

DESCRIPTION

METHOD FOR TRANSPORTING AND METHOD FOR STORING POLYMER PELLETS

5 TECHNICAL FIELD

The present invention relates to a method for transporting and a method for storing polymer pellets, more particularly, it relates to methods suitable for transporting and storing hygroscopic polymer pellets.

10 BACKGROUND ART

A polymer of e.g. a polycarbonate, a polyester or a polyamide, after a polycondensation reaction or the like in a predetermined production apparatus, is usually extruded into strands in a molten state, cooled with cooling water and then formed into pellets e.g. by a cutter as a finished product. In such a case, pellets of a polymer (hereinafter referred to as "polymer pellets") are
15 subjected to a predetermined drying means to remove water adsorbed on the surface or in the interior, pneumatically transported through a predetermined transportation piping in a stream of a pressure gas, and temporarily stored in a storage container such as a storage silo for inspection, shipping or the like.

As a method of drying polymer pellets, for example, Patent Document 1 discloses a method
20 of supplying pellets of a resin molding material to a storage capsule, and deaerated and dried by vacuum treatment.

Patent Document 1: JP-A-6-134764

DISCLOSURE OF THE INVENTION

25 OBJECT TO BE ACCOMPLISHED BY THE INVENTION

In general, if a compressed air to be used for pneumatically transporting polymer pellets or a gas in a storage container to store the polymer pellets contains water, hygroscopic polymer pellets adsorb water contained in the gas. In such a case, for example, a resin such as a polyester may undergo hydrolysis by the adsorbed water, and accordingly it is necessary to remove the adsorbed
30 water by a post-treatment such as drying.

However, a method of carrying out such a post-treatment not only requires an excessive equipment but also is problematic in view of energy saving.

Further, the polymer pellets have a sensible heat carried over from the molten state. Accordingly, when the strands in an molten state are cooled with the cooling water and formed into
35 pellets, in a step of pneumatically transporting the polymer pellets, water attached to the surface of the polymer pellets evaporates as a water vapor to the gas used for pneumatic transportation by the sensible heat.

In a case where the polymer pellets to be pneumatically transported have a high temperature, there is low possibility that the water vapor in the gas adheres to the surface of the polymer pellets again or diffuses into the interior of the polymer pellets. However, if the polymer pellets are cooled during the pneumatic transportation or in a storage container to which the polymer pellets are transported by the pneumatic transportation, there is possibility that the water is adsorbed in the polymer pellets again and finally included in the interior of the pellets. Particularly, such a phenomenon is likely to occur in a case where hygroscopic polymer pellets are pneumatically
45 transported. Accordingly, depending on the type of the polymer, the hydrolysis of the polymer, troubles in molding, etc. may occur.

By the way, an aromatic polycarbonate obtained by subjecting an aromatic dihydroxy compound such as bisphenol A and a diester carbonate such as diphenyl carbonate to a

polycondensation reaction by an ester exchange reaction, which is excellent in impact resistance and transparency, has been widely used for optical materials, etc. Particularly, an aromatic polycarbonate having a relatively low molecular weight is suitable for melt molding which requires heat resistance and flowability, and is particularly useful as an optical recording material such as an optical disk.

Such an aromatic polycarbonate having a relatively low molecular weight has such a tendency that the mechanical strength of a molded product to be obtained by using such an aromatic polycarbonate is dramatically decreased when hydrolysis occurs due to water adsorbed on the surface or in the interior of the polymer pellets, and accordingly no high quality optical disk or the like can be obtained.

Further, if melt molding is carried out at a high temperature of, for example, about 350°C, while water is adsorbed in the polymer pellets, surface defects such as silver streaks may occur on the surface of a molded product such as a disk, thus leading to a trouble in quality fatal as an optical recording material.

Under these circumstances, the present invention has been made to overcome the above problems of prior art.

That is, the object of the present invention is to provide a method for transporting polymer pellets, which comprises pneumatically transporting hygroscopic polymer pellets, by a simple means without an increase in the moisture content of the polymer pellets, and a method for storing polymer pellets.

In the present invention, the hygroscopic polymer pellets are pellets of a polymer having an equilibrium water absorption in water at 23°C of at least 0.1 wt% measured in accordance with ASTM D570.

MEANS TO ACCOMPLISH THE OBJECT

To achieve the above object, the present inventors have conducted extensive studies and as a result, found that by preliminarily removing water contained in a gas by a dehumidifier to adjust the dew point of the gas, and by carrying out pneumatic transportation of polymer pellets using such a gas having the dew point adjusted, the moisture content of the polymer pellets will not increase. They have accomplished the present invention based on this finding.

According to the present invention, a method for transporting polymer pellets, which comprises pneumatically transporting hygroscopic polymer pellets using a gas having a dew point of at most 0°C is provided.

The polymer pellets to be pneumatically transported are preferably pellets of a polycarbonate, a polyester or a polyamide.

Further, the polymer pellets to be pneumatically transported by the gas are preferably pellets of an aromatic polycarbonate having a viscosity average molecular weight (Mv) of from 10,000 to 17,000.

Further, the polymer pellets to be pneumatically transported by the gas are preferably pellets of an aromatic polycarbonate obtained by a melt polycondensation reaction using an aromatic dihydroxy compound and a diester carbonate as raw materials in the presence of an ester exchange catalyst.

Further, the gas to be used for the pneumatic transportation of the polymer pellets is preferably the air.

Further, the polymer pellets pneumatically transported by the gas having a dew point of at most 0°C has a moisture content of preferably at most 0.1 wt%, more preferably at most 0.05 wt%, furthermore preferably at most 0.02 wt%.

Further, the present invention provides a method for pneumatically transporting polymer

pellets, pneumatically transporting polymer pellets through a transportation piping together with a stream of a pressure gas, which comprises a gas dehumidification step of reducing the water content in a gas used for pneumatic transportation of the polymer pellets to adjust the dew point of the gas to at most 0°C, a gas compression step of compressing the gas having its dew point adjusted to at most 0°C in the gas dehumidification step, a pressure gas supplying step of supplying the pressure gas compressed in the gas compression step to a transportation piping at a rate of 50 Nm³/hr to 600 Nm³/hr per 1 ton of the polymer pellets, and a transportation step of pneumatically transporting the polymer pellets through the transportation piping together with a stream of the pressure gas supplied to the transportation piping in the pressure gas supplying step.

In the gas dehumidification step in the method for pneumatically transporting polymer pellets of the present invention, it is preferred to reduce the water content in the gas to be used for the pneumatic transportation of the polymer pellets to adjust the dew point of the gas to be used for the pneumatic transportation of the polymer pellets to at most -10°C.

Further, in the transportation step, it is preferred to pneumatically transport the polymer pellets together with a stream of a pressure gas supplied to the transportation piping to a storage facility preliminarily filled with a gas having a dew point of at most 0°C.

Further, the polymer pellets are preferably pellets of an aromatic polycarbonate having a viscosity average molecular weight (Mv) of from 10,000 to 17,000, and the pellets preferably contain phosphorous atoms in an amount of from 0.5 ppm to 10 ppm as calculated as weight.

Still further, the present invention provides a method for storing polymer pellets, which comprises filling a storage container with a gas having a dew point of at most 0°C, and storing hygroscopic polymer pellets in the storage container.

Further, the polymer pellets stored in the storage container preferably have a moisture content of at most 0.1 wt%.

EFFECTS OF THE INVENTION

According to the present invention, even when polymer pellets are hygroscopic, the polymer pellets can be pneumatically transported and stored by an easy means without moisture adsorption.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram illustrating one example of an aromatic polycarbonate production apparatus.

Fig. 2 is a diagram illustrating one example of a method for transporting and a method for storing polymer pellets according to an embodiment of the present invention.

MEANINGS OF SYMBOLS

2a: first raw material preparation tank, 2b: second raw material preparation tank, 3a, 3b: anchor agitating blade, 4a: raw material supply pump, 5a: catalyst supply port, 6a: first vertical reactor, 6b: second vertical reactor, 6c: third vertical reactor, 7a, 7b, 7c: Maxblend blade, 8a, 8b, 8c, 8d: distillation pipe, 9a: fourth horizontal reactor, 10a: agitating blade, 11a: extruder, 12a, 12b, 12c: additive supply port, 13a: strand cooling equipment, 14a: cutter, 14b: centrifugal dehydrator, 15a: sieving machine, 15b: pellets supply port, 16a, 16b: storage silo, 17: dehumidifier, 21: air supply port, 22: air discharge outlet, 23, 24, 25: air transportation piping, 26a, 26b: pellet outlet piping

BEST MODE FOR CARRYING OUT THE INVENTION

Now, the best mode for carrying out the present invention (hereinafter referred to as an embodiment of the present invention) will be described in detail. However, the present invention is by no means restricted to the embodiment, and various changes and modifications are possible

within a scope of the invention. Further, drawings are to illustrate the embodiment of the present invention and does not represent the actual size.

In the following description, the embodiment of the present invention will be described with reference to a polycarbonate as the polymer.

A polycarbonate is an engineering plastic excellent in mechanical properties such as impact resistance and also excellent in heat resistance, transparency, etc., and is thereby widely used for OA components, automobile components, building materials, etc.

