$P(OR^1)(OR^2)(OR^3)$

or formula (Ib)

$P(OR^1)(OR^2)(OR^3)(OR^4)(OR^5)$

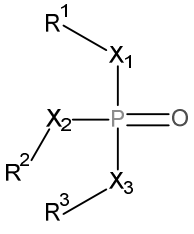
in which

X_1, X_2, and X_3 independently of another are oxygen, sulphur or a single bond, preferably oxygen or a single bond, and very preferably a single bond, and
R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to 20 carbon atoms,
with the proviso that the complex formed from the at least one Lewis Acid and the at least one phosphorus-containing compound of formula (I) or (Ia) or (Ib) has a melting point of not more than 60 ° C, preferably not more than 40 ° C, and especially not more than 20 ° C,

wherein compound (II) comprises at least one dihydrocarbyl ether of the general formula R^8-O-R^9 in which the variables R^8 and R^9 are each independently C_1- to C_{20}-alkyl radicals, C_1- to C_{20}-haloalkyl radicals, C_5- to C_8-cycloalkyl radicals, C_6- to C_{20}-aryl radicals, C_6- to C_{20}-haloaryl radicals, or C_7- to C_{20}-arylalkyl radicals is used.

In another aspect, there is provided iron trihalide-donor complexes consisting of at least one iron trihalide,

- optionally at least one organic compound (II) comprising at least one oxygen or nitrogen atom with at least one lone electron pair, preferably comprising at least one oxygen atom with at least one lone electron pair, very preferably selected from the group consisting of organic compounds with at least one ether function, organic compounds with at least one carboxylic ester function, organic compounds with at least one aldehyde function, organic compounds with at least one keto function, and organic compounds with at least one nitrogen containing heterocyclic ring, and
- at least one phosphorus-containing compound of formula (I)



or formula (Ia)

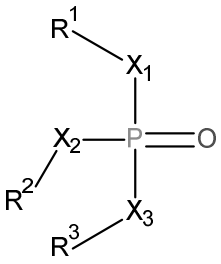
$P(OR^1)(OR^2)(OR^3)$

or formula (Ib)

or a single bond, and very preferably a single bond, and
R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to 20 carbon atoms,
wherein the complex formed from the at least one boron trihalide and the at least one phosphorus-containing compound of formula (I) or (Ia) or (Ib) have a melting point of not more than 60 ° C.

In another aspect, there is provided a metal halide-donor complexes consisting of

- at least one metal halide, selected from the group consisting of aluminum trihalide, alkylaluminum halide, gallium trihalide, titanium tetrahalide, zinc dihalide, tin dihalide, tin tetrahalide, and boron trihalide,
- at least one organic compound (II) comprising at least one oxygen or nitrogen atom with at least one lone electron pair with at least one ether function, organic compounds with at least one keto function, and organic compounds with at least one nitrogen containing heterocyclic ring, and
- at least one phosphorus-containing compound of formula (I)



or formula (Ia)

$P(OR^1)(OR^2)(OR^3)$

or formula (Ib)

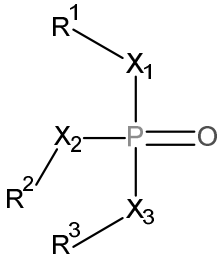
$P(OR^1)(OR^2)(OR^3)(OR^4)(OR^5)$

in which

X_1, X_2, and X_3 independently of another are oxygen, sulphur or a single bond, preferably oxygen or a single bond, and very preferably a single bond, and
R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to 20 carbon atoms.

Claims

1. A bulk- or solution polymerisation process for preparing high-reactivity isobutene homo- or copolymers with a number-average molecular weight M_n (determined by gel permeation chromatography) of preferably of 500 to 100 000 and a content of α-double bonds and β-double bonds (in sum) per polyisobutene chain end of at least 60 mol%, which comprises polymerizing isobutene or an isobutene-comprising monomer mixture in the presence of at least one Lewis Acid effective as a polymerization catalyst, selected from the group consisting of an aluminum trihalide-donor complex, an alkylaluminum halide-donor complex, an iron trihalide-donor complex, a gallium trihalide-donor complex, a titanium tetrahalide-donor complex, a zinc dihalide-donor complex, a tin dihalide-donor complex, a tin tetrahalide-donor complex, and a boron trihalide-donor complex, said complex comprising, as the donor, a mixture of
   - at least one organic compound (II) comprising at least one oxygen or nitrogen atom with at least one lone electron pair, preferably comprising at least one oxygen atom with at least one lone electron pair, very preferably selected from the group consisting of organic compounds with at least one ether function, organic compounds with at least one carboxylic ester function, organic compounds with at least one aldehyde function, organic compounds with at least one keto function, and organic compounds with at least one nitrogen containing heterocyclic ring, and
   - at least one phosphorus-containing compound of formula (I)



   or formula (Ia)

