

Organoleptically improved, low film-blocking Styrene Butadiene Block Copolymers

Description

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The invention relates to styrene butadiene block-copolymers (SBC), polymer compositions comprising said SBC, and the use of said polymer compositions for the production of films.

- 10 Stiff and tough styrene-butadiene block copolymers (SBCs) and compositions comprising SBC are known. For the production of shrink films, often mixtures of a tough SBC component and a stiff SBC component, optionally together with general purpose polystyrene (GPPS), are blended and extruded to a film. In a next online step, the film is heated by hot air and stretched orthogonal (transverse) on the extrusion direction (transverse machine direction orientation or TDO) by a factor 4 to 6 and eventually also stretched perpendicular (parallel) to machine direction (machine direction orientation or MDO) by factor up to 1.1. Finally, the edges are cut and the films are wrapped on big rolls. Later, the films can be cut into smaller rolls, printed, and sealed to a long cylindrical hose. Finally, the printed hose is cut into the dimensions of cylindrical labels and shrunk around a container (e.g. a bottle) by applying heat, typically in a heat tunnel. In another process, the film is stretched in MDO direction by factor 2 to 5 and eventually also stretched in TDO by factor up to 1.1. After cutting the film edges and wrapping the film on big rolls, the films are cut into smaller rolls and printed. The label is wrapped around a container, cut, glued and shrunk around a container by application of heat.

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- US 2011/098401 describes mixtures of styrene-butadiene block copolymers A and B for the production of heat-shrinkable films with high shrinkage capability and high stiffness/strength. Preferably SBC copolymer A has the structure $S-(B/S)_A-S$ or, preferred, is a single copolymer block $(B/S)_A$ wherein $(B/S)_A$ is a random vinylaromatic/diene copolymer hard block (diene 5 to 35 wt.-%, Mn 15,000 to 300,000 g/mol) and S is a vinylaromatic polymer hard block. Preferably the SBC block copolymers B are star shaped having short branches $S_e-(B/S)_B\sim$ and long branches $(B/S)_A-S_i-(B/S)_B-S_s\sim$ where $(B/S)_B$ is a soft random copolymer block (diene 80 to 40 wt.-%), S_e , S_i are long and S_s is a short vinylaromatic polymer block.

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- WO 2018/114569 and WO 2018/153808 describe SBC mixtures for shrink wrap films comprising a stiff star-shaped block copolymer A or A1 having two short branches of a single copolymer block $(B/S)_{Ai}$ (Mn 5,000 to 15,000 g/mol) and two long branches of the structure $S_i-[(B/S)_A]_n-(B/S)_{Ai}$ or $[(B/S)_A]_n-(B/S)_{Ai}$ wherein Mn of block $[(B/S)_A]_n$ is 50,000 to 150,000 g/mol and Mn of block S_i is 3,000 to 8,000 g/mol.

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Further comprised is a tough star shaped block copolymer B or A2 which preferably has three or two short branches of structure $S_e-(B/S)_B\sim$ or $S_e-(B/S)_B-S_s\sim$ and one or two long branch(es) of structure $(B/S)_{Ae}-S_i-(B/S)_B-$ or $(B/S)_{Ae}-S-(B/S)_B-S_s\sim$; where Mn of block $(B/S)_B$ is 5,000 to 40,000 g/mol, Mn of block $(B/S)_{Ae}$ is 30,000 to 100,000 g/mol, Mn of block S_e and S_i is 5,000 to 30,000 g/mol and Mn of block S_s is < 2,500 g/mol.

The diene content of (random) hard blocks $(B/S)_A$ of SBCs A, A1, B and A2 is 35 to 5 wt.-%; the diene content of soft blocks $(B/S)_B$ of SBC B is 80 to 40 wt.-% and of SBC A2 is 100 to 75 wt.-%, respectively.

The films made of said prior art SBC blends are made out of a soft phase and a hard phase wherein the soft has a cylindrical morphology.