Heretofore, as a method for producing a polycarbonate, a so-called interface method of using an aromatic dihydroxy compound such as a bisphenol compound and a carbonyl dichloride (phosgene) as raw materials, and a so-called melting method of subjecting an aromatic dihydroxy compound and a diester carbonate to ester exchange in a molten state to obtain an aromatic polycarbonate while a low molecular weight compound such as a phenol formed as a by-product is removed outside the system have been known.

In recent years, the latter melting method attracts attention since the former interface method has drawbacks such as use of phosgene harmful to the human body, use of a solvent with a high environmental burden such as dichloromethane, and a high load in waste water disposal.

In a case where an aromatic polycarbonate is produced by the melting method, 2,2-bis(4-hydroxyphenyl)propane (usually called "bisphenol A") or the like is used as the aromatic dihydroxy compound, diphenyl carbonate or the like is used as the diester carbonate, and an alkali metal compound, an alkaline earth metal compound, a basic compound or the like is used as the ester exchange catalyst. They are mixed, melted and subjected to a polycondensation reaction in a multi-stage procedure using a plurality of reactors (polycondensation step).

After the polycondensation reaction, various additives are respectively supplied in an extruder, and strands of the aromatic polycarbonate discharged from the extruder are cooled with cooling water by means of a strand bath or the like, and cut and pelletized by a cutter such as a strand cutter. Finally, the pellets are subjected to water removal by e.g. a centrifugal dehydrator and then transported to a storage silo as a storage container. During this procedure, the method for transporting and the method for storing polymer pellets of the present invention are applied.

The polycarbonate to be used in the embodiment of the present invention is preferably an aromatic polycarbonate obtained by continuously carrying out a melt polycondensation reaction using an aromatic dihydroxy compound and a diester carbonate as raw materials in the presence of an ester exchange catalyst. Particularly, among such aromatic polycarbonates, an aromatic polycarbonate having a relatively low molecular weight, having a viscosity average molecular weight (Mv) of at most 17,000, preferably at most 16,000, is suitable for melt molding which requires heat resistance and fluidity. Particularly, such an aromatic polycarbonate having a relatively low molecular weight is useful as a material of a substrate for an optical disk to be formed by injection molding usually at a high temperature of about 350°C, as an optical recording material. However, the viscosity average molecular weight (Mv) of an aromatic polycarbonate is usually at least 10,000, preferably at least 12,000.

Further, an aromatic polycarbonate obtained by the above-described melt polycondensation reaction, is formed into a finished product as pellets to which a phosphorous compound as a thermal stabilizer is added, in the latter half of the production process as described hereinafter. Such a phosphorous compound is hygroscopic in general and in addition, it functions as a catalyst to hydrolyze an aromatic polycarbonate in some cases, and it may accelerate the hydrolyzability of the aromatic polycarbonate as a finished product. In a case where pellets of such an aromatic polycarbonate having hygroscopicity and susceptible to hydrolysis are pneumatically transported, it is possible to transport and store the pellets without humidification of the pellets by use of a gas having a dew point of at most 0°C.

Here, the dew point of a gas is usually a temperature at which the partial pressure of water vapor in a gas is the saturated water vapor pressure, and is a temperature at which water contained in the gas which is gradually cooled starts condensing and being formed into dews.

In the embodiment of the present invention, pellets of e.g. an aromatic polycarbonate being hygroscopic means that the pellets have an equilibrium moisture content of at least 0.1 wt%.

Further, the equilibrium moisture content is a moisture content when moisture absorption and moisture desorption apparently reach equilibrium in a state at a temperature of 30°C at a humidity of 70%.

Further, in the embodiment of the present invention, the moisture content of the pellets is a proportion (wt%) of the difference in the weight ($m_1 - m_2$) between the predetermined weight m_1 (from 0.2 g to 1 g in the embodiment of the present invention) of the pellets and the weight m_2 of the pellets measured after heat dried at 250°C to the weight m_1 of the pellets before drying.

In the embodiment of the present invention, the moisture content of the pellets is measured by a coulometric titration method using a predetermined moisture content measuring apparatus and a water vaporizing apparatus.

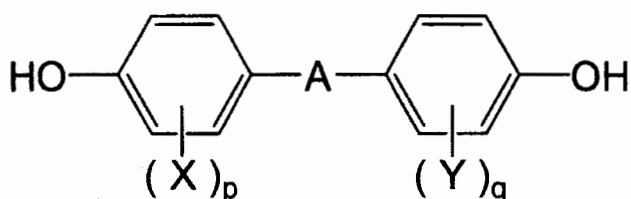
Pellets of a polymer such as a aromatic polycarbonate are shipped as a finished product usually in a state of a moisture content of at most 0.1 wt%. In the embodiment of the present invention, it is possible to maintain the moisture content of the polymer pellets to at most 0.1 wt% by controlling the dew point of the gas to be used for pneumatic transportation to at most 0°C.

Now, a method for producing an aromatic polycarbonate by continuously carrying out a melt polycondensation reaction using an aromatic dihydroxy compound and a diester carbonate as raw materials in the presence of an ester exchange catalyst will be described in detail below.

(Aromatic Dihydroxy Compound)

The aromatic dihydroxy compound to be used in the embodiment of the present invention may be a compound represented by the following formula (1):

Formula (1)



wherein A is a single bond, a C_{1-10} linear, branched or cyclic bivalent hydrocarbon group which may be substituted, or a bivalent group represented by -O-, -S-, -CO- or -SO₂-; each of X and Y which are independent of each other, is a halogen atom or a C_{1-6} hydrocarbon group; and each of p and q is an integer of from 0 to 2, provided that X and Y, and p and q, may be the same or different, respectively.

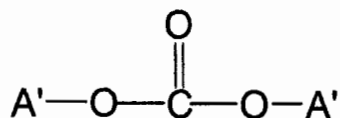
The aromatic dihydroxy compound may, for example, be specifically a bisphenol such as bis(4-hydroxydiphenyl)methane, 2,2-bis(4-hydroxyphenyl)propane, 2,2-bis(4-hydroxy-3-methylphenyl)propane, 2,2-bis(4-hydroxy-3-t-butylphenyl)propane, 2,2-bis(4-hydroxy-3,5-dimethylphenyl)propane, 2,2-bis(4-hydroxy-3,5-dibromophenyl)propane, 4,4-bis(4-hydroxyphenyl)heptane or 1,1-bis(4-hydroxyphenyl)cyclohexane; a biphenol such as 4,4'-dihydroxybiphenyl or 3,3',5,5'-tetramethyl-4,4'-dihydroxybiphenyl; bis(4-hydroxyphenyl) sulfone, bis(4-hydroxyphenyl) sulfide, bis(4-hydroxyphenyl) ether or bis(4-hydroxyphenyl) ketone.

Among them, 2,2-bis(4-hydroxyphenyl)propane ("bisphenol A", hereinafter sometimes abbreviated as BPA) is preferred. Such aromatic dihydroxy compounds may be used alone or as a mixture of two or more of them.

(Diester Carbonate)

The diester carbonate to be used in the embodiment of the present invention may be a compound represented by the following formula (2):

Formula (2)



5 wherein A' is a C₁₋₁₀ linear, branched or cyclic monovalent hydrocarbon group which may be substituted, provided that two A's may be the same or different.

The diester carbonate may, for example, be specifically a substituted diphenyl carbonate such as diphenyl carbonate or ditolyl carbonate; dimethyl carbonate, diethyl carbonate or di-t-butyl carbonate.

10 Among them, diphenyl carbonate (hereinafter sometime abbreviated as DPC) or a substituted diphenyl carbonate is preferred. Such carbonate diesters may be used alone or as a mixture of two or more of them.

Further, preferably at most 50 mol%, more preferably at most 30 mol% of the above diester carbonate may be replaced by a dicarboxylic acid or a dicarboxylate.

15 As a representative dicarboxylic acid or dicarboxylate, for example, terephthalic acid, isophthalic acid, diphenyl terephthalate or diphenyl isophthalate, may, for example, be mentioned. In a case where the diester carbonate is replaced by such a dicarboxylic acid or dicarboxylate, a polyester carbonate will be obtained.

20 Such a diester carbonate (including the above-describe dicarboxylic acid and dicarboxylate for replacement) is used in an excessive amount to the aromatic dihydroxy compound.

That is, the diester carbonate is used in a molar ratio of from 1.01 to 1.30, preferably from 1.02 to 1.20 to the aromatic dihydroxy compound. If the molar ratio is excessively low, terminal OH groups in the aromatic polycarbonate to be obtained will increase, and thermal stability of the aromatic polycarbonate to be obtained tends to be deteriorated. Further, if the molar ratio is
25 excessively high, the reaction rate in the ester exchange tends to decrease, whereby production of an aromatic polycarbonate having a desired molecular weight tends to be difficult and in addition, the amount of remaining unreacted diester carbonate tends to increase, which may be a cause of odor during molding processing or in molded products.

(Ester Exchange Catalyst)

30 The ester exchange catalyst to be used in the embodiment of the present invention may be usually a catalyst to be used for a production of an aromatic polycarbonate by an ester exchange method and is not particularly limited. In general, it may, for example, be a basic compound such as an alkali metal compound, a beryllium compound, a magnesium compound, an alkaline earth metal compound, a basic boron compound, a basic phosphorous compound, a basic ammonium
35 compound or an amine compound.

