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DESCRIPTION

BIAXIALLY ORIENTED FILM OF A POLYLACTIC ACID RESIN

Technical Field

The present invention relates to a biodegradable biaxially oriented film consisting mainly of a polylactic acid resin. More specifically, the present invention relates to a biodegradable film for bags, packaging and for various windows with superior coating adaptability and high-speed cutting property.

Background Art

Synthetic polymer compounds have been widely used as plastics due to their superior characteristics. With the increase in the consumption of the synthetic polymer compounds, however, the amount of waste has been also increasing. It has thus become a social problem how the waste plastics should be dealt with. Incineration causes problems, such as the damage to furnaces due to high heat generation and the risk of emission of toxic substances. Landfill also cause a problem that the plastics stay in the environment for good since they do not decay. Furthermore, considering the costs of classification, collection and regeneration, it is difficult to completely solve the problem only by recycling.

In the midst of such increasing environmental



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concern, needs for biodegradable plastics which decompose in the natural environment after being wasted have been increasing to reduce environmental load and to realize the sustainable society.

5 Known biodegradable plastics include starch-based ones, aliphatic-polyester resins produced by microorganisms, chemically synthetic aliphatic polyester resins and the same resins but partially modified in their chemical structure, and biodegradable
10 aliphatic aromatic polyester resins.

 Among these biodegradable plastics, polylactic acid resins have superior transparency, rigidity and processability, as compared with other biodegradable plastics. In particular, oriented films
15 of polylactic acid resins are suitable as various films for packaging such as bags, window films for containers with window, plastering films for outlook window envelopes, substitute films for cellophane, and the like, due to their high stiffness and high
20 transparency.

 On the other hand, in the field of plastic film applications, processing speed has been increasing with the progress of processing machinery. For example, in the affixing of films for envelope windows,
25 recent processing speed is 800 to 1,000 sheets/minute, or even 1000 or more sheets/minute due to the progress of window affixing machine, while the conventional processing speed was 400 to 600 sheets/minute. For

this reason, running speed of the film also has been increasing and thus there are needs for a film with superior high-speed cutting property. In addition, there are applications in which film surface is to be
5 coated with an antistatic agent, a lubricant, an antiblocking agent, or the like, to provide the film with machine adaptability and processability to suit the high-speed processing. For example, the above-described coating is indispensable in bags, packaging
10 films and films for various windows, particularly those for window of outlook window envelopes into which relatively light weight materials easily affected by static electricity, such as powder, granule, thin papers, film, fiber-like substance, are contained.
15 Therefore, the films are required to have coating adaptability, in addition to the high-speed cutting property. Biodegradable films, in particular polylactic acid film, with superior transparency and mechanical properties, satisfying these requirements
20 have not been obtained.

JP-A-2001-122989 discloses that a biaxially oriented polylactic acid polymer film consisting of crystalline polylactic acid and having the storage modulus E' at 120°C within the range from 100 MPa to 230
25 MPa, as determined by the test method for temperature dependency of dynamic viscoelasticity, is suitable for fold-packaging due to superior tacking property. This film, however, cannot satisfy the coating adaptability

and high-speed cutting property. JP-A-2000-198913 discloses an easily tearable, biaxially oriented film of a polylactic acid resin consisting of polylactic acid and crystalline aliphatic polyester. This film, however, only has limited applications due to significant haze. JP-A-2001-64413 discloses an easily tearable, biaxially oriented film of a polylactic acid resin consisting of polylactic acid and polyethylene terephthalate and/or polyethylene isophthalate. This film, however, only has limited applications due to incomplete biodegradability and insufficient coating adaptability and high-speed cutting property, although it is superior in straight tearing and hand tearing properties. JP-A-2001-354789 also discloses biodegradable polylactic acid resin films with a good balance among antistatic property, lubricity and antiblocking property, along with superior adhesion to paper. This film, however, does not have the high-speed cutting property.

The object of the present invention is to provide a biodegradable, biaxially oriented film of a polylactic acid resin suitable for films for bags, packaging and films for various windows with superior coating adaptability for antistatic agents, lubricants, antiblocking agents or the like, as well as high-speed cutting property.

Disclosure of the Invention

The present inventors have found, after extensive studies to solve the above-described problems, that a biodegradable, biaxially oriented film of a polylactic acid resin, which is suitable for films for bags, packaging and films for various windows with superior coating adaptability as well as high-speed cutting property, can be obtained by making the storage modulus E' at 80°C, as determined by the test method for temperature dependency of dynamic viscoelasticity, in accordance with JIS K7198 (method A), the heat shrinkage at 80°C and the tear strength in the width direction (TD direction) of a film within the specific ranges, respectively, despite the fact that the physical properties of the film are complicatedly influenced by its blend composition of crystalline polylactic acid and amorphous polylactic acid, drawing temperatures and drawing ratios in the MD and TD directions, and heat treatment conditions and the like. Based on these findings, the present invention has been accomplished.

Namely, the present invention comprises the following aspects:

- (1) A biaxially oriented film of a polylactic acid resin comprising not less than 50% by weight of a polylactic acid resin,

which has a storage modulus E' at 80°C, in at least one of a longitudinal direction (MD direction) and a width direction (TD direction) of the film, of

from 10 MPa to 3,000 MPa, as determined by the test method for temperature dependency of dynamic viscoelasticity in accordance with JIS K7198 (method A);

5 a heat shrinkage of not higher than 10%, upon heating at 80°C for 10 seconds; and

 a tear strength in the width direction (TD direction) of 10 to 200 mN, as determined in accordance with JIS K7128 (method B).

10 (2) The biaxially oriented film of a polylactic acid resin in accordance with (1), wherein the storage modulus E' at 80°C, in at least one of the longitudinal direction (MD direction) and the width direction (TD direction) of the film, is within the range from 50 MPa
15 to 1,000 MPa, as determined by the test method for temperature dependency of dynamic viscoelasticity.