   $P(OR^1)(OR^2)(OR^3)$

   or formula (Ib)

   $P(OR^1)(OR^2)(OR^3)(OR^4)(OR^5)$

   in which

   X_1, X_2, and X_3 independently of another are oxygen, sulphur or a single bond, preferably oxygen or a single bond, and very preferably a single bond, and
   R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to

20 carbon atoms,
with the proviso that the complex formed from the at least one Lewis Acid and the at least one phosphorus-containing compound of formula (I) or (Ia) or (Ib) has a melting point of not more than 60 ° C, preferably not more than 40 ° C, and especially not more than 20 ° C,

wherein compound (II) comprises at least one dihydrocarbyl ether of the general formula R^8-O-R^9 in which the variables R^8 and R^9 are each independently C_1- to C_{20}-alkyl radicals, C_1- to C_{20}-haloalkyl radicals, C_5- to C_8-cycloalkyl radicals, C_6- to C_{20}-aryl radicals, C_6- to C_{20}-haloaryl radicals, or C_7- to C_{20}-arylalkyl radicals is used.

2. A process according to claim 1, wherein X_1, X_2, and X_3 each are a single bond

3. A process according to claim 1 or 2, wherein R^1 to R^5 each are C_2-C_{18}-alkyl or C_6-C_{12}-aryl.

4. A process according to claim 1, wherein the compound for formula (II) is selected from the group consisting of tri-n-hexylphosphine oxide, tri-n-octylphosphine oxide, tri iso-nonyl phosphine oxide, tri-n-decylphosphine oxide, tri-n-dodecylphosphine oxide, tri iso-tridecyl phosphine oxide, tri-n-tetradecylphosphine oxide, tri iso-heptadecyl phosphine oxide, triphenylphosphine oxide, tritolylphosphine oxide, trinaphtylphosphine oxide, phosphorous acid tri (n-butyl) ester, phosphorous acid tri (n-hexyl) ester, phosphorous acid tri (2-ethylhexyl) ester, phosphorous acid tri (n-octyl) ester, phosphorous acid tri (2-propylheptyl) ester, phosphorous acid tri (n-decyl) ester, phosphorous acid tri (n-dodecyl) ester, phosphorous acid tri (n-tetradecyl) ester, phosphorous acid tri (n-hexadecyl) ester, tri-ethylphosphite, tri-n-butylphosphite, tri-n-hexylphosphite, tri-n-octylphosphite, tri iso-nonyl phosphite, tri-n-decylphosphite, tri-n-dodecylphosphite, tri iso-tridecyl phosphite, tri-n-tetradecylphosphite, tri iso-heptadecyl phosphite, triphenylphosphite, penta(ethoxy)phosphorane, penta(n-butyloxy)phosphorane, penta(hexyloxy)phosphorane, penta(n-octyloxy)phosphorane, penta(2-ethylhexyloxy)phosphorane, and penta(phenoxy)phosphorane.

5. The process according to any of the preceeding claims, wherein isobutene or an isobutene-comprising monomer mixture is polymerized in the presence of an aluminum trihalide-donor complex, an alkylaluminum halide-donor complex or an iron trihalide-donor complex.

6. The process according to any the claims 1 to 4, wherein isobutene or an isobutene-comprising monomer mixture is polymerized in the presence an iron-trihalide donor complex effective as a polymerization catalyst.

7. The process according to any of the preceeding claims, wherein the molar ratio of Lewis Acid to compound of formula (I) is from 1 : 0.1 to 10.

8. The process according to any of the preceeding claims, wherein the at least one organic compound (II) is selected from the group consisting of organic compounds with at least one ether function, organic compounds with at least one carboxylic ester function, organic compounds with at least one aldehyde function, and organic compounds with at least one keto function.

9. The process according to any of the claims 1 to 7, wherein the at least one organic compound with at least one ether function is selected from the group consisting of diethyl ether, di-n-butyl ether, di-isopropyl ether, and di-n-propyl ether, bis(2-chloroethyl) ether and 2-chloroethyl ethyl ether.

10. The process according to any of the preceeding claims, wherein the molar ratio of the aluminum trihalide or alkylaluminum halide to the isobutene monomer used in the case of homopolymerization of isobutene, or to the total amount of the polymerizable monomers used in the case of copolymerization of isobutene, based on each individual functional site of the aluminum trihalide or alkylaluminum halide, is from 0.001:1 to 0.2:1.

11. The process according to any of the preceeding claims, wherein the polymerization is performed with additional use of a mono- or polyfunctional initiator which is selected from organic hydroxyl compounds in which one or more hydroxyl groups are each bonded to an sp^3-hybridized carbon atom, organic halogen compounds in which one or more halogen atoms are each bonded to an sp^3-hybridized carbon atom and water.

