BOPP film with improved stiffness/toughness balance

The present invention relates to a new biaxially oriented polypropylene (BOPP) film, a process for the preparation of such film as well as the use of a polypropylene for the preparation of such film and an article comprising such film.

Biaxially oriented polypropylene (BOPP) films, also known as oriented polypropylene films, are used in a wide variety of technical applications such as packaging, tapes or capacitor films. Desired properties of these polypropylene films are typically high stiffness in combination with some flexibility and toughness, i.e. the BOPP film should have high modulus of elasticity as well as high elongation at break. However, due to the production of the BOPP film by sequential drawing in two orthogonal directions, at two different temperatures, the BOPP film processing introduces considerable anisotropy regarding these mechanical properties of the final BOPP film. To increase the stiffness, i.e. the modulus of elasticity, of the final BOPP film it was up to now necessary to increase the isotacticity and melting point of the base resin used for preparing the BOPP film. At the same time, however, the increase in isotacticity and melting point typically reduces the toughness, i.e. the elongation at break, of the BOPP film prepared from such resin.

Thus, there is still a need in the art for providing a biaxially oriented polypropylene (BOPP) film which avoids the foregoing disadvantages and especially allows for improving the mechanical properties of such a film. In other words, it would be desirable to provide a biaxially oriented polypropylene (BOPP) film featuring favourable mechanical properties like high stiffness and high toughness compared to prior art biaxially oriented polypropylene (BOPP) films.

Accordingly, it is an object of the present invention to provide a biaxially oriented polypropylene (BOPP) film featuring an improved balance of mechanical properties like stiffness and toughness. In particular, the final film should have a high modulus of elasticity as well as a high elongation at break.

Accordingly, the present invention is directed in a first aspect to a biaxially oriented polypropylene (BOPP) film comprising a polypropylene (PP), wherein the biaxially oriented polypropylene (BOPP) film has a) a modulus of elasticity in transverse direction (TD) of at least 5 000 N/mm2, and b) an elongation at break in machine direction (MD) of at least 170 %, and wherein the polypropylene (PP) is a random polypropylene copolymer (C-PP) having i) a melting temperature (Tm) measured by differential scanning calorimetry (DSC) in the range of from 164 to 169 °C, ii) a xylene cold soluble fraction (XCS) determined at 25 °C according to ISO 16152 in the range of from 1.0 to 3.5 wt.-%, iii) a content of ethylene units in the range from 0.01 to 0.5 wt.-%, based on the total weight of the random polypropylene copolymer (C-PP), iv) a crystallization temperature (Tc) measured by differential scanning calorimetry (DSC) of at least 115 °C and v) a comonomer corrected meso sequence length (MSL4') in the range of from 130 to 250 as determined by the following formula (IV) MSL4' = (((1-(fE*5))*[mmmm])/(((1-(fE*5))*0.5*[mmmr])+(0.5*2*fE)))+4 (IV). In one example, there is disclosed a biaxially

oriented polypropylene (BOPP) film, comprising a polypropylene (PP), wherein the biaxially oriented polypropylene (BOPP) film has

a) a modulus of elasticity in transverse direction (TD) of at least 5 000 N/mm^2, and

b) an elongation at break in machine direction (MD) of at least 170 %, and

wherein the polypropylene (PP) is a random polypropylene copolymer (C-PP) having

i) a melting temperature (T_m) measured by differential scanning calorimetry (DSC) in the range of from 164 to 169 °C,

ii) a xylene cold soluble fraction (XCS) determined at 25 °C according to ISO 16152 in the range of from 1.0 to 3.5 wt.-%,

iii) a content of ethylene units in the range from 0.01 to 0.5 wt.-%, based on the total weight of the random polypropylene copolymer (C-PP), and

iv) a comonomer corrected meso sequence length (MSL4') in the range of from 130 to 250 as determined by the following formula (IV)

$$MSL4' = (((1-(fE*5))*[mmmm])/(((1-(fE*5))*0.5*[mmmr])+(0.5*2*fE)))+4 \qquad (IV).$$