 (3) The biaxially oriented film of a polylactic acid resin in accordance with (1) or (2), wherein the storage modulus E' at 80°C, in at least one of the
20 longitudinal direction (MD direction) and the width direction (TD direction) of the film, is within the range from 10 MPa to 300 MPa, as determined by the test method for temperature dependency of dynamic viscoelasticity; and a heat of fusion, ΔH_m , at the
25 crystal melting peak, present at a temperature not lower than 100°C, is in the range from 15 to 30 J/g, as determined by a differential scanning calorimeter (DSC) with a temperature being increased from 0°C to 200°C in

accordance with JIS K7122.

(4) The biaxially oriented film of a polylactic acid resin in accordance with (1) or (2), wherein the polylactic acid resin is a mixture comprising of 95 to 5 60 parts by weight of crystalline polylactic acid with an optical purity of not lower than 85% and 5 to 40 parts by weight of amorphous polylactic acid with an optical purity of not higher than 80%.

(5) A window for an outlook window envelope, 10 comprising the biaxially oriented film of a polylactic acid resin in accordance with (1) or (2).

(6) The biaxially oriented film of a polylactic acid resin in accordance with (1) or (2), wherein said film is drawn at a ratio of not less than 4 in the 15 width direction (TD direction) of the film, and is subjected to a heat treatment at a temperature not lower than the glass transition temperature (T_g) thereof and not higher than the melting point (T_m) thereof.

20 (7) A method for producing a biaxially oriented film of a polylactic acid resin, comprising:

drawing a film comprising a resin containing not less than 50% by weight of a mixture comprising 95 to 60 parts by weight of crystalline polylactic acid 25 with an optical purity of not lower than 85% and 5 to 40 parts by weight of amorphous polylactic acid with an optical purity of not higher than 80%, at a ratio of not less than 4 in the width direction (TD direction)

of the film; and

subsequently subjecting the film to a heat treatment at a temperature not lower than the glass transition temperature (T_g) thereof and not higher than
5 the melting point (T_m) thereof.

Preferred Embodiments of the Invention

The present invention will be explained in more detail hereinbelow.

A film of the present invention comprises not
10 less than 50% by weight, preferably not less than 70% by weight, more preferably not less than 85% by weight, and further more preferably 100% by weight of, a polylactic acid resin. If the content of a polylactic acid resin is less than 50% by weight, the elastic
15 modulus and transparency of PLA tend to be lowered. Said polylactic acid resin means: a copolymer of polylactic acid or lactic acid and other hydroxycarboxylic acid(s), aliphatic cyclic ester(s), dicarboxylic acid(s) and/or diol(s), containing not
20 less than 85% by weight of lactic acid monomer units; or a composition of these polymers containing not less than 85% by weight of lactic acid monomer units.

Lactic acid has L-lactic acid and D-lactic acid as optical isomers, and polylactic acid obtained
25 by polymerization of lactic acid includes crystalline polylactic acid and amorphous polylactic acid. The former comprises about 10% or less of D-lactic acid

units and about 90% or more of L-lactic acid units, or about 10% or more of L-lactic acid units and about 90% or more of D-lactic acid unit, and has an optical purity of not lower than about 80%, while the latter
5 comprises 10% to 90% of D-lactic acid units and 90% to 10% of L-lactic acid units, and has an optical purity of not higher than about 80%.

A polylactic acid resin used in the present invention is preferably a polylactic acid resin that is
10 a mixture comprising 100 to 60 parts by weight of crystalline polylactic acid having an optical purity of not lower than 85% and 0 to 40 parts by weight of amorphous polylactic acid having an optical purity of not higher than 80%. Particularly preferably, a
15 polylactic acid resin is a mixture of 95 to 60 parts by weight of crystalline polylactic acid having an optical purity of not lower than 85% and 5 to 40 parts by weight of amorphous polylactic acid having an optical purity of not higher than 80%. The resins having the
20 compositions in these ranges are advantageous as an oriented film with superior heat sealing property while having the heat shrinkage suppressed to a low level after heat treatment, can be easily obtained therefrom. If the content of crystalline polylactic acid having an
25 optical purity of not lower than 85% is less than 60 parts by weight, heat shrinkage tends to increase.

The hydroxycarboxylic acid(s), a monomer(s) to be used as a copolymerization component with lactic

acid, include such as glycolic acid, 3-hydroxybutyric acid, 4-hydroxybutyric acid, 3-hydroxyvaleric acid, 4-hydroxyvaleric acid and 6-hydroxycaproic acid.

The aliphatic cyclic ester(s) includes
5 glycolide, lactide, β -propiolactone, γ -butyrolactone, δ -valerolactone, ϵ -caprolactone and substituted lactones with various groups such as a methyl group, and the like. The dicarboxylic acid(s) includes succinic acid, glutanic acid, adipic acid, azelaic acid, sebacic acid,
10 terephthalic acid and isophthalic acid, and the like. The polyvalent alcohol(s) includes aromatic polyvalent alcohols, such as bisphenol/ethylene oxide adducts; aliphatic polyvalent alcohols, such as ethylene glycol, propylene glycol, butanediol, hexanediol, octanediol,
15 glycerin, solbitan, trimethylolpropane, neopentyl glycol; and ether glycols, such as diethylene glycol, triethylene glycol, polyethylene glycol, polypropylene glycol.

Biodegradable plastics, such as aliphatic
20 polyesters, may be added to the above-described polylactic acid. The amount to be added, however, should be not higher than 50% by weight so as not to impair the properties of the polylactic acid resin itself.

25 As a method of polymerizing the polylactic acid resin, a known method, such as a polycondensation method, a ring opening polymerization method and the like can be employed. A method for increasing

molecular weight by using a binder, such as polyisocyanate, polyepoxy compound, acid anhydride and polyfunctional acid chloride, can also be employed.

The weight average molecular weight of the polylactic acid resin is preferably in the range from 20,000 to 1,000,000, more preferably in the range from 30,000 to 500,000. If the molecular weight is within these ranges, the melt viscosity will be in a suitable range and, thus, a stable film can be obtained even by using usual processing machine.

