Cross-linked Foams Made From Interpolymers of Ethylene/Alpha-Olefins

Field

[0001] The present disclosure relates to foams comprising at least one ethylene/α-olefin interpolymer and methods of making and using the foams in various applications, such as footwear applications.

Introduction

[0002] Ethylene vinyl acetate copolymers (EVA), polyolefins (PO), olefin block copolymers (OBC) and blends thereof are used to fabricate foam products in footwear applications such as inner soles, midsoles, outer soles, unisoles, and sole inserts. In particular, OBC's have been shown to provide for cross-linked foams with excellent resiliency over a range of temperatures and over many compression-recovery cycles. However, there are still needs for improved foams having high rebound resilience without limited split tear strength, which could result in premature failure of foam products. Accordingly, the present disclosure relates to novel foam formulations of a particular design (e.g., particular foam densities and polymer crystallinities) that provide a unique balance of resiliency, high temperature compression set, rebound, and foam split tear strength.

Summary

[0003] In one aspect, the present disclosure refers to a foam composition comprising at least one ethylene/α-olefin interpolymer comprising at least one soft segment and at least one hard segment wherein a hard segment is a block of polymerized units in which the comonomer content is less than 5 wt.%, based on the weight of the polymer, and wherein a soft segment is a block of polymerized units in which the comonomer content is greater than 5 wt.%, based on the weight of the polymer,

wherein the foam composition has a density of from 0.10 g/cc to 0.50 g/cc, wherein the ethylene/α-olefin interpolymer has a density of from 0.877 g/cc to 0.889 g/cc, wherein the at least one soft segment has a comonomer content of from 12 mol% to 14 mol %, and wherein the ethylene/α-olefin interpolymer:

(a) has a M_w/M_n from 1.7 to 3.5, at least one melting point, T_m, in degrees Celsius, and a density, d, in grams/cubic centimeter, wherein the numerical values of T_m and d correspond to the relationship:

$$T_m \geqq -2002.9+4538.5(d)-2422.2(d)^2;$$ and/or

(b) has a M_w/M_n from 1.7 to 3.5, and is characterized by a heat of fusion, ΔH in J/g, and a delta quantity, ΔT, in degrees Celsius defined as the temperature difference between the tallest DSC peak and the tallest CRYSTAF peak, wherein the numerical values of ΔT and ΔH have the following relationships:

$$\Delta T > -0.1299(\Delta H)+62.81$$ for ΔH greater than zero and up to 130 J/g,

$\Delta T \geqq 48°$ C. for ΔH greater than 130 J/g,

wherein the CRYSTAF peak is determined using at least 5 percent of the cumulative polymer, and if less than 5 percent of the polymer has an identifiable CRYSTAF peak, then the CRYSTAF temperature is 30° C.; and/or

(c) is characterized by an elastic recovery, Re, in percent at 300 percent strain and 1 cycle measured with a compression-molded film of the ethylene/α-olefin interpolymer, and has a density, d, in grams/cubic centimeter, wherein the numerical values of Re and d satisfy the following relationship when ethylene/α-olefin interpolymer is substantially free of a cross-linked phase:

$$Re > 1481-1629(d);$$ and/or

(d) has a storage modulus at 25° C., G′(25° C.), and a storage modulus at 100° C., G′(100° C.), wherein the ratio of G′(25° C.) to G′ (100° C.) is in the range of about 1:1 to about 9:1.

[0003a] Examples relate to foam compositions comprising at least one ethylene/α-olefin interpolymer comprising at least one soft segment and at least one hard segment, wherein the foam composition has a density of from 0.10 g/cc to 0.50

g/cc, wherein the ethylene/α-olefin interpolymer has a density of from 0.877 g/cc to 0.895 g/cc, wherein the at least one soft segment has a comonomer content of from 6 mol% to 15 mol %, and wherein the ethylene/α-olefin interpolymer:

(a) has a M_w/M_n from about 1.7 to about 3.5, at least one melting point, T_m, in degrees Celsius, and a density, d, in grams/cubic centimeter, wherein the numerical values of T_m and d correspond to the relationship:

$$T_m \geqq -2002.9+4538.5(d)-2422.2(d)^2;$$ and/or

[0003b] In another aspect, the present disclosure refers to a foamed article comprising the foam composition as disclosed herein.

