using the liquid crystalline resin 1 as a molding material, the heat-insulating layer formation material 3 was applied with double-sided tape onto the mold cavity surface of an ISO standard test piece mold, and molding was performed under molding conditions such as the injection speed and the mold temperature in Table 1, whereby an injection molded article was obtained. It should be noted that the molding conditions other than those shown in Table 1 are the same as Example 1.

Example 5

An injection molded article was manufactured by the same method as Example 4 except for changing the molding conditions to the conditions shown in Table 1. It should be noted that the molding conditions other than those shown in Table 1 are the same as Example 1.

Comparative Example 1

An injection molded article was manufactured by the same method as Example 4 except for changing the molding conditions to the conditions shown in Table 1. It should be noted that the molding conditions other than those shown in Table 1 are the same as Example 1.

Comparative Example 2

An injection molded article was manufactured by the same method as Example 1 except for a heat-insulating layer not being formed in the mold.

Comparative Example 3

An injection molded article was manufactured by the same method as Comparative Example 2 except for changing the molding conditions to the conditions shown in Table 1. It should be noted that the molding conditions other than those shown in Table 1 are the same as Example 1.

Evaluation of Molded Articles

Cross-cut adhesion test evaluation and ultrasonic cleaning test evaluation were carried out on the injection molded articles of the Examples and Comparative Examples.

Cross-cut Adhesion Test Evaluation

The evaluation was performed by a method based on JIS

K5400, and evaluation was performed by the number of grid cells peeled among one hundred 1-mm square grid cells. The evaluation test results are shown in Table 1.

Ultrasonic Cleaning Test Evaluation

The injection molded articles of the Examples and Comparative Examples were immersed in water, ultrasonic cleaning was conducted for 1 minute, and the fibril generation situation of the surface was measured as a whitening phenomenon of the surface, whereby the existence of fibril generation was evaluated. The evaluation test results are shown in Table 1.

[table 1]

		Exam ple 1	Exam ple 2	Exam ple 3	Exam ple 4	Exam ple 5	Comp arat ive Exam ple 1	Comp arat ive Exam ple 2	Comp arat ive Exam ple 3
PI Film Thickness (t1) (μ m)		70	10	20	125	125	125	0	0
injection speed (S) (mm/sec)		50	200	100	50	200	15	200	200
Molded Article Thickness (t2) (mm)		0.5	1	1	4	4	4	0.5	0.5
mold temperature (T) (°C)		80	100	100	100	100	80	80	140
$(t1 \times S)/t2+T$		7080	2100	2100	1662.5	6350	548.75	80	140
Cross- cut Adhesion Test Evaluati on	the peeli ng numbe r	0	0	0	23	0	100	100	100
Ultrason ic Cleaning Test Evaluati on	Exist ence of Fibri l Gener ation	Non- Exis tenc e	Non- Exis tenc e	Non- Exis tenc e	Exis tenc e	Non- Exis tenc e	Exis tenc e	Exis tenc e	Exis tenc e

[0073]

As is evident from Table 1, it has been clarified that surface peeling does not easily occur in the injection molded article obtained by the manufacturing method of present invention, as is evident from the peeling number in the cross-cut adhesion test evaluation. Since surface peeling does not easily occur in the injection molded article obtained according to the manufacturing method of the present invention in this way, it is possible to maintain a clean appearance.

In addition, as is evident from Table 1, a result of fibril generation entirely no occurring was obtained from the ultrasonic cleaning test evaluation for Examples 1 to 3 and 5. It has been confirmed for Examples 1 to 3 and 5 that a boundary between the outer layer and skin layer does not exist in the injection molded article surface. In addition, although fibril generation of the surface occurred in Example 4, the generated area thereof is extremely small when compared with the generated area of fibrillation occurring in the molded article surface of the Comparative Examples. Therefore, it has been confirmed that a boundary between the outer layer and skin layer exists in a part of Example 4.

It has been confirmed that the manufacturing method of the present invention can manufacture a high-quality injection molded article even under conditions of a mold temperature no higher than 100°C.

As is evident from the results of Examples 1 to 3 and 5 and the result of Example 4, it has been confirmed that a superior injection molded article is obtained for which a boundary between the outer layer and skin layer does not exist, by performing manufacturing of the injection molded article under conditions satisfying the above formula (II).

CLAIMS

1. A method of manufacturing an injection-molded article by injection molding of a liquid crystal resin composition, wherein injection molding is performed using a mold having a heat-insulating layer formed on a mold inner surface, and under molding conditions that satisfy the following formula (I), wherein t_1 is thickness of the heat-insulating layer (μm), S is injection molding speed (mm/sec), t_2 is thickness of the injection-molded article (mm), and T is mold temperature ($^{\circ}\text{C}$).

$$(t_1 \times S) / t_2 + T \geq 1000 \cdots (I)$$

2. The method of manufacturing an injection-molded article according to claim 1, wherein injection molding is performed under molding conditions that satisfy the following formula (II).

$$(t_1 \times S) / t_2 + T \geq 2000 \cdots (II)$$

3. The method of manufacturing an injection-molded article according to claim 1 or 2, wherein the heat-insulating layer has a thermal conductivity of no more than 5 W/(mK) .

4. The method of manufacturing an injection-molded article according to any one of claims 1 to 3, wherein the heat-insulating layer includes a polyimide resin.

5. The method of manufacturing an injection-molded article

according to any one of claims 1 to 4, wherein the mold temperature T is no greater than 100°C.