The biaxially oriented film of a polylactic acid resin of the present invention has a storage modulus E' at 80°C of from 10 MPa to 3,000 MPa at least in one of the MD and TD directions, as determined by the test method for temperature dependency of dynamic viscoelasticity, in accordance with JIS K7198 (method A). It is preferable that the storage modulus is in the above range at least in the MD direction, more preferably in both of the MD and TD directions. Since films are heated up to around 80°C by hot air for drying in a drying step after coating with an antistatic agent, a lubricant, an antiblocking agent or the like, if the storage modulus E' at 80°C of a film is less than 10 MPa, the film will have deformations, such as film elongation by tension exerted on film in drying process, which makes it difficult to obtain a good state of roll of film. On the other hand, a film of polylactic acid resin with a storage modulus E' thereof

at 80°C of higher than 3,000 MPa is practically difficult to obtain. Preferable range of E' of a film at 80°C is from 50 MPa to 1,000 MPa, and particularly preferable range is from 70 MPa to 500 MPa. A film
5 with E' at 80°C of not higher than 300 MPa is preferable as it has the superior heat sealing property.

The biaxially oriented film of a polylactic acid resin of the present invention has heat shrinkage, in both the MD and TD directions, of not higher than
10 10%, upon heating at 80°C for 10 seconds. The film with heat shrinkage over 10%, upon heating at 80°C for 10 seconds, exhibits heat shrinkage by hot air for drying in drying process after coating with an antistatic agent, a lubricant, an antiblocking agent or the like,
15 to have wrinkles on the film surface. It is therefore difficult to obtain a film with good appearance. The heat shrinkage upon heating at 80°C for 10 seconds is preferably not higher than 5%, and particularly preferably not higher than 3%.

20 Furthermore, the biaxially oriented film of a polylactic acid resin of the present invention is required to have a tear strength in the width direction of the film (TD direction) of 10 to 200 mN, as determined in accordance with JIS K7128 (method B). A
25 film with the tear strength in the TD direction over 200 mN has inferior high-speed cutting property and, thus, is not adaptable to high-speed bag manufacturing equipment and high-speed fabrication machine, in

particular to high-speed affixing machine for envelope windows. On the other hand, a film with said tear strength lower than 10 mN has undesired film breaks at high frequency during the slitting work. Preferable
5 range of said tear strength is from 20 to 150 mN, and particularly preferable range is from 20 to 100 mN.

Furthermore, the biaxially oriented film of a polylactic acid resin of the present invention preferably has a heat of fusion, ΔH_m , at the crystal
10 melting peak present at a temperature not lower than 100°C, of 15 to 30 J/g, in particular, 22 to 28 J/g, as determined by a differential scanning calorimeter (DSC) with the temperature being increased from 0°C to 200°C in accordance with JIS K7122. A film with the above
15 value not higher than 30 J/g is superior in heat sealing property, while a film with the value not smaller than 15 J/g exhibits little heat shrinkage and, thus, hardly shrinks during hot air drying after coating.

20 The biodegradable film of the present invention has a haze of preferably not higher than 5%, more preferably not higher than 3%, and particularly preferably not higher than 2%, as measured by a hazemeter (ASTM D 1003-95). If the haze is not lower
25 than 5%, the transparency will be reduced to make it difficult to see contents in the bag. In the case of general packaging film, it is difficult to see contents clearly through the film, and thus impairs the

appearance and value as a commercial product. In the application of the outlook window envelopes, in particular, if the haze is not lower than 5%, the transparency will be reduced to frequently cause
5 reading error of the information recorded in a bar code.

The polylactic acid resin film of the present invention may be compounded with, in addition to the above-described resins, known additives such as other
10 biodegradable resins, heat stabilizers, antioxidants and UV absorbers, in an amount not to impair the requirements in and the characteristics of, the present invention. In the case of mixing a resin which increases the haze, the maximum amount to be compounded
15 should be 5% based on the polylactic acid resin.

The thickness of a film of the present invention is preferably in the range from 5 to 100 μm , more preferably in the range from 7 to 50 μm . In particular, the thickness of film for envelope windows
20 is preferably in the range from 20 to 40 μm to provide stiffness suitable for affixing machine for the outlook window envelopes.

Hereinbelow, a method for producing a biaxially oriented film comprising not lower than 50%
25 by weight of a polylactic acid resin of the present invention will be described. First, a raw material resin(s) is fed into a single screw or twin screw extruder and melt mixed. The melt is then extruded

through a T die, a cylinder die or an I die and quenched to be in an amorphous-like state. The melt extrusion temperature range at this time is, in general, preferably from 100 to 250°C. The quenching temperature is preferably from 0 to 60°C. The resin is then biaxially drawn by a conventionally known drawing method including a roll method, a tenter method, a tubular method or the like. Among these drawing methods, the tenter method is preferable due to easiness to obtain a oriented film of the present invention because drawing ratios in the MD and TD directions can be independently controlled.

Drawing ratio in the drawing procedure may be selected from the range of 1.5 to 10 each for the longitudinal direction (MD direction) and the width direction (TD direction) of the film. The drawing ratio is preferably at least 4 in the TD direction, in view of the enhancement of film strength and film cutting property in the TD direction by imparting orientation, more preferably at least 2 in the MD direction and at least 4 in the TD direction, particularly preferably from 2.0 to 4.5 in the MD direction and from 4.5 to 7 in the TD direction. The ratios are further particularly preferably from 2.5 to 3.5 in the MD direction and from 5.2 to 7 in the TD direction. The ratio of (drawing ratio in the TD direction) / (drawing ratio in the MD direction) is preferably larger than 2.0. By drawing the film in the

TD direction at a ratio of 4 or more, the tear strength in the TD direction falls within a specified range and the high-speed film cutting property is improved.

Preferable drawing temperature is from 65°C to 90°C.