Among such ester exchange catalyst, an alkali metal compound is practically preferred. Such ester exchange catalysts may be used alone or in combination of two or more of them. The amount of the ester exchange catalyst is usually from 1×10^{-9} to 1×10^{-1} mol, preferably from 1×10^{-7} to 1×10^{-2} mol per 1 mol of the aromatic dihydroxy compound.

40 The alkali metal compound may, for example, be an inorganic alkali metal compound such as a hydroxide, a carbonate or a hydrogen carbonate compound of an alkali metal; or an organic alkali metal compound such as an alcohol, a phenol or a salt with an organic carboxylic acid of an alkali metal. The alkali metal may, for example, be lithium, sodium, potassium, rubidium or cesium.

Among such alkali metal compounds, a cesium compound is preferred, and cesium carbonate,

cesium hydrogen carbonate, cesium hydroxide or the like is particularly preferred.

The beryllium compound, the magnesium compound or the alkaline earth metal compound may, for example, be an inorganic alkaline earth metal compound such as a hydroxide or a carbonate of beryllium, magnesium or an alkaline earth metal; or an alcohol, a phenol or a salt with an organic carboxylic acid of such a metal. The alkaline earth metal may, for example, be calcium, strontium or barium.

The basic boron compound may, for example, be a sodium salt, a potassium salt, a lithium salt, a calcium salt, a magnesium salt, a barium salt or a strontium salt of a boron compound. The boron compound may, for example, be tetramethyl boron, tetraethyl boron, tetrapropyl boron, tetrabutyl boron, trimethylethyl boron, trimethylbenzyl boron, trimethylphenyl boron, triethylmethyl boron, triethylbenzyl boron, triethylphenyl boron, tributylbenzyl boron, tributylphenyl boron, tetraphenyl boron, benzyltriphenyl boron, methyltriphenyl boron or butyltriphenyl boron.

The basic phosphorous compound may, for example, be a trivalent phosphorous compound such as triethylphosphine, tri-n-propylphosphine, triisopropylphosphine, tri-n-butylphosphine, triphenylphosphine or tributylphosphine, or a quaternary phosphonium salt derived from such a compound.

The basic ammonium compound may, for example, be tetramethylammonium hydroxide, tetraethylammonium hydroxide, tetrapropylammonium hydroxide, tetrabutylammonium hydroxide, trimethylethylammonium hydroxide, trimethylbenzylammonium hydroxide, trimethylphenylammonium hydroxide, triethylmethylammonium hydroxide, triethylbenzylammonium hydroxide, triethylphenylammonium hydroxide, tributylbenzylammonium hydroxide, tributylphenylammonium hydroxide, tetraphenylammonium hydroxide, benzyltriphenylammonium hydroxide, methyltriphenylammonium hydroxide or butyltriphenylammonium hydroxide.

The amine compound may, for example, be 4-aminopyridine, 2-aminopyridine, N,N-dimethyl-4-aminopyridine, 4-diethylaminopyridine, 2-hydroxypyridine, 2-methoxypyridine, 4-methoxypyridine, 2-dimethylaminoimidazole, 2-methoxyimidazole, imidazole, 2-mercaptoimidazole, 2-methylimidazole or aminoquinoline.

(Aromatic Polycarbonate Production Process)

Now, a process for producing the aromatic polycarbonate will be described below.

Production of the aromatic polycarbonate is carried out by preparing an aromatic dihydroxy compound and a diester carbonate compound as raw materials (raw material preparation step) and subjecting these compounds to a multi-stage polycondensation reaction in a molten state using a plurality of reactors in the presence of an ester exchange reaction catalyst (polycondensation step). The reaction method may be any one of a batch method, a continuous method or a combination of the batch method and the continuous method. As reactors, usually a plurality of reactors are used. These reactors are installed in series, and treatment is carried out continuously.

After the polycondensation step, the reaction is terminated with a terminator in an extruder, unreacted materials and reaction by-products in the reaction liquid are removed, and additives such as a thermal stabilizer and a mold release agent are added (extrusion step). Strands of the aromatic polycarbonate discharged from the extruder are cooled with cooling water by means of a strand bath or the like, and formed into pellets having a desired particle size (pelletizing step). Now, the respective steps in the production process will be described below.

(Raw Material Preparation Step)

The aromatic dihydroxy compound and the diester carbonate used as raw materials of the aromatic polycarbonate are usually prepared as a molten mixture using a batch type, semi-batch type or continuous stirring bath type apparatus in an atmosphere of an inert gas such as nitrogen or argon. The temperature of the molten mixture is, for example, in an case where bisphenol A is used as the aromatic dihydroxy compound and diphenyl carbonate is used as the diester carbonate,

usually from 120°C to 180°C, preferably from 125°C to 160°C.

In such a case, the ratio of the diester carbonate to the aromatic dihydroxy compound is adjusted so that the diester carbonate is in excess, and is adjusted so that the amount of the diester carbonate is usually from 1.01 mol to 1.30 mol, preferably from 1.02 mol to 1.20 mol per 1 mol of the aromatic dihydroxy compound.

(Polycondensation Step)

The polycondensation by an ester exchange reaction of the aromatic dihydroxy compound and the diester carbonate compound is usually carried out continuously in a multi-stage procedure comprising at least two stages, preferably from 3 to 7 stages. As specific reaction conditions, the temperature is from 150°C to 320°C, the pressure is from normal pressure to 0.01 Torr (1.3 Pa), and the average residence time is from 5 minutes to 150 minutes.

In the respective reactors in the multi-stage procedure, in order to more effectively discharge phenol formed as a by-product along with the progress of the polycondensation reaction, the reaction conditions are set within the above range so that the temperature and the degree of vacuum become higher step by step. However, in order to prevent a decrease in the quality of the aromatic polycarbonate to be obtained such as the hue, it is preferred to set the temperature low and the residence time short as far as possible, and the temperature of the final reactor may be set lower than the temperature of the prior reactor.

In the polycondensation in the multi-stage procedure, preferably, a plurality of vertical reactors provided with an agitating blade are connected, and in the final step, a horizontal reactor is provided to increase the average molecular weight of the aromatic polycarbonate. Usually from 2 to 5, preferably from 3 to 4 vertical reactors are provided.

The agitating blade in the vertical reactor may, for example, be a turbine blade, a paddle blade, a pfaudler blade, an anchor blade, a Fullzone blade (manufactured by Shinko Pantec Co., Ltd.), a SANMELER blade (manufactured by Mitsubishi Heavy Industries, Ltd.), a MAXBLEND blade (manufactured by Sumitomo Heavy Industries, Ltd.), a helical ribbon blade or a Lattice-type twisting blade (manufactured by Hitachi, Ltd.).

Further, the horizontal reactor is one of which the axis of rotation of the agitating blade is horizontal (in a horizontal direction). The agitating blade of the horizontal reactor may, for example, be a uniaxial type agitating blade such as a disk type or a paddle type, HVR, SCR or N-SCR (manufactured by Mitsubishi Heavy Industries, Ltd.), BIVOLAK (manufactured by Sumitomo Heavy Industries, Ltd.) or a biaxial type agitating blade such as a spectacle-shaped blade or a Lattice blade (manufactured by Hitachi, Ltd.).

Further, the ester exchange catalyst to be used for polycondensation of the aromatic dihydroxy compound and the diester carbonate compound is usually preliminarily prepared as an aqueous solution. The concentration of the catalyst aqueous solution is not particularly limited, and is adjusted to be an optional concentration depending on the solubility of the catalyst in water. Further, instead of water, another solvent such as acetone, an alcohol, toluene or phenol may be selected.

The properties of water to be used to dissolve the catalyst are not particularly limited so long as the type and the concentration of impurities contained are constant, and usually distilled water, deionized water or the like is preferably used.

(Extrusion Step)

After the polycondensation step, low molecular weight compounds such as unreacted raw materials, a hydroxy compound formed as a by-product in the ester exchange reaction and a polycarbonate oligomer in the reaction liquid are removed in the extrusion step. This removal is usually carried out continuously by a vented extruder.

The extruder to be used may be any type so long as it has a vented portion and is not

particularly limited. For example, a vented single screw or multi screw extruder may be mentioned, and particularly an intermeshing twin screw extruder is preferred. The rotational direction of axes of the extruder may be the same direction or the opposite direction. As the number of vents, usually multi-stage vents of from 2 to 10 stages are employed.

Further, it is preferred that in the extrusion step, the basic ester exchange catalyst remaining in the aromatic polycarbonate after the polycondensation reaction is neutralized/deactivated by an acidic compound or a derivative thereof, whereby the side-reaction in the extruder can be suppressed, and remaining unreacted raw materials and hydroxy compound can be removed.