US 2005/009990 discloses mixtures comprising linear block copolymers made from vinylaromatic monomers and from dienes of the structure (I) $S_1-B_1-S_2$ and (II) $S_3-B_2-S_4$, where S_1 is a block made from vinylaromatic monomers with number-average molar mass Mn in the range from 40,000 to 100,000 g/mol, each of S_2 , S_3 and S_4 is a block made from vinylaromatic monomers with number-average molar mass Mn in the range from 5,000 to 20,000 g/mol, each of B_1 and B_2 is a block made from dienes or a copolymer block made from dienes and from vinylaromatic monomers with number-average molar mass Mn in the range from 15,000 to 40,000 g/mol, and the ratio of the block copolymers (I)/(II) is in the range from 0.6 to 2. The transitions between the blocks are sharp. The Examples show simultaneously prepared mixtures of SBC (I) (Mn $\approx$ 97,000 to 100,000 g/mol) and SBCs (II) (Mn $\approx$ 45,000 to 49,000 g/mol) which mixtures have a butadiene content in the range of 21.6 to 35 wt.%. Blends of said mixtures with GPPS have high toughness together with high stiffness and can be used for the production of thin films.

Films produced from the SBC polymers or polymer compositions according to the prior art often have the tendency to stick when wrapped onto rolls during the production process. This blocking of the stretched film can cause various technical problems. In some cases, it is even impossible to unwind the roll after several days. Prior art films often suffer unwanted stretching and eventually ripping during processing.

Moreover, prior art materials often have an unpleasant odor. Thus, the blocking of the films and the organoleptic properties of said materials are still in need of improvement.

One object of the invention is to provide a material based on styrene butadiene block-copolymers (SBC) which allows extrusion of blown and cast films with high melt strength,

which is suitable for the production of shrink films with good mechanical properties and with reduced layer-to-layer stickiness. Moreover, the organoleptic properties of the material shall be improved.

- 5 The problem is solved by the block copolymer and polymer composition according to the claims.

One aspect of the invention is a linear block copolymer (A) comprising (or consisting of) at least two polymer blocks S of different number average molecular weight M_n essentially consisting of at least one vinylaromatic monomer, and at least one polymer block B essentially consisting of at least one conjugated diene, wherein at least two of the blocks S are terminal blocks S1 and S2;

10 wherein block copolymer (A) consists of - based on the entire block copolymer (A) - 65 to 85% by weight, preferably from 68 to 80% by weight, more preferably 70 to 75% by weight, of at least one vinylaromatic monomer, in particular styrene, and 15 15 to 35% by weight, preferably 20 to 32%, more preferably 25 to 30% by weight, of at least one conjugated diene, in particular butadiene and/or isoprene, more preferably butadiene;

20 wherein the proportion of a soft phase, built essentially from polymerized conjugated diene, is from 15 to 35% by volume - based on the entire block copolymer (A), and wherein the soft phase - embedded in a hard phase (proportion 65 to 85% by volume) built essentially from polymerized vinylaromatic monomer - has a cylindrical morphology; and

25 wherein block copolymer (A) has sharp block transitions, and has a number average molecular weight M_n of at least 140,000 g/mol.

In the context of the invention, "sharp block transitions" means that the transitions between the blocks of the block copolymer are sharply separated (i.e. the composition changes suddenly). Block copolymer (A) does not comprise blocks with tapered block transitions.

30 Preferably block copolymer (A) does not comprise random blocks.

Morphologies are determined by transmission electron microscopy (TEM) on OsO_4 stained ultramicrotome samples of SBC polymers or polymer compositions.

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In the context of the invention "diene" means a conjugated diene. "Butadiene" means 1,3-butadiene. In the context of the invention a (co)polymer comprising a monomer and optionally further comonomers means a (co)polymer comprising structural units derived from said polymerized monomer(s).

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In the context of the invention a polymer (block) "essentially consists of" at least one vinylaromatic monomer or at least one conjugated diene means that the polymer consists of 85 to 100% by weight of the at least one vinylaromatic monomer or 85 to 100% by weight of the at least one conjugated diene and optionally of 0 to 15% by weight of at least one conjugated diene or 0 to 15% by weight of at least one vinyl aromatic monomer, respectively.

