The present inventors have compared the polymer of the invention to a broad range of commercial injection moulding grades of comparable tensile modulus to show that the relationship in claim 1 is not one which can be found in commercial polymers and is one which yields the advantageous properties highlighted above.

Summary

The disclosure provides a multimodal polyethylene polymer having an MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29\left(M_w/M_n\right) + 0.8.$$

In one aspect, there is provided multimodal polyethylene polymer having an MFR_2 of 0.1 to 2 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

Preferably, the multimodal polyethylene polymer comprises a lower molecular weight homopolymer component and a higher molecular weight copolymer component, e.g. with a C3-12 alpha olefin comonomer.

Thus, the diclosure provides a multimodal polyethylene polymer having a lower molecular weight homopolymer component and a higher molecular weight copolymer component, e.g. with a C3-12 alpha olefin comonomer and having an MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29\left(M_w/M_n\right) + 0.8.$$

In another aspect, there is provided multimodal polyethylene copolymer derived from the comonomer 1-butene, wherein the copolymer has MFR_2 of 0.05 to 10.0

g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

The polymer of the disclosure has a large Mw/Mn ratio and small Mz/Mw ratio. This molecular distribution structure results in injection moulded articles, and in particular caps and closures, which have a good aspect (e.g. lower high-tip and less angel-hair).

In another aspect, there is provided a multimodal polyethylene copolymer having MFR_2 of 0.05 to 10.0 g/10min, an Mz in the range of 400 kD to 700 kD, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

The disclosure provides a multimodal polyethylene polymer having an MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more, wherein

$\frac{M_w^2}{M_n M_z} \geq 2.8$ and wherein

$$M_z / M_w \leq 0.29 \left(M_w / M_n \right) + 0.8 .$$

Preferably, said multimodal polyethylene polymer comprises a lower molecular weight homopolymer component and a higher molecular weight copolymer component, e.g. with a C3-12 alpha olefin comonomer.

Thus, the disclosure provides a multimodal polyethylene polymer having a lower molecular weight homopolymer component and a higher molecular weight copolymer component, e.g. with a C3-12 alpha olefin comonomer and having an MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more, wherein

$\frac{M_w^2}{M_n M_z} \geq 2.8$ and wherein

$$M_z / M_w \leq 0.29 \left(M_w / M_n \right) + 0.8 .$$

The disclosure provides an injection or compression moulded article, such as a cap or closure comprising a polymer as herein before defined. Such caps or closures may weight from 1 to 10 g. Moreover, caps or closures of the disclosure may possess a high tip of less than 0.5 mm in height, such as less than 0.25 mm in height. In another aspect, there is provided an injection or compression moulded article comprising a polymer as herein before defined.

In another aspect, there is provided an injection or compression moulded article comprising a cap having a high tip of less than 0.5 mm or having no high tip at all, wherein the cap comprises a multimodal polyethylene copolymer having MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

The disclosure provides the use of the polymer as hereinbefore defined in the manufacture of a injection moulded or compression article, such as a cap or closure.

In another aspect, there is provided a process for the preparation of a polyethylene as herein before defined comprising;

polymerising ethylene and optionally at least one C3-10 alpha olefin comonomer so as to form a lower molecular weight component (A); and subsequently

polymerising ethylene and optionally at least one C3-10 alpha olefin comonomer in the presence of component (A) so as to form a higher molecular weight component (B). The disclosure further comprises compression or injection moulding the product of said process to form an article. Preferably, the multimodal polyethylene polymer made in this process comprises a lower molecular weight homopolymer component and a higher molecular weight copolymer component, e.g. with a C3-12 alpha olefin comonomer.

Definitions

The term Mz refers to the Z average molecular weight of the polymer. The Mz is measured by establish thermodynamic equilibrium where molecules distribute according to molecular size. Mz is more sensitive than the other averages to the largest molecules present in the sample and hence the values we report in the present invention represent polymers with a less pronounced high molecular weight tail..

Detailed Description of Invention

It has been found that the high density polyethylene polymer according to the invention provides an improved material for compression or especially injection moulding, in particular for cap and closure applications, which combines very good mechanical properties e.g. in terms of FNCT and tensile modulus with excellent processability and aspect, e.g. in terms of high tip and angel hair. Whilst problems of angel hair and high tips are not so critical when a cap is compression moulded, the improvements which we observe in terms of FNCT and tensile modulus are important in compression moulded caps.