The acidic compound or a derivative thereof to be added in the extrusion step is not particularly limited so long as it neutralizes the basic ester exchange catalyst. It may, for example, be a Bronsted acid or an ester thereof, such as hydrochloric acid, nitric acid, boric acid, sulfuric acid, sulfurous acid, phosphoric acid, phosphorous acid, hypophosphorous acid, polyphosphoric acid, adipic acid, ascorbic acid, aspartic acid, azelaic acid, adenosine phosphate, benzoic acid, formic acid, valeic acid, citric acid, glycolic acid, glutamic acid, glutaric acid, cinnamic acid, succinic acid, acetic acid, tartaric acid, oxalic acid, p-toluenesulfinic acid, p-toluenesulfonic acid, naphthalenesulfonic acid, nicotinic acid, picric acid, picolinic acid, phthalic acid, terephthalic acid, propionic acid, benzenesulfinic acid, benzenesulfonic acid, malonic acid or maleic acid. Among such acidic compounds and derivatives thereof, a sulfonic acid or an ester thereof is particularly preferred.

The acidic compound or the derivative thereof may be directly added or may be added as prepared as a so-called masterbatch. Otherwise, it may be diluted with a solvent and then added. The solvent is not particularly limited so long as the above acidic compound or the derivative thereof is dissolved. Water is particularly preferred. Further, for an acidic compound or a derivative thereof insoluble in water alone, a solvent mixture comprising water and an organic solvent such as acetone may be used. The amount of use of such an acidic compound or a derivative thereof is from 0.1 to 50 times, preferably from 0.5 to 30 times based on the neutralization equivalent of the basic ester exchange catalyst used for the polycondensation reaction.

Further, in the embodiment of the present invention, in the extrusion step, as the case requires, various additives are respectively supplied to the extruder. The additives may, for example, be a thermal stabilizer, an antioxidant, a weathering agent, a mold release agent, a lubricant, an antistatic agent, a plasticizer, a pigment, a dye, a filler, a reinforcing agent and a flame retardant.

Among such additives, the thermal stabilizer is mentioned as an example. A preferred thermal stabilizer may, for example, be a phosphorous stabilizer, a hindered phenol stabilizer, a sulfur stabilizer, an epoxy stabilizer or a hindered amine stabilizer. Among such thermal stabilizers, a phosphorous stabilizer is preferred. They may be used alone or in combination of two or more of them.

The phosphorous stabilizer may, for example, be phosphoric acid, phosphorous acid, hypophosphorous acid, pyrophosphoric acid, polyphosphoric acid, a phosphate or a phosphite. Among them, the phosphate may, for example, be a trialkyl phosphate such as trimethyl phosphate, triethyl phosphate, tributyl phosphate, trioctyl phosphate, tridecyl phosphate, trioctadecyl phosphate, distearyl pentaerythrityl diphosphate, tris(2-chloroethyl) phosphate or tris(2,3-dichloropropyl) phosphate; a tricycloalkyl phosphate such as tricyclohexyl phosphate; or a triaryl phosphate such as triphenyl phosphate, tricresyl phosphate, tris(nonylphenyl) phosphate or 2-ethylphenyldiphenyl phosphate.

Further, the phosphite may, for example, be a trialkyl phosphite such as trimethyl phosphite, triethyl phosphite, tributyl phosphite, trioctyl phosphite, tris(2-ethylhexyl) phosphite, trinonyl phosphite, tridecyl phosphite, trioctadecyl phosphite, tristearyl phosphite, tris(2-chloroethyl)

phosphite or tris(2,3-dichloropropyl) phosphite; a tricycloalkyl phosphite such as tricyclohexyl phosphite; a triaryl phosphite such as triphenyl phosphite, tricresyl phosphite, tris(ethylphenyl) phosphite, tris(2,4-di-t-butylphenyl) phosphite, tris(nonylphenyl) phosphite or tris(hydroxyphenyl) phosphite; or an arylalkyl phosphite such as phenyldecyl phosphite, diphenyldecyl phosphite, diphenylisooctyl phosphite, phenylisooctyl phosphite or 2-ethylhexyldiphenyl phosphite. Further, distearyl pentaerythrityl diphosphite or bis(2,4-di-t-butylphenyl) pentaerythrityl diphosphite may, for example, be mentioned. Among them, a phosphite is preferred, and tris(2,4-di-t-butylphenyl) phosphite is particularly preferably used.

The hindered phenol stabilizer may, for example, be n-octadecyl-3-(4-hydroxy-3',5'-di-t-butylphenyl) propionate, tetrakis[methylene-3-(3',5'-di-t-butyl-4-hydroxyphenyl)propionate] methane, 1,1,3-tris(2-methyl-4-hydroxy-5-t-butylphenyl)butane, distearyl(4-hydroxy-3-methyl-5-t-butyl)benzyl malonate or 4-hydroxymethyl-2,6-di-t-butylphenol.

The sulfur stabilizer may, for example, be sulfurous acid, sulfuric acid, a sulfinic acid compound, a sulfonic acid compound or a derivative thereof. More specifically, as a sulfurous acid derivative, dimethyl sulfite, diethyl sulfite, dipropyl sulfite, dibutyl sulfite or diphenyl sulfite may, for example, be mentioned. As a sulfuric acid derivative, dimethyl sulfate, diethyl sulfate, dipropyl sulfate, dibutyl sulfate or diphenyl sulfate may, for example, be mentioned. As the sulfinic acid compound, benzenesulfinic acid, toluenesulfinic acid or naphthalenesulfinic acid may, for example, be mentioned. As the sulfonic acid compound or a derivative thereof, a sulfonic acid such as benzenesulfonic acid or p-toluenesulfonic acid; a sulfonate such as methyl benzene sulfonate, ethyl benzene sulfonate, butyl benzene sulfonate, octyl benzene sulfonate, phenyl benzene sulfonate, methyl p-toluene sulfonate, ethyl p-toluene sulfonate, butyl p-toluene sulfonate, octyl p-toluene sulfonate or phenyl p-toluene sulfonate; an ammonium salt of sulfonic acid such as ammonium p-toluene sulfonate; or a sulfonic acid compound such as trifluoromethanesulfonic acid, naphthalenesulfonic acid, sulfonated polystyrene or a methyl acrylate/sulfonated styrene copolymer may, for example, be mentioned.

The epoxy stabilizer may, for example, be epoxidized soybean oil, epoxidized linseed oil, phenyl glycidyl ether, allyl glycidyl ether, t-butylphenyl glycidyl ether, 3,4-epoxycyclohexylmethyl-3',4'-epoxycyclohexyl carboxylate, 3,4-epoxy-6-methylcyclohexylmethyl-3',4'-epoxy-6'-methylcyclohexyl carboxylate, 2,3-epoxycyclohexylmethyl-3',4'-epoxycyclohexyl carboxylate, 4-(3,4-epoxy-5-methylcyclohexyl)butyl-3',4'-epoxycyclohexyl carboxylate, 3,4-epoxycyclohexyl ethylene oxide, cyclohexylmethyl 3,4-epoxycyclohexyl carboxylate, 3,4-epoxy-6-methylcyclohexylmethyl-6'-methylcyclohexyl carboxylate, bisphenol A diglycidyl ether, tetrabromobisphenol A glycidyl ether, diglycidyl ester of phthalic acid, diglycidyl ester of hexahydrophthalic acid, bis-epoxydicyclopentadienyl ether, bis-epoxyethylene glycol, bis-epoxycyclohexyl adipate, butadiene diepoxide, tetraphenylethylene epoxide, octyl epoxy tallate, epoxidized polybutadiene, 3,4-dimethyl-1,2-epoxycyclohexane, 3,5-dimethyl-1,2-epoxycyclohexane, 3-methyl-5-t-butyl-1,2-epoxycyclohexane, octadecyl-2,2-dimethyl-3,4-epoxycyclohexyl carboxylate, N-butyl-2,2-dimethyl-3,4-epoxycyclohexyl carboxylate, cyclohexyl-2-methyl-3,4-epoxycyclohexyl carboxylate, N-butyl-2-isopropyl-3,4-epoxy-5-methylcyclohexyl carboxylate, octadecyl-3,4-epoxycyclohexyl carboxylate, 2-ethylhexyl-3',4'-epoxycyclohexyl carboxylate, 4,6-dimethyl-2,3-epoxycyclohexyl-3',4'-epoxycyclohexyl carboxylate, 4,5-epoxytetrahydrophthalic anhydride, 3-t-butyl-4,5-epoxytetrahydrophthalic anhydride, diethyl 4,5-epoxy-cis-1,2-cyclohexyl dicarboxylate or di-n-butyl-3-t-butyl-4,5-epoxy-cis-1,2-cyclohexyl dicarboxylate. Among them, an alicyclic epoxy compound is preferably used, and 3,4-epoxycyclohexylmethyl-3',4'-epoxycyclohexyl carboxylate is particularly preferably used.

The addition amount of the thermal stabilizer is usually from 0.0001 part by weight to 0.5 part by weight, preferably from 0.001 part by weight to 0.2 part by weight per 100 parts by weight of the

aromatic polycarbonate.

In the embodiment of the present invention, in a case where the phosphorous stabilizer is used as the thermal stabilizer, the effect to be obtained by the present invention will be high when pellets of the aromatic polycarbonate formed into a finished product by means of the after-mentioned pelletizing step contains the phosphorous stabilizer in an amount of from 0.5 ppm to 10 ppm, preferably from 0.5 to 5 ppm as the amount (as calculated as weight) of phosphorous atoms, by adding the phosphorous stabilizer in an amount within the above range.