Polymer block S of block copolymer (A) preferably consists of 90 to 100 wt.-% of at least one vinylaromatic monomer and 0 to 10 wt.-% of at least one conjugated diene; and polymer blocks B of block copolymer (A) preferably consist of 90 to 100 wt.-% of at least one conjugated diene and 0 to 10 wt.-%, of at least one vinylaromatic monomer.

In the context of the invention, the number average molecular weight M_n is determined by GPC according to ISO 16014-3:2012 (size exclusion with relative calibration method against polystyrene standards at a temperature $< 60\text{ }^{\circ}\text{C}$).

Preferably block copolymer (A) consists of two terminal polymer blocks S1 and S2, and one polymer block B.

More preferably block copolymer (A) consists of two terminal vinylaromatic homopolymer blocks S1 and S2 and one diene homopolymer block B.

In particular preferred block copolymer (A) is a linear block copolymer (A) of the structure (I) S1-B-S2 wherein S1 and S2 are polystyrene blocks and B is a polybutadiene block.

Examples of vinylaromatic monomers which may be used for the preparation of block copolymer (A) are styrene, alpha-methylstyrene, ring-alkylated styrenes, such as p-methylstyrene or tert-butylstyrene, or a mixture of these. Preferred are styrene and/or alpha-methylstyrene, in particular preferred is styrene.

Suitable dienes which may be used for the preparation of block copolymer (A) are 1,3-butadiene, isoprene, 2,3-dimethylbutadiene, 1,3-pentadiene or 1,3-hexadiene, or a mixture of these; 1,3-butadiene and isoprene are preferred; 1,3-butadiene is particularly preferred.

Particularly preferred block copolymer (A) comprises (or consists of) styrene and butadiene.

Preferably the number average molecular weight M_n of block copolymer (A) is in the range of from 140,000 to 1,000,000 g/mol, more preferably 140,000 to 500,000 g/mol, most preferably 140,000 to 300,000 g/mol.

Preferably the number average molecular weight M_n of polymer block S1 is in the range of from 12,000 to 50,000 g/mol, more preferably 15,000 to 30,000. Preferably the number average molecular weight M_n of polymer block S2 is in the range of from 40,000 to 150,000 g/mol, more preferably 60,000 to 140,000 g/mol. Preferably the number average molecular weight M_n of polymer block B is in the range of from 15,000 to 80,000 g/mol, more preferably 20,000 to 60,000 g/mol.

Preferred is a block copolymer (A) of the structure (I) S1-B-S2 made from 68 to 80% by weight, preferably 70 to 75% by weight, of at least one vinylaromatic monomer, in particular styrene, and 20 to 32% by weight, preferably 25 to 30% by weight, of at least one diene, in particular butadiene, having a number average molecular weight M_n in the range of from 140,000 to 500,000 g/mol.

More preferred is a block copolymer (A) of the structure (I) S1-B-S2 made from 70 to 75% by weight of at least one vinylaromatic monomer, in particular styrene, and 25 to 30% by weight, of at least one diene, in particular butadiene, having a number average molecular weight M_n in the range of from 140,000 to 300,000 g/mol.

The proportion of the soft phase – built essentially from polymerized conjugated diene – is generally from 15 to 35% by volume, preferably 18 to 32% by volume, more preferably 22 to 30% by volume – based on block copolymer (A); accordingly, the proportion of the hard phase – built essentially from vinylaromatic monomer – is from 65 to 85% by volume, more preferably 68 to 82% by volume, most preferably 70 to 78% by volume – based on block copolymer (A).

The amount of the soft phase and the hard phase is determined based on OsO_4 stained TEM pictures and computer processing calculating diene rich (and hence soft) phases (black in TEM) and vinylaromatic rich (and hence hard) phases (white in TEM).

According to the invention block copolymer (A) has sharp block transitions and the soft phase of block copolymer (A) has a cylindrical morphology.

Block copolymer (A) according to the invention may be prepared, preferably is prepared, by sequential anionic polymerization of vinylaromatic monomers and conjugated dienes with organo-alkali-metal initiator.