5 To obtain the biaxially oriented film of a polylactic acid resin of the present invention, the film is heat treated at a temperature range not lower than the glass transition temperature and not higher than the melting point of the polylactic acid resin
10 used as a raw material, after the biaxial drawing. When a tubular method is employed, a heat treatment method wherein a film is heated by external hot air and the like, while being kept in tensed state by maintaining the internal pressure by sealing internal
15 air, is usually employed. In the tenter method, a heat treatment method wherein a film is passed through a heat treatment zone with the film being hold with clips. Preferably, the film is heat treated at a temperature of not lower than the drawing temperature
20 but not higher than the melting point of a film for a period not shorter than 1 second depending on the treatment temperature, and particularly preferably heat-treated at a temperature range not lower than 100°C and not higher than the melting point for a period not
25 shorter than 2 seconds. If the temperature is too low or if the heat treatment time is too short, the heat shrinkage of the drawn film may exceed 10%, upon heating at 80°C for 10 seconds. Heat treatment in the

state where the tension in the TD direction and/or the MD direction is relaxed is effective to reduce the heat shrinkage. Heat treatment under excessive relaxation, however, tends to increase tear strength in the TD direction resulting in lower high-speed cutting property. Thus, it is preferable to carry out the heat treatment in the state where the tension to the film is relaxed to such an extent that the tear strength in the TD direction becomes not higher than 200 mN, in order to obtain a film with superior high-speed cutting property.

The film of a polylactic acid resin is more hydrophilic than films based on a polyolefin resin or a polystyrene resin. However, it is preferable to impart further hydrophilicity to the film by a method such as corona treatment of the film surface to be coated, for uniform coating of the biaxially oriented film of a polylactic acid resin of the present invention with an antistatic agent, a lubricant, an antiblocking agent or the like. This hydrophilicity imparting treatment improves the uniformity of the coating and effectively provides antistatic property or lubrication effect. Said hydrophilicity imparting treatment is preferably carried out so that the surface tension becomes in the range from 400 $\mu\text{N}/\text{cm}$ to 600 $\mu\text{N}/\text{cm}$.

The biaxially oriented film of a polylactic acid resin of the present invention is biodegradable and useful as films for bags, packaging and various

containers with windows, to which an antistatic agent, a lubricant, an antiblocking agent or the like is applied, since it has superior coating adaptability and high-speed cutting property. It is especially suitable
5 for films for the outlook window envelopes. The film, when used for bags or packaging, preferably has a tensile strength, as mechanical strength, of not lower than 20 MPa and a tensile elongation of from 20 to 1,000%. These values are specified depending on the
10 applications.

Examples

The present invention will now be explained by way of Examples and Comparative Examples.

First, evaluation methods used in the
15 Examples and Comparative Examples are described below.

(1) Composition of D- and L-lactic acids in polylactic acid polymer and optical purity

The optical purity of polylactic acid polymer is calculated by the following equation based on a
20 composition ratio of L-lactic acid units and/or D-lactic acid units composing the polylactic acid, as described above.

$$\text{optical purity(\%)} = \frac{|[L] - [D]|}{|[L] + [D]|} \times 100$$

wherein $[L] + [D] = 100$, and $|[L] - [D]|$
25 represents an absolute value of $[L] - [D]$.

Composition ratio of L-lactic acid units and/or D-lactic acid units composing polylactic acid

polymer is determined by:

preparing a hydrolyzed sample (liquid) by
alkaline decomposition of a sample with 1N-NaOH,
followed by neutralizing with 1N-HCl and adjusting the
5 concentration with distilled water;

passing the hydrolyzed sample through a high
performance liquid chromatography (HPLC: LC-10A-VP)
from Shimadzu Corp. to obtain an area ratio of detected
peaks (area is measured by a vertical line method)
10 corresponding to L-lactic acid and D-lactic acid at 254
nm UV;

obtaining a weight ratio of L-lactic acid [L]
(unit: %) composing the polylactic acid polymer and a
weight ratio of D-lactic acid [D] (unit: %) composing
15 the polylactic acid polymer from the area ratio; and

taking the mean (rounded) of three
measurement values per polymer as the measurement value
of the composition ratio.

(2) Weight average molecular weight M_w of polylactic
20 acid polymer

The weight average molecular weight M_w was
determined using a gel permeation chromatography
equipment (GPC: data processing part; GPC-8020,
detection part; RI-8020) from Toso Co., Ltd., under the
25 following measuring conditions, as polystyrene
equivalent value based on the standard polystyrene.
Three measurement values per polymer were
arithmetically averaged and rounded and the average was

employed as the measurement value.

Column: connected column of Shodex K-805 and K-801 from Showa Denko Co., Ltd. (7.8 mm diameter x 60 cm length)

5 Eluate: chloroform

Concentration of sample solution: 0.2 wt/vol%

Volume of sample solution charged: 200 μ L

Flow rate of solvent: 1 ml/min.

Column/detector temperature: 40°C

10 (3) Glass transition temperature (T_g), melting point (T_m) and crystal heat of fusion (ΔH_m)

A sample was heated from 0°C to 200°C in differential scanning calorimeter (DSC) in accordance with JIS-K7121 and JIS-K-7122 to measure T_g , T_m and
15 heat of fusion ΔH_m of crystal melting peak, present at a temperature not lower than 100°C. That is, about 10 mg of test sample was cut out from a sample film conditioned (by leaving to stand for 1 week) in the standard state (23°C, 65%RH) and the DSC curve of the
20 sample was drawn with a differential scanning calorimeter model DSC-7 (heat flux type DSC) from Perkin-Elmer Inc., with nitrogen gas being flowed at a rate of 25 ml/min and temperature being increased from 0°C to 200°C at a rate of 10°C/min. Melting point T_m
25 (°C) was determined from a top of melting (endothermic) peak in the temperature increasing process, crystal heat of fusion ΔH_m (J/g) from an endothermic peak area, and T_g (°C) from a crossing point (midpoint glass

transition temperature) of step-wise changing part of a curve in the temperature increasing process and a line with equal distance in vertical axis direction, from extended lines of both baselines. Four measurement
5 values per polymer were arithmetically averaged and rounded and the average was employed as the measurement value.

(4) Drawing ratios in the MD direction and TD direction

10 Drawing ratios in the MD direction and TD direction were determined by the following equations.

Drawing ratio in the MD direction = (film flow rate after drawing in the MD direction) / (original sheet flow rate before drawing in the MD
15 direction)

Drawing ratio in the TD direction = (film width after drawing in the TD direction) / (original sheet width before drawing in the TD direction)

In a tenter method, film or sheet width means
20 a width between clips before and after drawing in the TD direction.