If the amount of the thermal stabilizer added to the pellets of the aromatic polycarbonate is excessively small, at the time of injection molding under high temperature conditions of about 350°C for example, the hue of the aromatic polycarbonate tends to be deteriorated. Further, if the amount of the thermal stabilizer added to the pellets of the aromatic polycarbonate is excessively large, particularly when the phosphorous stabilizer is used as the thermal stabilizer, such a phosphorous stabilizer itself is hygroscopic, and further, may function as a catalyst to hydrolyze the aromatic polycarbonate, and accordingly the hydrolyzability of the aromatic polycarbonate formed into a finished product may be accelerated in some cases. If a substrate for an optical disk is formed by an injection molding method using pellets of such an aromatic polycarbonate which has absorbed water, silver streaks tend to occur on the surface of the obtained substrate.

In the extrusion step, in a case where an extruder provided with multi-stage vent ports is used, the acidic compound or the derivative thereof is added upstream of a vent port closest to a resin supply port. As the shape of the aromatic polycarbonate to be supplied to a neutralization and devolatilization treatment by an extruder, a method of introducing the aromatic polycarbonate in a molten state immediately after the polycondensation reaction to an extruder, followed by treatment, or a method of once cooling and solidifying it, and then introducing it to an extruder, followed by treatment, may, for example, be mentioned.

(Pelletizing Step)

Strands of the aromatic polycarbonate discharged from the extruder in the extrusion step are usually cooled with cooling water by means of a strand bath or the like and cut into pellets usually having a particle size of from about 1 mm to about 5 mm by a strand cutter, and then subjected to water removal by a dehydrator or the like and then stored in a storage silo.

In the embodiment of the present invention, in order to obtain an aromatic polycarbonate having a viscosity average molecular weight (Mv) of at most 17,000 and having a viscosity average molecular weight (Mv) of at least 10,000 useful as an optical recording material, as the amounts of use of the aromatic dihydroxy compound and the diester carbonate as raw materials, usually the diester carbonate is used in a molar ratio of from 1.05 to 1.20, preferably from 1.10 to 1.15 to the aromatic dihydroxy compound.

Further, the amount of use of the ester exchange catalyst is, in a case where the ester exchange catalyst is an alkali metal, usually from 1×10^{-8} to 1×10^{-5} mol, preferably from 1×10^{-7} to 1×10^{-6} mol as the metal atom content per 1 mol of the aromatic dihydroxy compound.

(Production Apparatus)

Now, one example of the process for producing an aromatic polycarbonate according to the embodiment of the present invention will be specifically described with reference to a drawing.

Fig. 1 is a diagram illustrating one example of an aromatic polycarbonate production apparatus. In the production apparatus shown in Fig. 1, the aromatic polycarbonate is produced by means of a raw material preparation step of preparing an aromatic dihydroxy compound and a diester carbonate compound as raw materials, and a polycondensation step of subjecting such raw materials in a molten state to a polycondensation reaction using a plurality of reactors, and then, an extrusion step of removing unreacted raw materials and reaction by-products in the reaction liquid and adding optional additives, followed by melt kneading, and a pelletizing step are carried out to

form pellets of the aromatic polycarbonate.

In the raw material preparation step, a first raw material preparation tank 2a and a second raw material preparation tank 2b connected in series, and a raw material supply pump 4a to supply the prepared raw materials to the polycondensation step are provided. The first raw material
 5 preparation tank 2a and the second raw material preparation tank 2b are provided with, for example, anchor agitating blades 3a and 3b, respectively.

Further, to the first raw material preparation tank 2a, diphenyl carbonate (hereinafter sometimes referred to as DPC) as a diester carbonate is supplied in a molten state from a DPC supply port 1a-1, bisphenol A (hereinafter sometimes referred to as BPA) as an aromatic dihydroxy
 10 compound is supplied in a powder state from a BPA supply port 1b, and bisphenol A is dissolved in the molten diphenyl carbonate.

Then, in the polycondensation step, a first vertical reactor 6a, a second vertical reactor 6b and a third vertical reactor 6c connected in series, and a fourth horizontal reactor 9a connected in series to the latter stage of the third vertical reactor 6c are provided. The first vertical reactor 6a, the
 15 second vertical reactor 6b and the third vertical reactor 6c are provided with Maxblend blades 7a, 7b and 7c, respectively. Further, the fourth horizontal reactor 9a is provided with agitating blades 10a.

Further, the four reactors are provided with distillation pipes 8a, 8b, 8c and 8d to discharge e.g. by-products formed by the polycondensation reaction, respectively. The distillation pipes 8a, 8b, 8c and 8d are connected to condensers 81a, 81b, 81c and 81d, respectively, and the respective
 20 reactors are kept in predetermined reduced pressure states by pressure reducing devices 82a, 82b, 82c and 82d.

In the extrusion step, an extruder 11a having additive supply ports 12a, 12b and 12c is provided.

In the pelletizing step, a strand cooling equipment 13a to cool the strands of the aromatic polycarbonate discharged from the extruder 11a with cooling water, a cutter 14a to cut the cooled
 25 strands to a predetermined particle size, a centrifugal dehydrator 14b to remove water in the pellets, a sieving machine 15a to remove off-specification pellets by sieving, and storage silos 16a and 16b to store the dried pellets, are provided.

In the aromatic polycarbonate production apparatus shown in Fig. 1, a DPC molten liquid prepared in a nitrogen gas atmosphere at a predetermined temperature and a BPA powder weighed in a nitrogen gas atmosphere are continuously supplied to the first raw material preparation tank 2a
 30 respectively from the DPC supply port 1a-1 and the BPA supply port 1b. When the liquid level of the first raw material preparation tank 2a exceeds the maximum level in the transportation piping, the raw material mixture is transported to the second raw material preparation tank 2b.

Then, the raw material mixture is continuously supplied to the first vertical reactor 6a through the raw material supply pump 4a. Further, as a catalyst, cesium carbonate in the form of an aqueous solution is continuously supplied from a catalyst supply port 5a in the middle of the raw material mixture transportation piping.

In the first vertical reactor 6a, a polycondensation reaction is carried out while the liquid level
 40 is kept constant so that the average residence time is 60 minutes while the number of revolutions of the Maxblend blade 7a is maintained at 160 rpm and phenol formed as a by-product is discharged from the distillation pipe 8a in a nitrogen atmosphere, for example, at a temperature of 220°C under a pressure of 13.33 KPa (100 Torr). Then, the polycondensation reaction liquid discharged from the first vertical reactor 6a is continuously supplied to the second vertical reactor 6b, the third vertical
 45 reactor 6c and the fourth horizontal reactor 9a sequentially, whereby the polycondensation reaction proceeds. The reaction conditions in the respective reactors are set so that the temperature becomes higher, the degree of vacuum becomes higher and the stirring rate becomes lower as the polycondensation reaction proceeds. During the polycondensation reaction, the liquid level is

controlled so that the average residence time in each reactor is, for example, about 60 minutes, and in the respective reactors, phenol formed as a by-product are distilled off from the distillation pipes 8b, 8c and 8d.

In the embodiment of the present invention, by-products such as phenol are continuously liquefied and recovered from the condensers 81a and 81b respectively attached to the first vertical reactor 6a and the second vertical reactor 6b. Further, the condensers 81c and 81d respectively attached to the third vertical reactor 6c and the fourth horizontal reactor 9a are provided with cold traps (not shown), from which by-products are continuously solidified and recovered.

Then, the aromatic polycarbonate drawn from the fourth horizontal reactor 9a is supplied as in a molten state to the twin screw extruder 11a provided with three-stage vent ports. To the extruder 11a, for example, various additives such as butyl p-toluenesulfonic acid, tris(2,4-di-t-butylphenyl) phosphite and monoglyceride stearate are supplied respectively from the additive supply ports 12a, 12b and 12c. The conditions of the extruder 11a are set, for example, with a discharge amount of 50 kg/hr at a number of revolutions of 150 rpm at a maximum resin temperature of from 270 to 320°C.

The strands of the aromatic polycarbonate discharged from the extruder 11a are pelletized by the cutter 14a by means of the strand cooling equipment 13a, subjected to centrifugal dehydration treatment by the centrifugal dehydrator 14b, subjected to the sieving machine 15a to remove the off-specification pellets, and then introduced to the storage silos 16a and 16b by pneumatic transportation. The pneumatic transportation will be described hereinafter.

Fig. 2 is a diagram illustrating one example of a method for transporting and a method for storing polymer pellets according to an embodiment of the present invention.

Fig. 2 illustrates storage silos 16a and 16b (storage container, storage facility) to store the pellets (polymer pellets) of the aromatic polycarbonate supplied from the production apparatus shown in Fig. 1, and a dehumidifier 17 to dehumidify and compress and then send the air to be used for the pneumatic transportation of the pellets of the aromatic polycarbonate.

Further, at the bottom of the storage silos 16a and 16b, pellet outlet pipings 26a and 26b are respectively provided to discharge the pellets of the aromatic polycarbonate stored in their interior.

As shown in Fig. 2, the dehumidifier 17 is provided with an air transportation piping 23 to supply the air to pneumatically transport the pellets of the aromatic polycarbonate supplied from the sieving machine 15a (Fig. 1) of the production apparatus shown in Fig. 1 to the storage silos 16a and 16b.