Sequential anionic polymerization is known per se. The anionic polymerization initiator used may be any of the conventional mono- or bifunctional alkyl, aryl, or aralkyl compounds of an alkali metal. Preferably, monolithium hydrocarbon compounds R-Li are used as initiator, where R can be an aliphatic, cycloaliphatic, or aromatic hydrocarbon

moiety having from 1 to 12 C atoms. It is preferable to use n-butyllithium or sec-butyllithium, more preferably sec-butyllithium.

The amount of polymerization initiator needed depends on the desired molecular weight.

- 5 It is generally in the range from around 0.01 to around 0.07 mol %, preferably 0.01 to 0.07 mol %, based on the total amount of monomer.

- 10 The polymerization is preferably undertaken in the presence of a solvent. Suitable solvents are the conventional aliphatic, cycloaliphatic, or aromatic hydrocarbons having from 4 to 12 carbon atoms and used for anionic polymerization, such as pentane, hexane, heptane, cyclohexane, methylcyclohexane, isooctane, benzene, alkylbenzenes, such as toluene, xylene, ethylbenzene, or decalin, or a suitable mixture. Preference is given to the use of cyclohexane and methylcyclohexane.

- 15 The polymerization temperature is generally from 0 to 100°C, preferably from 30 to 90°C, particularly preferably from 40 to 90°C. The polymerization reaction is generally carried out in a plurality of stages, where the initiator is added once, using a single initiation process.

- 20 The sequence of monomer addition depends on the selected block structure. In the case of a batch process, it is preferable to begin by using all of, or a portion of, the solvent, such as cyclohexane, as initial charge. Next, the vinylaromatic monomer required for the first block S1 is added. Afterwards the initial charge of initiator, such as sec-butyllithium, that is required to establish the desired molar mass, plus what is known as a titration amount, which serves to destroy traces of impurities in the solvent and in the reactor tank is added. The portion of monomers required to produce block S1 is used as initial charge in the reactor after which the polymerization reaction is initiated via addition of the initiator. In order to get sharp block transitions it is required to let the polymerization run until all monomer has reacted before adding the second monomer. This is typically observed by monitoring the reaction temperature. All monomers have reacted when the temperature starts to decrease after a temperature increase during the reaction. Then - after total consumption of the vinyl aromatic monomer - diene monomer is added and polymerized, in order to produce the block B.

- 35 Thereafter, - after total consumption of the diene monomer – the remaining amount of vinylaromatic monomer is added and polymerized, in order to produce the block S2.

Once the polymerization has ended, the living polymer chains may be capped using a chain terminator.

Suitable chain terminators are protonating substances or Lewis acids, for example water, alcohols (such as isopropanol), aliphatic or aromatic carboxylic acids, or else inorganic acids, such as carbonic acid or boric acid.

- 5 By use of a chain terminator as afore-mentioned a linear block copolymer S1-B-S2 may be obtained.

A further aspect of the invention is a polymer composition comprising block copolymer (A) as described, and further one or more optional additives and/or processing aids (B)
10 and/or at least one optional thermoplastic polymer (C) – different from (A) and (B).

Generally the proportion of the soft phase built essentially (at least 85 wt.-%, often 85 to 100 wt.-%) from polymerized diene of the polymer composition according to the invention is from 15 to 35 wt.-%, and the soft phase - embedded in a hard phase (proportion 66 to
15 85 wt.-%) built essentially (at least 85 wt.-%, often 85 to 100 wt.-%) from polymerized vinylaromatic monomer - has a cylindrical morphology.

The at least one further thermoplastic polymer (C) – different from (A) and (B) – is in particular at least one vinylaromatic polymer, preferably at least one styrene polymer,
20 e.g. standard polystyrene (GPPS).

Standard polystyrenes that are suitable as polymer (C), and their production, structure and properties, are described in detail in the review literature (A. Echte, F. Haaf, J. Hambrecht in Angew. Chem. (Int. Ed. Engl.) 20, 344-361 (1981); and also in Kunststoffhandbuch, edited by R. Vieweg and G. Daumiller, volume 4 "Polystyrol", Carl-Hanser-Verlag
25 Munich (1996).