The polymer of the invention is a multimodal high density ethylene polymer and may be an ethylene homopolymer or an ethylene copolymer. By ethylene copolymer is meant a polymer the majority by weight of which derives from

Claims

1. A multimodal polyethylene polymer having an MFR_2 of 0.1 to 2 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

2. A multimodal polyethylene polymer as claimed in claim 1 wherein

$$\frac{M_w^2}{M_n M_z} \geq 2.8$$

3. A multimodal polyethylene polymer as claimed in claim 1 having a density of 950 to 960 kg/m^3.

4. A multimodal polyethylene polymer as claimed in claim 1 having tensile modulus 910 MPa or more.

5. A multimodal polyethylene polymer as claimed in claim 1 wherein Mz is in the range of 400 kD to 700 kD.

6. A multimodal polyethylene polymer as claimed in claim 1 having FNCT more than 50 h.

7. A multimodal polyethylene polymer as claimed in claim 1 having 0.1 to 1 mol% comonomer.

8. A multimodal polyethylene polymer as claimed in claim 1 wherein said polymer is a copolymer with the comonomer 1-butene.

9. A multimodal polyethylene polymer as claimed in claim 1 having a lower molecular weight component and a higher molecular weight copolymer component wherein said lower molecular weight component is a homopolymer or a copolymer with a comonomer content of less than 0.2 mol%.

10. A multimodal polyethylene polymer as claimed in claim 1 having a lower molecular weight component and a higher molecular weight copolymer component wherein said lower molecular weight component is a homopolymer or a copolymer with a comonomer content of less than 0.1 mol%.

11. A multimodal polyethylene polymer as claimed in claim 1 having a lower molecular weight component and a higher molecular weight copolymer component wherein said lower molecular weight component is a homopolymer or a copolymer with a comonomer content of less than 0.05 mol%.

12. A multimodal polyethylene polymer as claimed in claim 1 having a lower molecular weight (LMW) homopolymer component and a higher molecular weight (HMW) ethylene copolymer component.

13. A multimodal polyethylene polymer as claimed in claim 1 having a lower molecular weight (LMW) homopolymer component and a higher molecular weight

(HMW) ethylene copolymer component, wherein said HMW copolymer component comprises at least one C3-12 alpha olefin.

14. A multimodal polyethylene polymer as claimed in claim 1 having a lower molecular weight (LMW) homopolymer component and a higher molecular weight (HMW) ethylene copolymer component, wherein said HMW copolymer component comprises but-1-ene, hex-1-ene or oct-1-ene.

15. A multimodal polyethylene polymer as claimed in claim 1 having 48 to 55 wt% of a HMW component (B) and 52 to 45 wt% LMW component (A).

16. An injection or compression moulded articlecomprising a polymer as claimed in claim 1.

17. An injection or compression moulded article of claim 16, wherein the article is a cap or closure.

18. A process for the preparation of a polyethylene as claimed in claim 1 comprising;

polymerising ethylene and optionally at least one C3-10 alpha olefin comonomer so as to form a lower molecular weight component (A); and subsequently

polymerising ethylene and optionally at least one C3-10 alpha olefin comonomer in the presence of component (A) so as to form a higher molecular weight component (B).

19. A multimodal polyethylene copolymer derived from the comonomer 1-butene, wherein the copolymer has MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

20. A multimodal polyethylene copolymer having MFR_2 of 0.05 to 10.0 g/10min, an Mz in the range of 400 kD to 700 kD, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$

21. A multimodal polyethylene polymer as claimed in claim 20 wherein Mz is in the range of 450 kD to 600 kD.

22. An injection or compression moulded article comprising a cap having a high tip of less than 0.5 mm or having no high tip at all, wherein the cap comprises a multimodal polyethylene copolymer having MFR_2 of 0.05 to 10.0 g/10min, a density of 940 kg/m^3 or more, a tensile modulus of 900 MPa or more and wherein

$$M_z/M_w \leq 0.29(M_w/M_n) + 0.8.$$