Further, an air transportation piping 24 to introduce the air discharged from the dehumidifier 17 to the storage silos 16a and 16b, branched from the air transportation piping 23, is provided.

Further, an air transportation piping 25 to supply the air to transport the pellets of the aromatic polycarbonate discharged from the storage silos 16a and 16b to the outside the apparatus, branched from the air transportation piping 23 and merging with the pellet outlet pipings 26a and 26b provided at the bottom of the storage silos 16a and 16b, is provided.

In the embodiment of the present invention, the dehumidifier 17 may, for example, be a honeycomb adsorption type dehumidifier. In the interior of the dehumidifier 17, a dehumidifying rotor (not shown) formed in the form of a rotor, using a non-woven fabric formed in the form of a honeycomb impregnated with a dehumidifying agent such as lithium chloride, zeolite or silica gel, is built-in. The dehumidifying rotor is rotary-driven by a predetermined motor.

When the air introduced from an air supply port 21 of the dehumidifier 17 into the dehumidifier 17 passes through the dehumidifying rotor (not shown) built in the dehumidifier 17, the water contained in the air is adsorbed in a dehumidifying material (air dehumidification step). Then, the air is compressed by an air compressor which is not shown in the Figure (air compression step) and discharged from an air discharge outlet 22 of the dehumidifier 17.

In the embodiment of the present invention, the air introduced into the dehumidifier 17 is preliminarily subjected to filtration through a filter with a filtration accuracy of at most 5 micron, preferably at most 1 micron, the water contained in the air is adsorbed in the dehumidifying material by the dehumidifying rotor in the dehumidifier 17, and the air is controlled to have a dew point of at most 0°C, preferably at most -10°C, furthermore preferably at most -20°C. The lower limit of the dew point is not particularly limited.

As shown in Fig. 2, the pellets (polymer) of the aromatic polycarbonate are supplied from the production apparatus shown in Fig. 1 through a pellet supply port 15b to the air transportation piping 23 (pressure air supplying step). Further, they are pneumatically transported in the air transportation piping 23 by compressed air having its dew point adjusted to at most 0°C in the dehumidifier 17 and discharged from the air discharge outlet 22 (transportation step) and introduced to and stored in the storage silos 16a and 16b.

In the embodiment of the present invention, since the pellets of the aromatic polycarbonate are pneumatically transported by the compressed air having its dew point adjusted to at most 0°C, they are stored in the storage silos 16a and 16b in a state where the moisture content of the pellets is kept to be at most 0.1 wt%, preferably at most 0.05 wt%, more preferably at most 0.02 wt%. The lower limit of the moisture content of the pellets is not particularly limited.

Particularly, pellets of the aromatic polycarbonate stored in the storage silos 16a and 16b in a state where the moisture content is kept to be at most 0.02 wt%, are suitable, for example, as a material for a substrate of an optical disk to be formed by an injection molding method at about 350°C.

In the embodiment of the present invention, the air flow of the compressed air supplied from the air discharge outlet 22 of the dehumidifier 17 to the air transportation piping 23 is usually from 50 Nm³/hr to 600 Nm³/hr, preferably from 100 Nm³/hr to 500 Nm³/hr, more preferably from 100 Nm³/hr to 400 Nm³/hr per 1 ton of the pellets of the aromatic polycarbonate. If the air flow of the compressed air is too small, the pellets of the aromatic polycarbonate tend not to be pneumatically transported. If the air flow of the compressed air is too large, breakage of the pellets and formation of impalpable powder due to collision of the pellets against the inner wall of the piping tend to increase.

In the embodiment of the present invention, by the compressed air being supplied to the air transportation piping 23 with an air flow within the above-described range, whereby the pellets of the aromatic polycarbonate are pneumatically transported at a transportation rate of usually from 1 t (ton)/hr to 20 t/hr, preferably from 2 t/hr to 10 t/hr, more preferably from 3 t/hr to 8 t/hr.

Further in the embodiment of the present invention, as shown in Fig. 2, the air having its dew point adjusted to at most 0°C by the dehumidifier 17 is supplied from the air discharge outlet 22 of the dehumidifier 17 through the air transportation piping 24 to the storage silos 16a and 16b, and the storage silos 16a and 16b are filled with such an air, whereby the interior of the storage silos 16a and 16b is always kept in a dry state so that the pellets of the aromatic polycarbonate stored in the storage silos 16a and 16b do not absorb water.

As described above, by the storage silos 16a and 16b filled with the air having its dew point adjusted to at most 0°C, for example, even in a case where the pellets of the aromatic polycarbonate, which contain a phosphorous stabilizer as a thermal stabilizer, have increased hygroscopicity, the pellets are stored in the storage silos 16a and 16b without an increase in the moisture content.

In the embodiment of the present invention, when the pellets of the aromatic polycarbonate are discharged from the storage silos 16a and 16b for inspection, shipping or the like of products, the pellets are discharged from the pellet outlet pipings 26a and 26b respectively provided at the bottom of the storage silos 16a and 16b.

As shown in Fig. 2, the pellets of the aromatic polycarbonate discharged from the storage

silos 16a and 16b through the pellet outlet pipings 26a and 26b are pneumatically transported outside the production apparatus by the air having its dew point adjusted to at most 0°C by the dehumidifier 17 and supplied through the air transportation piping 25, while the pellets of the aromatic polycarbonate are kept in a dry state so that they do not adsorb water.

5 In the above, the embodiment of the present invention has been described with reference to a honeycomb adsorption type dehumidifier as the dehumidifier 17 as an example. However, a dehumidifier in another form may be used so long as it has a dehumidifying function to dehumidify the air to be used for pneumatic transportation and adjust its dew point to at most 0°C, and the dehumidifier is not particularly limited.

10 Further, in the above, the air is used as a gas to pneumatically transport the pellets of the aromatic polycarbonate, but the gas is not limited to the air, and for example, a nitrogen gas, an argon gas, a carbon dioxide gas or the like may be used depending on the properties, etc. of the pellets of the polymer to be pneumatically transported.

15 In the above, the embodiment of the present invention has been described with reference to the pellets of the aromatic polycarbonate as an example. However, the method for transporting the polymer pellets according to the embodiment of the present invention is applicable to other pellets of a hygroscopic polymer. Such a polymer may, for example, be pellets of a polyester, a polyamide or the like.

20 The shape of the pellets of the polymer may, for example, be a granular shape, an irregular shape, a flat plate shape or a cylinder shape and is not particularly limited. Further, as the size of the pellets, preferred are pellets processed to have a length at the longest portion of at most 20 mm.

EXAMPLES

25 Now, the present invention will be described in detail with reference to Examples. However, it should be understood that the present invention is by no means restricted to the following Examples. Methods for measuring and methods for evaluating various physical properties of polymer pellets used in Examples and Comparative Examples are as shown in the following (1) to (6).

(1) Method for measuring moisture content of polymer pellets

30 The moisture content of polymer pellets were measured by a coulometric titration method using a moisture content measuring apparatus (Model CA-100 manufactured by DIA Instruments Co., Ltd.) and a water vaporizing apparatus (Model VA-100 manufactured by DIA Instruments Co., Ltd.). The weight of the polymer pellets as a sample is from 0.2 g to 1 g. The condition for heating the polymer pellets in the water vaporizing apparatus is 250°C.

(2) Method for measuring dew point of gas

35 The dew point of a gas to be used for pneumatic transportation of polymer pellets was measured in the following procedure using a dew point measuring apparatus (Model ISUZU-1A manufactured by Isuzu Seisakusho Co., Ltd.).

40 (i) The gas of which the dew point is to be measured is continuously sprayed on a cooling cylinder of the dew point measuring apparatus.

(ii) Ethanol is put in the cooling cylinder on which the gas is continuously sprayed, and small pieces of dry ice are charged little by little for gradual cooling with careful stirring. The mirror surface of the cooling cylinder is visually observed, and charging of the dry ice is terminated upon formation of dews on the mirror surface. The temperature of ethanol in the cooling cylinder upon formation of dews on the mirror surface is regarded as T1.

45 (iii) Then, ethanol and the dry ice put in the cooling cylinder are stirred, and the temperature is gradually increased until the dews on the mirror surface of the cooling cylinder disappear. The temperature of ethanol in the cooling cylinder upon disappearance of the dews on the mirror surface

is regarded as T2.

(iv) The average of T1 and T2 is regarded as the dew point of the gas.

(3) Method for evaluating silver streaks on disk surface

Pneumatically transported pellets of an aromatic polycarbonate are supplied to an injection molding machine (DISC 3 manufactured by Sumitomo Heavy Industries, Ltd.), 100 disks (diameter (ϕ): 120 mm, thickness: 0.6 mm) of the aromatic polycarbonate were formed, and presence or absence of silver streaks on the surface of the obtained disks were visually confirmed.

Barrel set temperature: 350°C, 370°C, 380°C, 380°C from the pellet supply side

Mold temperature: 128°C

Molding cycle: 6.0 seconds

The initial 100 shots of molding by the injection molding machine are disposed of.