(5) Storage modulus E' (MPa)

Storage modulus E' was measured in accordance with JIS K7198 (method A). Namely, it was measured by
25 a tensile vibration method under the conditions of frequency of 1 Hz and temperature increasing from 20°C to 160°C at a rate of 2°C/min, with a test piece having a width of 7 mm being held so that the distance between

the chucks was 22 mm, using RSA-II from Rheometric Scientific F.E. Inc.

(6) Heat shrinkage (%)

A test piece with 150 mm x 150 mm was cut out from a film sample in such a manner that one film side was parallel to the MD direction. On the test piece a square of 100 mm x 100 mm was drawn in such a manner that one side thereof was parallel to the MD direction. In the square, two sets of nine straight lines were drawn at 10 mm intervals with the sets being in parallel to the MD direction and the TD direction, respectively, to prepare the test piece on which the squares of 10 mm x 10 mm were drawn. The test piece was placed in a hot air drying chamber set at 80°C for 10 seconds and allowed to shrink freely. Heat shrinkage was determined by taking the mean of the values from the following equation and the dimensions of 11 lines drawn in the MD direction and TD direction.

$$\text{Heat shrinkage (\%)} = \frac{[(\text{line dimension before heat shrinkage}) - (\text{line dimension after heat shrinkage})]}{(\text{line dimension before heat shrinkage})} \times 100$$

(7) Haze (%)

A test piece of square film with a size of 50 mm x 50 mm and a thickness of 25 μm was cut out from a film sample conditioned (by leaving to stand for 1 week at 23°C) under the standard conditions (23°C, 65%RH). Haze (%) was measured at the standard condition in

accordance with ASTM D1003-95, using a hazemeter, model NDH-1001DP from Nippon Denshoku Ind. Co., Ltd. Six measurement values per film type were arithmetically averaged and rounded to obtain the haze.

5 (8) Tear strength (mN)

Tear strengths (mN) in the MD direction and TD direction of a film was measured in accordance with JIS K7128 (method B).

(9) Coating adaptability

10 Coating adaptability was evaluated by using a coating composition improving antistatic property and lubricity (consisting of 50% by weight of "TSF-4441" from Toshiba Silicone Co., Ltd. as a polyether-modified silicone and 50% by weight of "Nymeen F-215",
15 polyoxyethylene-alkyl(coconut oil)amine from NOF Corp. as a surfactant) as a surface treatment agent. First, the film surface to be coated was subjected to corona treatment so as to impart a surface tension of 500 $\mu\text{N}/\text{cm}$, using model AGI-060MD from Kasuga Electric
20 Machine Co., Ltd. The film surface was then coated with an aqueous solution of said coating composition having a concentration of the surface treatment agent of 0.3% by weight, using a spray coater. The film was
25 moisture. The coating amount was controlled to be 2.5 mg/m^2 by adjusting the conditions of the spray coater (air pressure and line speed). Coating adaptability was evaluated according to the following criteria from

the film coating state and the heat shrink state after the coating and hot air drying.

◎: a film having a good coating, showing uniform coating without generation of wrinkle, film extension, sagging, or the like caused by heat shrink.

○: a film having a coating practically usable without problem, showing uniform coating and a little generation of wrinkles, film extension, sagging, or the like caused by heat shrink.

10 ×: a film not suitable for practical use, showing generation of much wrinkles, film extension, sagging, or the like caused by heat shrink.

(10) High-speed cutting property and envelope window affixing adaptability

15 To evaluate high-speed film cutting property and envelope window affixing adaptability, the upper limit of practically possible cutting speed at which window can be affixed without displacement was measured by affixing test for envelope window on a window frame
20 of 50 x 90 mm on an envelope of 135 x 235 mm (made of paper), under various cutting speeds, using envelope window affixing machine (model HELIOS 202 from WINKLER+DUNNERBIER), followed by visual inspection of displacement with respect to the a envelope window
25 frame. High-speed cutting property and envelope window affixing adaptability were evaluated according to the following criteria based on these test results.

◎: a film that can be cut at a cutting speed of

600 sheets or more/min and affixed without causing displacement

○ - ◎ : a film that can be cut at a cutting speed of 500 to 600 sheets/min and affixed without causing
5 displacement

○: a film that can be cut at a cutting speed of 400 to 500 sheets/min and affixed without causing displacement

×: a film that cannot be cut at a cutting speed
10 of not lower than 400 sheets/min or a film that causes displacement due to delay, even if cutting at such a speed is possible

(11) Tensile strength (MPa)

Tensile strengths (MPa) of the film in the MD
15 direction and TD direction were measured in accordance with ASTM D882.

(12) Tensile elongation (%)

Tensile elongations (%) of the film in the MD direction and TD direction were measured in accordance
20 with ASTM D882.

(13) Heat sealing property

Three test pieces of rectangular film with a length of 250 mm in the longitudinal direction (the MD direction) x a width of 25.4 mm (1 inch) were cut out
25 from a film sample conditioned (by leaving to stand for 1 week at 23°C) under the standard condition (23°C, 65%RH). Hot tack strength (HT strength; unit: N/1 inch width) was measured in accordance with ASTM- F1921-98,

as a peak strength observed within 1,000 mS (= 1 sec) after die opening, using a hot tack measurement instrument from Theller Ltd. under the following sealing conditions.

5 Shape of the upper die: metal die, V type of 60 degree (tip cross-section of half-circle shape with R = 1 mm, 5.25 inch length)

 Shape of the lower die: die with rubber lining, plain type (0.5 inch width x 5.25 inch length)

10 Dimension of seal surface: 1 inch x 1 mm
 seal temperature: (upper die) 110°C, (lower die) 25°C

 seal time: 1,000 mS

 seal pressure: 13 ± 1 MPa

15 Heat seal property of a film was evaluated by hot tack strength (HT strength: peak strength, unit: N/1 inch width), corresponding to high-speed heat seal strength in packaging machine or bag making machine, in view of continuous heat seal stability not to cause
20 breaking out of the content from the seal part or partial peeling off (or breakage) of seal part, when it is continuously subjected to heat sealing process from original wound film state to form packaging or bags by packaging machine or bag making machine, according to
25 the following criteria.