The blending of block copolymer (A) may take place at any desired juncture once the polymerization has ended, e.g. after termination, devolatilization, or other work-up steps.
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Moreover, polymer compositions according to the invention may optionally comprise additives and/or processing aids (B). Said additives and/or processing aids may be used in amounts of 0.01 to 5% by weight based on the total polymer composition.

35 Suitable additives and/or processing aids are in particular stabilizers, antiblocking agents, dyes and UV absorbers. Preferred is the use of a stabilizer, in particular oxygen radical scavengers such as Irganox® 1010, Songnox® 1010, Irganox 1076, Irganox 565 and blends thereof, carbon radical scavengers such as Sumilizer® GS, Sumilizer GM and blends thereof, and/or secondary stabilizers such as Irgafos® 168. Said stabilizers are
40 commercially available.

The afore-mentioned stabilizers are preferably used in amounts of 0.01 to 0.5 wt.-%, more preferably 0.1 to 0.3 wt.-%. Furthermore preferred is the use of an antiblocking agent such as high impact polystyrene (HIPS). Antiblocking agents are preferably used in amounts of 0.1 to 1 wt.-%.

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Polymer compositions according to the invention may be prepared by compounding during the devolatilization of block copolymer (A), for example by adding polystyrene in the form of "Coldfeed" into a vented extruder. Joint work-up gives homogeneous compositions which are also capable of direct use by processors on non-mixing injection molding machinery. As an alternative, however, mixtures of pellets may also be processed directly in kneaders, extruders, or injection molding machinery which provides mixing, to give polymer compositions according to the invention.

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It was found that materials based on block copolymer (A) allow the extrusion of blown and cast films with high melt strength.

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A further aspect of the invention is a shaped article, in particular a film, produced from block copolymer (A) or a polymer composition according to the invention. Due to the specific structure with sharp block transitions and the specific increased total molecular weight of block copolymer (A), films produced from block copolymer (A) or a polymer composition comprising it - have good mechanical properties and show a reduced blocking (layer-to-layer stickiness when wrapped onto rolls during the production process). Moreover, it was found that - due to the cylindrical morphology and the specific total diene proportion of the soft phase - the organoleptic properties of materials based on block copolymer (A) are significantly improved.

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A further aspect of the invention is the use of block copolymer (A) or a polymer composition according to the invention for the preparation of films. The invention is further illustrated by the claims and the following Examples.

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Examples

All used solvents and monomers were dried and purified prior to use.

Test Methods

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The melt mass flow index (= MFI, [ml/10 min]) was measured on a polymer melt at 220°C and 5 kg load according to ISO 1133-1:2011.

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The number average molecular weight M_n was determined by GPC according to ISO 16014-3:2012 ($T < 60^\circ\text{C}$ size exclusion with relative calibration method against polystyrene standards).

Organoleptic trials were made in a 100 ml Erlenmeyer flask, filled with 10 g of SBC polymer granules. Boiling water was prepared and poured directly out of the boiler into the Erlenmeyer flask. The water vapor was gently waved by hand towards the nose, and rated by a panel of at least 3 persons by following criteria:

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- 0 = completely neutral; no smell at all
- 1 = slight indication of smell
- 2 = smell detectable but fully acceptable
- 3 = strong smell, still acceptable

10 4 = very strong smell, unacceptable

Extrudability (melt strength) was rated in a "Rheotens type" test as follows: Polymer melt was heated to $T = 200^{\circ}\text{C}$ and 230°C and poured out of the heated vessel:

15	Observation	$T = 200^{\circ}\text{C}$ viscous flow, No droplets	$T = 230^{\circ}\text{C}$ Viscous flow, no droplets	Rating high extrudability
20		Viscous flow No/few droplets	light flow, few/many droplets	good extrudability
		Light flow Few/many droplets	light flow many droplets	poor extrudability

25 Film blocking (stickiness) was tested by casting a 1 mm film from a 220°C hot melt on a chilled roll, followed by compressing a double film layer by an external weight with 5 kg on 10 cm^2 . After 1 day, the film was manually separated and the stickiness was rated with a value of 0 to 2 by a panel of technical experts:

- 30 0 = easy separation, no stickiness
 1 = separation possible with slight stickiness
 2 = separation possible but strong stickiness, close to

35 The tensile properties (elongation at break) were determined according to DIN EN ISO 527-3:2019-02. Morphologies were determined by transmission electron microscopy on OsO_4 stained ultramicrotome samples of SBC polymers or their polymer compositions.