What is claimed is:

1. A foam composition comprising at least one ethylene/α-olefin interpolymer comprising at least one soft segment and at least one hard segment wherein a hard segment is a block of polymerized units in which the comonomer content is less than 5 wt.%, based on the weight of the polymer, and wherein a soft segment is a block of polymerized units in which the comonomer content is greater than 5 wt.%, based on the weight of the polymer,

wherein the foam composition has a density of from 0.10 g/cc to 0.50 g/cc, wherein the ethylene/α-olefin interpolymer has a density of from 0.877 g/cc to 0.889 g/cc, wherein the at least one soft segment has a comonomer content of from 12 mol% to 14 mol %, and wherein the ethylene/α-olefin interpolymer:

(a) has a M_w/M_n from 1.7 to 3.5, at least one melting point, T_m, in degrees Celsius, and a density, d, in grams/cubic centimeter, wherein the numerical values of T_m and d correspond to the relationship:

$T_m \geqq -2002.9+4538.5(d)-2422.2(d)^2$; and/or

(b) has a M_w/M_n from 1.7 to 3.5, and is characterized by a heat of fusion, ΔH in J/g, and a delta quantity, ΔT, in degrees Celsius defined as the temperature difference between the tallest DSC peak and the tallest CRYSTAF peak, wherein the numerical values of ΔT and ΔH have the following relationships:

$\Delta T > -0.1299(\Delta H)+62.81$ for ΔH greater than zero and up to 130 J/g,

$\Delta T \geqq 48°$ C. for ΔH greater than 130 J/g,

wherein the CRYSTAF peak is determined using at least 5 percent of the cumulative polymer, and if less than 5 percent of the polymer has an identifiable CRYSTAF peak, then the CRYSTAF temperature is 30° C.; and/or

(c) is characterized by an elastic recovery, Re, in percent at 300 percent strain and 1 cycle measured with a compression-molded film of the ethylene/α-olefin interpolymer, and has a density, d, in grams/cubic centimeter, wherein the

numerical values of Re and d satisfy the following relationship when ethylene/α-olefin interpolymer is substantially free of a cross-linked phase:

$Re > 1481 - 1629(d)$; and/or

(d) has a storage modulus at 25° C., G′(25° C.), and a storage modulus at 100° C., G′(100° C.), wherein the ratio of G′(25° C.) to G′ (100° C.) is in the range of about 1:1 to about 9:1.

2. The foam composition of claim 1, wherein the ethylene/α-olefin interpolymer
has a melt index of from 0.3 dg/min to 6.0 dg/min (ASTM D-1238 at 190°C, 2.16 kg).

3. The foam composition of claim 1, further comprising a foam split tear strength of greater than 2.5 kg/cm, a foam rebound percentage of greater than 50.0%, and a skin rebound percentage of greater than 50.0%.

4. The foam composition of claim 1, wherein the α-olefin of the ethylene/α-olefin interpolymer is a C_{6-10} α-olefin.

5. The foam composition of claim 1, wherein the ethylene/α-olefin interpolymer is cross-linked by a cross-linking agent.

6. The foam composition of claim 5, wherein the cross-linking agent is a peroxide.

7. The foam composition of claim 1, wherein the foam is a closed-cell foam and further comprises a blowing agent.

8. The foam composition of claim 7, wherein the blowing agent is an azodicarbonamide.

9. The foam composition of claim 1, further comprising a second polymer component selected from an ethylene/α-olefin random copolymer and an ethylene vinyl acetate copolymer.

10. The foam composition of claim 1, further comprising at least one additive, wherein the additive is a nucleating agent, a stability control agent, a filler, a pigment, an antioxidant, an acid scavenger, a UV stabilizer, a flame retardant, a lubricant, a processing aid, an extrusion aid, a blowing agent activator, a coagent, or a combination thereof.

11. A foamed article comprising the foam composition of claim 1.

12. The foamed article of claim 11, wherein the foamed article is a footwear article.