 ©: a film having a hot tack strength of not lower than 7N/1 inch width and sufficient strength and no breaking out of its content or seal line failure,

showing a very good state

○: a film having a hot tack strength of not lower than 5N/1 inch width which is at the level where the film can be practically used without problem, and no
5 breaking out of its content or seal line failure

×: a film having a hot tack strength of lower than 5N/1 inch width wherein seal line may be peeled off (broken) and the content may be broken out

Polylactic acid resins used in the following
10 Examples 1 to 16 and Comparative Examples 1 to 6 were crystalline polylactic acids (a), (b) and amorphous polylactic acid (c) having the weight average molecular weights and the optical purities shown in Table 1, obtained by the polymerization with the catalyst
15 amount, polymerization conditions, monomer composition and the like being controlled in accordance with Examples 1B to 7B in JP-A-4-504731. However, the compositions of the polylactic acid resins in the present invention should not be limited thereto.

Table 1

	Weight average Mw	Content of D-lactic acid	Optical purity	Tg	Tm
Crystalline polylactic acid (a)	250,000	4.5%	91%	57°C	153°C
Crystalline polylactic acid (b)	270,000	1.5%	97%	58°C	170°C
Amorphous polylactic acid(c)	280,000	13.0%	74%	53°C	None

<Examples 1 to 11 and Comparative Examples 1 to 6>

In Examples 1 to 11 and Comparative Examples 1 to 6, pellets of crystalline polylactic acid (a) or (b) and amorphous polylactic acid (c) shown in Table 1 were dry blended to the compositions shown in Table 2, followed by melt blending using a co-rotating twin screw extruder, extruding molten resins at a resin temperature of 200°C through a T-die, quenching by a casting roll kept at a temperature of 35°C to obtain substantially amorphous sheets. Then the sheets obtained were heated at 75°C, roll-drawn in the MD direction at the drawing ratios shown in Table 2, and then tenter-drawn in the TD direction at 85°C at the drawing ratios shown in Table 2. Thereafter, all the films, except for the film in Comparative Example 2, were introduced into a heat treatment zone adjusted to have the temperatures shown in Table 2 to subject the films to the heat-treatments for the periods shown in Table 2, with the films being kept in the drawn and held state. Thereafter, the films were cooled to a room temperature to obtain biaxially oriented films of a polylactic acid resin with a thickness of 25 μm . In Comparative Example 2, a film was cooled to a room temperature without undergoing the heat treatment, to obtain a biaxially oriented film of a polylactic acid resin with a thickness of 25 μm . Evaluation results of the physical properties of the films obtained are shown in table 2.

Table 2-1

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10	Example 11
Blend ratio (wt parts)											
Crystalline polylactic acid (a)	100	100		90	80		80	70			
Crystalline polylactic acid (b)			100			80			60	50	40
Amorphous polylactic acid (c)	0	0	0	10	20	20	20	30	40	50	60
Drawing ratio in the MD direction (times)	2.5	3.0	3.0	2.5	3.0	3.5	2.5	2.5	3	3	2.5
Drawing ratio in the TD direction (times)	6	5.1	4.5	6.2	6.2	5.1	4.5	6.3	5.5	6.0	6.0
Heat treatment condition	140	140	140	140	140	140	130	130	140	140	130
Time (sec)	3	3	3	3	3	3	3	3	3	3	5
Storage modulus E' (MPa)	360	370	490	210	160	220	150	110	90	60	30
TD direction	160	150	250	95	80	100	70	60	70	40	30
Heat shrinkage at 80°C for 10 sec (%)	0.5	0.5	0.5	0.7	0.7	1.0	1.0	2.5	2.5	4.5	8.0
TD direction	1.0	0.5	0.3	1.2	1.5	1.5	2.5	3.0	3.5	4.5	8.5
Heat of crystal fusion ΔH_m (J/g)	31	31	40	28	25	35	25	24	26	25	20
Haze (%)	0.9	0.8	1	0.7	0.5	0.9	0.5	0.5	0.7	0.6	0.5
Tear strength (mN)	55	80	190	70	80	140	180	79	81	80	130
Coating adaptability	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	○	○	○
High speed cutting property (envelope window affixing adaptability)	⊙	⊙	○	⊙	⊙	○-⊙	○	⊙	⊙	⊙	○-⊙

Table 2-2

	Comp. Example 1	Comp. Example 2	Comp. Example 3	Comp. Example 4	Comp. Example 5	Comp. Example 6
Blend ratio (wt parts)						
Crystalline polylactic acid (a)	100	100		80		
Crystalline polylactic acid (b)			90		50	30
Amorphous polylactic acid (c)	0	0	10	20	50	70
Drawing ratio in the MD direction (times)	3.0	3.0	2.5	3.0	2.5	2.5
Drawing ratio in the TD direction (times)	3.0	6.0	3.5	2.5	3.8	6.0
Heat treatment conditions	140	Nil	140	140	130	130
Time (sec)	3		3	3	5	5
Storage modulus E' (MPa)	370	70	290	150	40	4
TD direction	160	140	130	70	25	7
MD direction	0.5	>20	0.8	1.0	5.0	13
TD direction	0.5	>20	0.5	1.2	6.0	15
Heat of crystal fusion ΔH_m (J/g)	31	30	38	25	25	16
Haze (%)	0.8	0.7	0.9	0.5	0.6	0.5
Tear strength (mN)	280	50	250	300	220	170
Coating adaptability	⊙	×	⊙	⊙	○	×
High speed cutting property (envelope window affixing adaptability)	×	⊙	×	×	×	○

As shown in Table 2, the biaxially oriented films of a polylactic acid resin obtained in Examples 1 to 11 are found to be superior in the coating adaptability, high-speed cutting property and envelope window affixing adaptability.

Examples 12 to 16

In Examples 12 to 16, pellets of crystalline polylactic acid (a) or (b) and amorphous polylactic acid (c) shown in Table 1 were dry blended to the compositions shown in Table 3, followed by melt blending using a co-rotating twin screw extruder, extruding molten resins at a resin temperature of 200°C through a T-die, quenching by a casting roll kept at a temperature of 35°C to obtain substantially amorphous sheets. Then the sheets obtained were heated at 75°C, roll-drawn in the MD direction at the drawing ratios shown in Table 3, and then tenter-drawn in the TD direction at 85°C at the drawing ratios shown in Table 3. Then, these films were introduced into a heat treatment zone adjusted to have the temperatures shown in Table 3 to subject the films to the heat treatment for the periods shown in Table 3, with the films being kept in the drawn and held state. Thereafter, the films were cooled to a room temperature to obtain biaxially oriented films of the polylactic acid resins with a thickness of 20 μm . Evaluation results of physical properties of the films obtained are shown in

Table 3.