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General Preparation Method of Styrene Butadiene Block Copolymers

The tested SBC block copolymers were obtained by living anionic polymerization of styrene and butadiene in anhydrous cyclohexane under exclusion of moisture at temperatures of approximately 50 to 100 °C, using sec-Butyl lithium as initiator. Reaction times: between 2.5 and 3.5 hours.

Tapered blocks - of linear SBCs of the structure S1-B-S2 or star shaped SBCs having branches of structure S1-B-S2~ - were synthesized by simultaneous addition of styrene and butadiene, which leads to a polymerization of butadiene in first instance, followed by a tapered sequence that ends up in a short styrene sequence.

Sharp blocks - of linear SBCs of the structure S1-B-S2 or star shaped SBCs having branches of structure S1-B-S2~ - were synthesized by first addition and polymerization of styrene up to complete monomer consumption and then addition and polymerization of butadiene up to complete monomer consumption.

Then, - in case of linear SBCs – isopropanol was added as chain terminator or - in case of star shaped SBCs – epoxydized soybean oil was added as chain terminator at a ratio of 1L epoxydized soybean oil per 9.01 mol of sec-Butyl lithium initiator used.

Finally, each SBC polymer solution was acidified with CO₂/water and stabilized with 1500 ppm Irganox 1010, 1500 ppm Sumilzer GS and 1800 ppm Irgaphos 168.

The concentration of the final polymer in cyclohexane was 30 % by weight.

Each individually obtained SBC polymer solution was subsequently fed to a 25 mm twin screw extruder and the cyclohexane was degassed via vacuum and extruder domes at melt temperatures of approximately 200 °C to a residual cyclohexane content of 2000 mg per kg of polymer.

The polymer melt of each individual SBC or optionally its blend with polystyrene (PS) - a standard radically polymerized styrene with Mw 250,000 g/mol and Mn 100,000 g/mol - was extruded through a die and the strands were cut by a strand pelletizer.

For the preparation of films, films of a desired thickness were casted from a 220°C hot melt of the SBC or its blend with GPPS on chilled rolls by use of a single screw extruder.

The obtained test data are shown in Table 1. Examples C1 to C5 are comparative Examples.

Table 1: Rating of different SBC structures

Exa m- ple	Structure	Morphol- ogy	Buta- diene (wt.- %)	Mp (g/mol)	Sticky- ness	Ex- trud- ability	Or- gano- leptics	Elon- gation at break (%)
C1	SBC star with tapered block	lamellae	26	220,000	2(high)	high	3 (poor)	250
C2	SBC star with sharp block	lamellae	26	200,000	2(high)	high	3 (poor)	150
C3	SBC star with tapered block + 60 % PS	cylindrical	26	220,000	1(low)	high	3 (poor)	15
C4	SBC linear with tapered block	lamellae	27	82,000	2(high)	poor	3 (poor)	400
C5	SBC linear with sharp block	cylindrical	27	74,000	1(low)	poor	1 (good)	30
1	SBC linear with sharp block	cylindrical	27	148,000	1(low)	good	1 (good)	50

- 5 The data show that a SBC block copolymer according to inventive Example 1 has an improved extrudability (melt strength) in comparison to a linear SBC block copolymer with tapered blocks (see Example C4) or a linear SBC block copolymer with sharp blocks (see Example C5), each having a low number average molecular weight M_n of 82,000 g/mol or 74,000 g/mol, respectively.

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Moreover, the organoleptic properties of the SBC block copolymer according to the invention (see Example 1) are improved in comparison to a linear SBC block copolymer with tapered blocks (see Example C4). In addition - compared with the linear SBC block copolymer of Example C5 - the elongation at break is improved.