Preferably the values for the modulus of elasticity in transverse direction (TD) and the elongation at break in machine direction (MD) are obtained if the polypropylene (PP) when drawn in transverse direction has a drawing temperature ($T_{draw'}$) in the range of the inequation (II)

$$Tm - 25 \leq Tdraw' \leq Tm + 10 \qquad (II),$$

wherein

Tdraw' is the drawing temperature ($T_{draw'}$) in °C of the first segment of the drawing zone (DZT) in the oven where the polypropylene (PP) is drawn in transverse direction, wherein further this first segment of the drawing zone (DZT) is defined as the zone where the draw ratio of the drawn polypropylene (PP) is at least 1.1, preferably is in the range of 1.1 to 5.0, more preferably is in the range 1.1 to 4.0, yet more preferably is in the range of 1.1 to 3.5; and Tm is the melting temperature (T_m) of the polypropylene (PP) in °C.

The inventors surprisingly found out that the foregoing biaxially oriented polypropylene (BOPP) film has an improved balance of mechanical properties compared to prior art biaxially oriented polypropylene films. More precisely, the inventors found out that the biaxially oriented polypropylene (BOPP) film has high stiffness in combination with high toughness, i.e. the BOPP film has high modulus of elasticity as well as high elongation at break.

According to a second aspect, the present invention is directed to a process for the preparation of a biaxially oriented polypropylene (BOPP) film, the process comprises at least the steps of

a) providing a polypropylene (PP) being a random polypropylene copolymer (C-PP) as defined herein,

CLAIMS

1. Biaxially oriented polypropylene (BOPP) film comprising a polypropylene (PP), wherein the biaxially oriented polypropylene (BOPP) film has
   a) a modulus of elasticity in transverse direction (TD) of at least 5 000 N/mm^2, and
   b) an elongation at break in machine direction (MD) of at least 170 %, and

   wherein the polypropylene (PP) is a random polypropylene copolymer (C-PP) having
   i) a melting temperature (T_m) measured by differential scanning calorimetry (DSC) in the range of from 164 to 169 °C,
   ii) a xylene cold soluble fraction (XCS) determined at 25 °C according to ISO 16152 in the range of from 1.0 to 3.5 wt.-%,
   iii) a content of ethylene units in the range from 0.01 to 0.5 wt.-%, based on the total weight of the random polypropylene copolymer (C-PP),
   iv) a crystallization temperature (T_c) measured by differential scanning calorimetry (DSC) of at least 115 °C and
   v) a comonomer corrected meso sequence length (MSL4') in the range of from 130 to 250 as determined by the following formula (IV)

$$MSL4' = (((1-(fE*5))*[mmmm])/(((1-(fE*5))*0.5*[mmmr])+(0.5*2*fE)))+4 \quad (IV).$$

2. Biaxially oriented polypropylene (BOPP) film according to claim 1, wherein the biaxially oriented polypropylene (BOPP) film has
   a) a modulus of elasticity in machine direction (MD) of at least 2 000 N/mm^2, and/or
   b) an elongation at break in transverse direction (TD) of at least 46 %.

3. Biaxially oriented polypropylene (BOPP) film according to claim 1 or 2, wherein the biaxially oriented polypropylene (BOPP) film has a tensile strength in machine direction (MD) of at least 110 N/mm^2 and/or a tensile strength in transverse direction (TD) of at least 300 N/mm^2.

4. Biaxially oriented polypropylene (BOPP) film according to any one of the preceding claims, wherein the polypropylene (PP) is a random polypropylene copolymer (C-PP) having
   a) a crystallization temperature (T_c) measured by differential scanning calorimetry (DSC) of at least 118 °C, and/or
   b) a melt flow rate MFR_2 (230 °C) measured according to ISO 1133 of ≤ 7.0 g/10min, preferably of ≤ 5.0 g/10min, and/or