(4) Method for evaluating initial hue of aromatic polycarbonate

Pneumatically transported pellets of an aromatic polycarbonate are dried in a nitrogen atmosphere at 120°C for 6 hours. Then, the dried pellets of the aromatic polycarbonate are supplied to an injection molding machine (Model J75EII manufactured by The Japan Steel Works, Ltd.), and an operation of molding an injection molded piece (60 mm × 60 mm × 3 mm in thickness) under conditions at a resin temperature of 360°C for a molding cycle of 30 seconds, is repeatedly carried out.

The yellow index (YI) value of each of injection molded pieces obtained at the sixth to fifteenth shots is measured by a color tester (CM-3700d manufactured by Konica Minolta Holdings, Inc.), and their average value is calculated. The lower the yellow index (YI) value, the better the hue and the more excellent the quality.

(5) Method for evaluating hue of aromatic polycarbonate which has resided in a heated state

In the above-described evaluation of the initial hue of the aromatic polycarbonate, the molding cycle for preparation of an injection molded piece by the injection molding machine is changed to 10 minutes from the sixteenth shot, and the molding operation is repeatedly carried out until the twenty-second shot. The YI value of each of the injection molded products obtained at the twentieth to the twenty-second shots is measured by a color tester, and their average value is calculated.

(6) Method for measuring viscosity average molecular weight (Mv) of aromatic polycarbonate

Pellets of an aromatic polycarbonate are dissolved in methylene chloride, and the intrinsic viscosity $[\eta]$ of the methylene chloride solution at 20°C is measured by an Ubbelohde viscometer to determine the viscosity average molecular weight (Mv) from the following viscosity equation (1):

$$[\eta] = 1.23 \times 10^{-4} \times (\text{Mv})^{0.83} \quad (1)$$

EXAMPLE 1

Using a polycarbonate as a polymer, a compressed air having a dew point adjusted to -20°C by using a honeycomb adsorption type dehumidifier was supplied to an air transportation piping to pneumatically transport polymer pellets of the polycarbonate to storage silos. The air flow in the air transportation piping was 1,800 Nm³/hr, and the polymer pellets were pneumatically transported to the storage silos at a transportation rate of 4 t (ton)/hr.

The moisture content of the polymer pellets transported to the storage silos was measured, whereupon it was 0.09 wt%.

COMPARATIVE EXAMPLE 1

Using polybutylene terephthalate (PBT) as a polymer, a compressed air having a dew point of 6°C was supplied to a transportation piping to pneumatically transport polymer pellets of PBT to storage silos. The air flow in the transportation piping was 1,800 Nm³/hr, and the polymer pellets were pneumatically transported to the storage silos at a transportation rate of 4 t (ton)/hr.

The moisture content of the polymer pellets transported to the storage silos was measured, whereupon it was 0.2 wt%.

EXAMPLE 2

Using polybutylene succinate lactate (PBSL) as a polymer, a compressed air having a dew point adjusted to -30°C by a honeycomb adsorption type dehumidifier was supplied to a transportation piping to pneumatically transport polymer pellets of PBSL to storage silos. The air flow in the transportation piping was $720\text{ Nm}^3/\text{hr}$, and the polymer pellets were pneumatically transported to the storage silos at a transportation rate of 2 t (ton)/hr .

The moisture content of the polymer pellets transported to the storage silos was measured, whereupon it was $0.05\text{ wt\%}$.

COMPARATIVE EXAMPLE 2

Using polybutylene succinate lactate (PBSL) as a polymer, a compressed air using untreated external air (dew point: 26°C) with a humidity of 70% at 32°C was supplied to a transportation piping to pneumatically transport polymer pellets of PBSL to storage silos. The air flow in the transportation piping was $723\text{ Nm}^3/\text{hr}$, and the polymer pellets were pneumatically transported to the storage silos at a transportation rate of 2 t (ton)/hr .

The moisture content of the polymer pellets transported to the storage silos was measured, whereupon it was $0.2\text{ wt\%}$.

EXAMPLE 3

An aromatic polycarbonate having a viscosity average molecular weight (Mv) of $15,300$ was prepared by using a production apparatus shown in Fig. 1 in accordance with the following operation.

First, in a nitrogen atmosphere, to a first raw material preparation tank 2a of which the internal temperature was controlled to 140°C , diphenyl carbonate (DPC) was continuously supplied from a DPC supply port 1a-1, and bisphenol A (BPA) was continuously supplied from a BPA supply port 1b, to obtain a mixture in which DPC and BPA were in a uniform molten state at a constant molar ratio (DPC/BPA=1.12) (hereinafter sometimes referred to as a (DPC/BPA) mixture).

Then, the (DPC/BPA) mixture prepared in the first raw material preparation tank 2a was sent to a second raw material preparation tank 2b controlled at 140°C , and then the (DPC/BPA) mixture was continuously supplied to a first vertical reactor 6a using a raw material supply pump 4a so that the supply amount per unit time would be constant. Then, an aqueous solution of cesium carbonate as an ester exchange reaction catalyst was continuously supplied from a catalyst supply port 5a in an amount of $0.4 \times 10^{-6}\text{ mol}$ per 1 mol of BPA, to continuously carry out a melt polycondensation reaction of DPC and BPA in the first vertical reactor 6a.

The first vertical reactor 6a was controlled at an internal temperature of 220°C under a pressure of 13.3 kPa . The liquid level of the polycondensation reaction liquid was kept constant by adjusting the aperture of a valve (not shown) provided at a discharge line at the bottom of the first vertical reactor 6a, whereby the average residence time of the polycondensation reaction liquid in the first vertical reactor 6a was adjusted to be 1.5 hours .

Then, the polycondensation reaction liquid discharged from the bottom of the first vertical reactor 6a was continuously supplied to a second vertical reactor 6b, a third vertical reactor 6c and a fourth horizontal reactor 9a sequentially. The second vertical reactor 6b was kept at an internal temperature of 260°C under a pressure of 4 kPa , and the average residence time of the polycondensation reaction liquid in the second vertical reactor 6b was 1 hour . The third vertical reactor 6c was kept at an internal temperature of 270°C under a pressure of 700 Pa , and the average residence time of the polycondensation reaction liquid in the third vertical reactor 6c was 1 hour . The fourth horizontal reactor 9a was kept at an internal temperature of 270°C under a pressure of 200 Pa , and the average residence time of the polycondensation reaction liquid in the fourth horizontal reactor 9a was 1.5 hours .

Then, the polycondensation reaction liquid of the aromatic polycarbonate was discharged from the fourth horizontal reactor 9a, and supplied to a twin screw extruder 11a as in a molten state.

Then, butyl p-toluenesulfonate as a catalyst deactivator was added to the extruder 11a in an amount of 4 ppm as calculated as weight based on the weight of the aromatic polycarbonate, and then tris(2,4-di-t-butylphenyl) phosphite as a thermal stabilizer was added in an amount of 2.4 ppm as calculated as weight of phosphorous atoms based on the weight of the aromatic polycarbonate, and monoglyceride stearate as a mold release agent was added in an amount of 400 ppm as calculated as weight based on the weight of the aromatic polycarbonate.

Then, from the twin screw extruder 11a, the aromatic polycarbonate with which the thermal stabilizer and the mold release agent were mixed as described above, was discharged in a molten state in the form of strands, and the discharged strands of the aromatic polycarbonate were cooled with water and solidified in a strand bath 13a. Then, the cooled and solidified strands of the aromatic polycarbonate were cut by a strand cutter 14a to form pellets, water attached to the pellets were removed by a centrifugal dehydrator 14b, and from the pellets from which water was removed, pellets having off-specification sizes were removed by a sieving machine 15a.

The pellets of the aromatic polycarbonate (Mv: 15,300) prepared by the above operation were pneumatically transported to storage silos 16a and 16b by a compressed air supplied to an air transportation piping. The compressed air was preliminarily adjusted to have a dew point of -35°C by a honeycomb adsorption type dehumidifier. The air flow in the air transportation piping was $1,800 \text{ Nm}^3/\text{hr}$. The transportation rate of the pellets of the aromatic polycarbonate was 4 t (ton)/hr . Further, the storage silos 16a and 16b were filled with an air having its dew point adjusted to -35°C .

The moisture content of the pellets of the aromatic polycarbonate pneumatically transported by the compressed air having a dew point of -35°C was $0.005 \text{ wt\%}$. A part of the pellets of the aromatic polycarbonate pneumatically transported to the storage silos 16a and 16b were sampled in a moisture-proof bag having an aluminum-evaporated inner bag, the moisture-proof bag was opened immediately before measurement of the moisture content, and the moisture content of the pellets of the aromatic polycarbonate was measured by the above-described operation ((1) Method for measuring moisture content of polymer pellets).

Based on the above-described method for evaluating silver streaks ((3) Method for evaluating silver streaks on disk surface), 100 disks were formed by an injection molding machine, and presence or absence of silver streaks on the surface of the obtained disks were visually confirmed, whereupon no silver streaks were observed on all 100 disks.

Further, the initial hue of the pellets of the aromatic polycarbonate evaluated by the above-described method for evaluating the initial hue ((4) Method for evaluating initial hue of aromatic polycarbonate) was 1.25, and the hue of the pellets of the aromatic polycarbonate evaluated by the method for evaluating the hue after the aromatic polycarbonate has resided in a heated state ((5) Method for evaluating hue of aromatic polycarbonate which has resided in a heated state) was 3.07.