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The shaped articles, in particular thin films, produced from the SBC block copolymer of the examples have advantageous properties.

Patent Claims

- 5 1. A linear block copolymer (A) comprising
- at least two polymer blocks S of different number average molecular weight M_n essentially consisting of at least one vinylaromatic monomer, and at least one polymer block B essentially consisting of at least one conjugated diene, wherein at least two of the blocks S are terminal blocks S1 and S2; wherein block copolymer (A) consists of, based on the entire block copolymer (A):
- 10 65 to 85% by weight, preferably from 68 to 80% by weight, more preferably 70 to 75% by weight, of at least one vinylaromatic monomer, and
- 15 15 to 35% by weight, preferably 20 to 32%, more preferably 25 to 30% by weight, of at least one conjugated diene;
- wherein the proportion of a soft phase, built essentially from polymerized conjugated diene, is from 15 to 35% by volume - based on the entire block copolymer (A), and wherein the soft phase - embedded in a hard phase built essentially from polymerized vinylaromatic monomer - has a cylindrical morphology; and wherein block copolymer (A)
- 20 • has sharp block transitions; and
- has a number average molecular weight M_n of at least 140,000 g/mol.
2. The block copolymer (A) according to claim 1 having a number average molecular weight M_n of block copolymer (A) in the range of from 140,000 to 1,000,000 g/mol, more preferably 140,000 to 500,000 g/mol, most preferably 140,000 to 300,000 g/mol.
- 25 3. The block copolymer (A) according to claim 1 or 2 of the structure (I) S1-B-S2.
- 30 4. The block copolymer (A) according to any of claims 1 to 3 comprising from 68 to 80% by weight, preferably 70 to 75% by weight, of at least one vinylaromatic monomer, in particular styrene, and 20 to 32%, preferably 25 to 30% by weight, of at least one conjugated diene, in particular butadiene and/or isoprene.
- 35 5. The block copolymer (A) according to any of claims 1 to 4 wherein M_n of polymer block S1 is from 12,000 to 50,000 g/mol, M_n of polymer block S2 is from 40,000 to 150,000 g/mol, and M_n of polymer block B is from 15,000 to 80,000 g/mol.

6. The block copolymer (A) according to any of claims 1 to 5 wherein the vinylaromatic monomer is styrene and the conjugated diene is butadiene.
- 5 7. The block copolymer (A) according to any of claims 1 to 6 wherein the proportion of a soft phase, built essentially from polymerized conjugated diene, is from 18 to 32% by volume.
- 10 8. The block copolymer (A) according to any of claims 1 to 6 wherein the proportion of a soft phase, built essentially from polymerized conjugated diene, is from 22 to 30% by volume.
9. A process for the preparation of a block copolymer (A) according to any of claims 1 to 6 by sequential anionic polymerization of the monomers.
- 15 10. A polymer composition comprising at least one block copolymer (A) according to any of claims 1 to 8 and further one or more optional additives and/or processing aids (B) and/or at least one thermoplastic polymer (C) – different from (A) and (B).
- 20 11. The polymer composition according to claim 8 wherein the thermoplastic polymer (C) is polystyrene.
- 25 12. The polymer composition according to claim 10 or 11 wherein the proportion of the soft phase formed from polymerized diene, based on the entire polymer composition, is from 15 to 35 wt.-%, and the soft phase - embedded in a hard phase formed from polymerized vinylaromatic monomer - has a cylindrical morphology.
13. The polymer composition according to claim 10 wherein the proportion of the soft phase formed from polymerized diene, based on the entire polymer composition, is from 18 to 32 wt.-%, preferably 22 to 30 wt.-%.
- 30 14. A shaped article, in particular a film, produced from block copolymer (A) according to any of claims 1 to 8, or a polymer composition according to any of claims 10 to 13.
- 35 15. Use of block copolymer (A) according to any of claims 1 to 8, or of a polymer composition according to any of claims 10 to 13 for the preparation of films.