Table 3

		Example 12	Example 13	Example 14	Example 15	Example 16
Blend ratio (wt parts)						
	Crystalline polylactic acid (a)	100		90	80	
	Crystalline polylactic acid (b)		100			70
	Amorphous polylactic acid (c)	0	0	10	20	30
Drawing ratio in the MD direction (times)		2.5	2.5	2.3	2.6	2.5
Drawing ratio in the TD direction (times)		5.5	5.1	5.2	5.5	4.8
Heat treatment conditions	Temp. (°C)	140	140	130	130	130
	Time (sec)	3	3	3	3	3
Storage modulus E' (MPa)	MD direction	360	460	200	150	150
	TD direction	150	260	100	80	80
Heat shrinkage at 80°C for 10 sec (%)	MD direction	0.5	0.5	0.7	1.0	1.2
	TD direction	1.0	0.5	1.3	1.7	1.8
Heat of crystal fusion ΔH_m (J/g)		31	41	28	25	32
Haze (%)		0.6	0.7	0.5	0.4	0.5
Tear strength (mN)	TD direction	40	90	55	60	110
Coating adaptability		◎	◎	◎	◎	◎
High-speed cutting property (envelope window affixing adaptability)		○-◎	○-◎	○-◎	○-◎	○

As shown in Table 3, the biaxially oriented films of a polylactic acid resin obtained in Examples 12 to 16 are found to be superior in the coating adaptability, high-speed cutting property and envelope window affixing adaptability.

The polylactic acid resins used in the

following Examples 17 to 27 and Comparative Examples 7 to 10 were crystalline polylactic acid (a) and amorphous polylactic acid (b) having the weight average molecular weights and optical purities shown in Table 4, and obtained by polymerization under the controls of catalyst amount, polymerization conditions, monomer composition or the like in accordance with Examples 1B to 7B in JP-A-4-504731. However, the compositions of polylactic acid resins in the present invention should not be limited thereto.

Table 4

	Weight average Mw	Content of D-lactic acid	Optical purity	Tg	Tm
Crystalline polylactic acid (a)	290,000	4.5%	91%	59°C	153°C
Amorphous polylactic acid(b)	300,000	12.5%	75%	53°C	None

<Examples 17 to 25, 27 and Comparative Examples 7 to 9>

In Examples 17 to 25, 27 and Comparative Examples 7 to 9, pellets of crystalline polylactic acid (a) and amorphous polylactic acid (b) shown in Table 4 were dry blended to the composition shown in Table 5, followed by melt blending using co-rotating twin screw extruder, extruding the molten resins at a resin temperature of 200°C through a T-die, quenching by a casting roll kept at a temperature of 35°C to obtain substantially amorphous sheets. Then the sheets

obtained were heated at 75°C and roll-drawn at a drawing ratio of 2.5 in the MD direction, and then at 80°C tenter-drawn at a drawing ratio of 6 in the TD direction. In Examples 17 to 25, 27 and Comparative Examples 7, the films were then introduced into a heat treatment zone adjusted to have the temperatures shown in Table 3 to subject the films to the heat treatment for the periods shown in Table 5, with the films being kept in the drawn and held state. Thereafter, the films were cooled to a room temperature to obtain biaxially oriented films of the polylactic acid resin with a thickness of 25 μm . In Comparative Example 8 and 9, the films were cooled to a room temperature without undergoing the heat-treatment to obtain biaxially oriented films of the polylactic acid resins with a thickness of 25 μm . Evaluation results of physical properties of the films obtained are shown in table 5.

<Example 26>

In Example 26, a film was oriented in the same manner as in Examples 17 to 25 and 27, except that polylactic acid (a) and (b) shown in Table 4 were used and that the drawing ratios were 3 in the MD direction and 5.5 in the TD direction as shown in Table 5. The film was then subjected to the heat treatment under the conditions shown in Table 5 and cooled to a room temperature to obtain a biaxially oriented film of a

polylactic acid resin with a final thickness of 25 μm by adjusting the degree of die-lip opening. Evaluation results of the physical properties of the films obtained are shown in table 5.

5

<Comparative Example 10>

In Comparative Example 10, a film having the same composition as in Example 27 was drawn in the same manner as in Example 27, except that the film was drawn
10 at ratios of 2.5 in the MD direction and 3 in the TD direction as shown in Table 5. The film was subjected to the heat treatment under the conditions shown in Table 5 and cooled to a room temperature to obtain a biaxially oriented film of a polylactic acid resin with
15 a final thickness of 25 μm by adjusting the degree of die-lip opening. Evaluation results of the physical properties of the film obtained are shown in table 5.