From the results in Example 3, it is understood that by pneumatically transporting the pellets of the aromatic polycarbonate having a viscosity average molecular weight (Mv) of 15,300 useful as an optical material for e.g. an optical disk by a compressed air having a dew point of -35°C , the pellets can be stably stored in the storage silos 16a and 16b in a state where the moisture content of the pellets after the pneumatic transportation is significantly decreased.

On a disk formed by using the pellets of the aromatic polycarbonate stored in the storage silos 16a and 16b in such a state that the moisture content is decreased, no silver streaks are observed. Thus, it is understood that the method for pneumatically transporting polymer pellets of the present invention is excellent as a method for transporting pellets of an aromatic polycarbonate useful as an optical material.

Further, in the above-described preparation of the aromatic polycarbonate, the amount of DPC as the raw material supplied to the first raw material preparation tank 2a was decreased, DPC and BPA were supplied and mixed so that the molar ratio of the raw materials DPC to BPA

(DPC/BPA) was 1.11, and the fourth horizontal reactor 9a was set under conditions at an internal temperature of 275°C under a pressure of 150 Pa to prepare an aromatic polycarbonate having a viscosity average molecular weight (Mv) of 18,000. However, the aromatic polycarbonate having a viscosity average molecular weight (Mv) of 18,000, which has a high viscosity, cannot be molded into a substrate for an optical disk by an injection molding machine.

EXAMPLE 4

Pellets of an aromatic polycarbonate were pneumatically transported in the same manner as in Example 3 except that a compressed air having its dew point adjusted to -20°C was used.

The moisture content of the pellets of the aromatic polycarbonate pneumatically transported by the compressed air having a dew point of -20°C was 0.009 wt%.

Based on the method for evaluating silver streaks, disks were formed by an injection molding machine, and presence or absence of silver streaks on the surface of the obtained disks was visually observed, whereupon no silver streaks were observed on 97 disks among the 100 formed disks.

Further, the initial hue of the aromatic polycarbonate evaluated by the method for evaluating the initial hue was 1.28, and the hue of the aromatic polycarbonate evaluated by the method for evaluating the hue after having been resided in a heated state was 3.11.

EXAMPLE 5

Pellets of an aromatic polycarbonate were pneumatically transported in the same manner as in Example 3 except that a compressed air having its dew point adjusted to -5°C was used.

The moisture content of the pellets of the aromatic polycarbonate pneumatically transported by the compressed air having a dew point of -5°C was 0.015 wt%.

Based on the method for evaluating silver streaks, disks were formed by an injection molding machine, and presence or absence of silver streaks on the surface of the obtained disks was visually observed, whereupon no silver streaks were observed on 92 disks among the 100 formed disks.

Further, the initial hue of the aromatic polycarbonate evaluated by the method for evaluating the initial hue was 1.30, and the hue of the aromatic polycarbonate evaluated by the method for evaluating the hue after having been resided in a heated state was 3.20.

COMPARATIVE EXAMPLE 3

Pellets of an aromatic polycarbonate were pneumatically transported in the same manner as in Example 3 except that a compressed air having its dew point adjusted to 5°C was used.

The moisture content of the pellets of the aromatic polycarbonate pneumatically transported by the compressed air having a dew point of 5°C was 0.025 wt%.

Among 100 disks formed based on the method for evaluating silver streaks, the number of disks on which silver streaks were observed was significantly increased to 31 disks.

Further, the initial hue of the aromatic polycarbonate evaluated by the method for evaluating the initial hue was 1.37, and the hue of the aromatic polycarbonate evaluated by the method for evaluating the hue after having been resided in a heated state was 3.23.

EXAMPLE 6

Pellets of an aromatic polycarbonate were pneumatically transported in the same manner as in Example 4 except that tris(2,4-di-t-butylphenyl) phosphite was added to the extruder 11a in an amount of 0.4 ppm as calculated as weight of phosphorous atoms based on the weight of the aromatic polycarbonate.

The moisture content of the pellets of the aromatic polycarbonate pneumatically transported by the compressed air having a dew point of -20°C was 0.009 wt% which was the same as in Example 4.

No silver streaks were observed on 100 disks formed based on the method for evaluating silver streaks.

Further, the initial hue of the aromatic polycarbonate evaluated by the method for evaluating

the initial hue was 1.44, and the hue of the aromatic polycarbonate evaluated by the method for evaluating the hue after having been resided in a heated state was 3.50, which indicates that the hue was deteriorated as compared with results in Example 4.

EXAMPLE 7

Pellets of an aromatic polycarbonate were pneumatically transported in the same manner as in Example 4 except that tris(2,4-di-t-butylphenyl) phosphite was added to the extruder 11a in an amount of 13 ppm as calculated as weight of phosphorous atoms based on the weight of the aromatic polycarbonate.

The moisture content of the pellets of the aromatic polycarbonate pneumatically transported by the compressed air having a dew point of -20°C was 0.009 wt% which was the same as in Example 4.

Silver streaks were observed on 15 disks among 100 disks formed based on the method for evaluating silver streaks, but no silver streaks were observed on 85 disks. This is considered to be because a hydrolysis reaction was accelerated as compared with a case of the pellets of the aromatic polycarbonate obtained in Example 4, since the amount of the phosphorous atoms added to the aromatic polycarbonate was large as compared with Example 4.

Further, the initial hue of the aromatic polycarbonate evaluated by the method for evaluating the initial hue was 1.41, and the hue of the aromatic polycarbonate evaluated by the method for evaluating the hue after having been resided in a heated state was 3.46, which indicates that the hue was deteriorated as compared with results in Example 4.

As described above, according to the method for transporting and the method for storing polymer pellets of the present invention, hygroscopic polymer pellets can be transported by a simple means without moisture absorption of the polymer pellets, without a large scale device such as a dryer. Further, hygroscopic polymer pellets can be stored by a simple means without moisture absorption.

INDUSTRIAL APPLICABILITY

According to the present invention, hygroscopic polymer pellets can be transported by a simple means without an increase in the moisture content of the polymer pellets, and further, the polymer pellets can be stored without moisture absorption, and accordingly the present invention is industrially useful.

The entire disclosure of Japanese Patent Application No. 2007-073111 filed on March 20, 2007 including specification, claims, drawings and summary are incorporated herein by reference in its entirety.

CLAIMS

1. A method for transporting polymer pellets, which comprises pneumatically transporting hygroscopic polymer pellets using a gas having a dew point of at most 0°C.
2. The method for transporting polymer pellets according to Claim 1, wherein the polymer pellets
5 are pellets of a polycarbonate, a polyester or a polyamide.
3. The method for transporting polymer pellets according to Claim 1 or 2, wherein the polymer pellets are pellets of an aromatic polycarbonate having a viscosity average molecular weight (Mv) of from 10,000 to 17,000.
4. The method for transporting polymer pellets according to any one of Claims 1 to 3, wherein
10 the polymer pellets are pellets of an aromatic polycarbonate obtained by a melt polycondensation reaction using an aromatic dihydroxy compound and a diester carbonate as raw materials in the presence of an ester exchange catalyst.
5. The method for transporting polymer pellets according to any one of Claims 1 to 4, wherein the gas is the air.
- 15 6. The method for transporting polymer pellets according to any one of Claims 1 to 5, wherein the polymer pellets pneumatically transported by the gas having a dew point of at most 0°C has a moisture content of at most 0.1 wt%.
7. A method for pneumatically transporting polymer pellets,
through a transportation piping together with a stream of a pressure gas, which comprises a
20 gas dehumidification step of reducing the water content in a gas used for pneumatic transportation of the polymer pellets to adjust the dew point of the gas to at most 0°C, a gas compression step of compressing the gas having its dew point adjusted to at most 0°C in the above gas dehumidification step, a pressure gas supplying step of supplying the pressure gas compressed in the above gas compression step to a transportation piping at a rate of 50 Nm³/hr to 600 Nm³/hr per 1 ton of the
25 polymer pellets, and a transportation step of pneumatically transporting the polymer pellets through the transportation piping together with a stream of the pressure gas supplied to the transportation piping in the above pressure gas supplying step.
8. The method for pneumatically transporting polymer pellets according to Claim 7, wherein in the gas dehumidification step, the dew point of the gas used for pneumatic transportation of the
30 polymer pellets is adjusted to at most -10°C.
9. The method for pneumatically transporting polymer pellets according to Claim 7 or 8, wherein in the transportation step, the polymer pellets are pneumatically transported together with a stream of the pressure gas supplied to the transportation piping to a storage facility preliminary filled with a gas having a dew point of at most 0°C.
- 35 10. The method for pneumatically transporting polymer pellets according to any one of Claims 7 to 9, wherein the polymer pellets are pellets of an aromatic polycarbonate having a viscosity average molecular weight (Mv) of from 10,000 to 17,000, and the pellets contain phosphorus atoms in an amount of from 0.5 ppm to 10 ppm as calculated as weight.
11. A method for storing polymer pellets, which comprises filling a storage container with a gas
40 having a dew point of at most 0°C, and storing hygroscopic polymer pellets in the storage container.
12. The method for storing polymer pellets according to Claim 11, wherein the polymer pellets stored in the storage container have a moisture content of at most 0.1 wt%.