Table 5-1

	Example 17	Example 18	Example 19	Example 20	Example 21	Example 22	Example 23	Example 24	Example 25	Example 26	Example 27
Blend ratio (wt parts)											
Crystalline polylactic acid (a)	80	75	70	60	50	40	95	90	85	80	100
Amorphous polylactic acid (b)	20	25	30	40	50	60	5	10	15	20	0
Drawing ratio in the MD direction (times)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.0	2.5
Drawing ratio in the TD direction (times)	6	6	6	6	6	6	6	6	6	5.5	6
Heat treatment conditions	130	130	130	130	120	120	140	140	140	140	140
Time (sec)	3	3	3	3	5	5	3	3	3	3	3
Storage modulus E'	150	130	110	70	40	20	250	210	180	170	350
TD direction	70	65	60	50	25	20	110	95	80	65	150
MD direction	1.0	1.8	2.5	3.8	4.5	8.0	0.5	0.7	0.8	1.0	0.5
Heat shrinkage at 80°C for 10 sec (%)	2.5	2.5	3.0	4.5	4.5	8.5	1.0	1.2	1.5	1.2	1.0
Heat of crystal fusion ΔH_m (J/g)	25	24	23	21	18	16	30	28	26	25	32
Haze (%)	0.5	0.4	0.4	0.3	0.3	0.4	0.8	0.7	0.6	0.5	0.9
Tear strength (mN)	80	80	79	81	75	130	75	79	79	90	79
TD direction											
MD direction	95	90	90	80	75	69	100	100	100	110	110
Tensile strength (MPa)	175	170	160	140	125	120	180	180	180	180	190
TD direction											
MD direction	190	190	190	200	210	220	190	190	190	180	190
TD direction	90	90	90	100	100	110	80	80	80	100	80
Coating adaptability	☉	☉	☉	○	○	○	☉	☉	☉	☉	☉
Heat seal property (hot tack strength / inch width)	☉ 9	☉ 10	☉ 11	☉ 13	☉ 15	☉ 17	○ 5	☉ 7	☉ 8	☉ 9	☉ 2
High speed cutting property (envelope window affixing adaptability)	☉	☉	☉	☉	☉	○	☉	☉	☉	☉	☉

Table 5-2

		Comp. Example 7	Comp. Example 8	Comp. Example 9	Comp. Example 10
Blend ratio (wt parts)					
	Crystalline polylactic acid (a)	30	100	80	100
	Amorphous polylactic acid (b)	70	0	20	0
Drawing ratio in the MD direction (times)		2.5	2.5	2.5	2.5
Drawing ratio in the TD direction (times)		6	6	6	3
Heat treatment conditions	Temp. (°C)	120	No treatment	No treatment	140
	Time (sec)	5			3
Storage modulus E' (MPa)	MD direction	2	55	40	310
	TD direction	5	250	160	160
Heat shrinkage at 80°C for 10 sec (%)	MD direction	>20	>20	>20	0.5
	TD direction	11	>20	>20	0.8
Heat of crystal fusion ΔH_m (J/g)		12	31	25	31
Haze (%)		0.4	0.7	0.5	0.8
Tear strength (mN)	TD direction	140	60	65	250
	MD direction	65	140	100	100
Tensile strength (MPa)	TD direction	100	250	200	120
	MD direction	250	200	210	150
Tensile elongation (%)	TD direction	130	80	80	160
	Coating adaptability	×	×	×	⊙
Heat seal property (hot tack strength / inch width)		⊙	×	⊙	×
High speed cutting property (envelope window affixing adaptability)		19	2	9	2
		○	⊙	⊙	×

As shown in Table 5, the biaxially oriented films of the polylactic acid resins obtained in Examples 17 to 27 are found to have tensile strengths of not lower than 60 MPa, that is, the mechanical strength sufficient for films to be used as bags. At the same time, these biaxially oriented films of a polylactic acid resin are found to be superior in the coating adaptability and high-speed cutting property.

10 Industrial Applicability

The biaxially oriented film of a polylactic acid resin of the present invention is biodegradable as it mainly comprises a polylactic acid resin and has the superior coating adaptability for an antistatic agent, a lubricant, an antiblocking agent or the like, and the superior high-speed cutting property. Therefore, the present invention can provide a biaxially oriented film of a polylactic acid resin suitable for bags, packaging film and plastering film for various windows, particularly those for outlook window envelopes.

CLAIMS

1. A biaxially oriented film of a polylactic acid resin comprising not less than 50% by weight of a polylactic acid resin,

which has a storage modulus E' at 80°C, in at least one of a longitudinal direction (MD direction) and a width direction (TD direction) of the film, of from 10 MPa to 3,000 MPa, as determined by a test method for temperature dependency of dynamic viscoelasticity in accordance with JIS K7198 (method A);

a heat shrinkage of not higher than 10%, upon heating at 80°C for 10 seconds; and

a tear strength in the width direction (TD direction) of 10 to 200 mN, as determined in accordance with JIS K7128 (method B).

2. The biaxially oriented film of a polylactic acid resin in accordance with claim 1, wherein the storage modulus E' at 80°C, in at least one of the longitudinal direction (MD direction) and the width direction (TD direction) of the film, is within the range from 50 MPa to 1,000 MPa, as determined by the test method for temperature dependency of dynamic viscoelasticity.

3. The biaxially oriented film of a polylactic acid resin in accordance with claim 1 or 2, wherein the storage modulus E' at 80°C, in at least one of the longitudinal direction (MD direction) and the width

direction (TD direction) of the film, is within the range from 10 MPa to 300 MPa, as determined by the test method for temperature dependency of dynamic viscoelasticity; and a heat of fusion, ΔH_m , at the crystal melting peak, present at a temperature not lower than 100°C, is in the range from 15 to 30 J/g, as determined by a differential scanning calorimeter (DSC) with a temperature being increased from 0°C to 200°C in accordance with JIS K7122.

4. The biaxially oriented film of a polylactic acid resin in accordance with claim 1 or 2, wherein the polylactic acid resin is a mixture comprising 95 to 60 parts by weight of crystalline polylactic acid with an optical purity of not lower than 85% and 5 to 40 parts by weight of amorphous polylactic acid with an optical purity of not higher than 80%.

5. A window for an outlook window envelope, comprising the biaxially oriented film of a polylactic acid resin in accordance with claim 1 or 2.

6. The biaxially oriented film of a polylactic acid resin in accordance with claim 1 or 2, wherein said film is drawn at a ratio of not less than 4 in the width direction (TD direction) of the film, and is subjected to a heat treatment at a temperature not lower than the glass transition temperature (T_g) thereof and not higher than the melting point (T_m) thereof.

7. A method for producing a biaxially oriented

film of a polylactic acid resin, comprising:

drawing a film comprising a resin containing not less than 50% by weight of a mixture comprising 95 to 60 parts by weight of crystalline polylactic acid with an optical purity of not lower than 85% and 5 to 40 parts by weight of amorphous polylactic acid with an optical purity of not higher than 80%, at a ratio of not less than 4 in the width direction (TD direction) of the film; and

subsequently subjecting the film to a heat treatment at a temperature not lower than the glass transition temperature (T_g) thereof and not higher than the melting point (T_m) thereof.