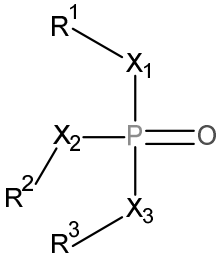
12. The process according to claim 11, wherein the initiator is selected from water, methanol, ethanol, 1-phenylethanol, 1-(p-methoxyphenyl)ethanol, n-propanol, isopropanol, 2-phenyl-2-propanol, n-butanol, isobutanol, sec.-butanol, tert-butanol, 1-phenyl-1-chloroethane, 2-phenyl-2-chloropropane, tert-butyl chloride and 1,3- or 1,4-bis(1-hydroxy-1-methylethyl)benzene.

13. The process according to claim 11 or 12, wherein the molar ratio of the initiators mentioned to the isobutene monomer used in the case of homopolymerization of isobutene, or to the total amount of the polymerizable monomers used in the case of copolymerization of isobutene, based on each individual functional site of the initiator, is from 0.0005:1 to 0.1:1, or when water is used as the sole initiator or in combination with organic hydroxyl compounds and/or organic halogen compounds as further initiators, the molar ratio of water to the isobutene monomer used in the case of homopolymerization of isobutene, or to the total amount of the polymerizable monomers used in the case of copolymerization of isobutene, is from 0.0001:1 to 0.1:1.

14. The process according to any of the preceding claims, wherein the polymerization is performed at a temperature of -90° C to +30° C.

15. Iron trihalide-donor complexes consisting of at least one iron trihalide,

- optionally at least one organic compound (II) comprising at least one oxygen or nitrogen atom with at least one lone electron pair, preferably comprising at least one oxygen atom with at least one lone electron pair, very preferably selected from the group consisting of organic compounds with at least one ether function, organic compounds with at least one carboxylic ester function, organic compounds with at least one aldehyde function, organic compounds with at least one keto function, and organic compounds with at least one nitrogen containing heterocyclic ring, and
- at least one phosphorus-containing compound of formula (I)



or formula (Ia)

$P(OR^1)(OR^2)(OR^3)$

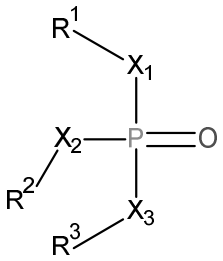
or formula (Ib)

$P(OR^1)(OR^2)(OR^3)(OR^4)(OR^5)$

in which

X_1, X_2, and X_3 independently of another are oxygen, sulphur or a single bond, preferably oxygen or a single bond, and very preferably a single bond, and
R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to 20 carbon atoms,
wherein the complex formed from the at least one iron trihalide and the at least one phosphorus-containing compound of formula (I) or (Ia) or (Ib) have a melting point of not more than 60 ° C.

16. Boron trihalide-donor complexes consisting of at least one boron trihalide,
- optionally at least one organic compound (II) comprising at least one oxygen or nitrogen atom with at least one lone electron pair, preferably comprising at least one oxygen atom with at least one lone electron pair, very preferably selected from the group consisting of organic compounds with at least one ether function, organic compounds with at least one carboxylic ester function, organic compounds with at least one aldehyde function, organic compounds with at least one keto function, and organic compounds with at least one nitrogen containing heterocyclic ring, and
- at least one phosphorus-containing compound of formula (I)



or formula (Ia)

$P(OR^1)(OR^2)(OR^3)$

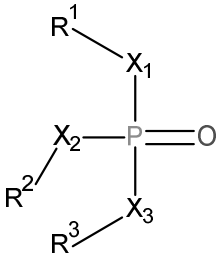
or formula (Ib)

$P(OR^1)(OR^2)(OR^3)(OR^4)(OR^5)$

in which

X_1, X_2, and X_3 independently of another are oxygen, sulphur or a single bond, preferably oxygen or a single bond, and very preferably a single bond, and
R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to 20 carbon atoms,
wherein the complex formed from the at least one boron trihalide and the at least one phosphorus-containing compound of formula (I) or (Ia) or (Ib) have a melting point of not more than 60 ° C.

17. Metal halide-donor complexes consisting of
- at least one metal halide, selected from the group consisting of aluminum trihalide, alkylaluminum halide, gallium trihalide, titanium tetrahalide, zinc dihalide, tin dihalide, tin tetrahalide, and boron trihalide,
- at least one organic compound (II) comprising at least one oxygen or nitrogen atom with at least one lone electron pair with at least one ether function, organic compounds with at least one keto function, and organic compounds with at least one nitrogen containing heterocyclic ring, and
- at least one phosphorus-containing compound of formula (I)



or formula (Ia)

$P(OR^1)(OR^2)(OR^3)$

or formula (Ib)

$P(OR^1)(OR^2)(OR^3)(OR^4)(OR^5)$

in which

X_1, X_2, and X_3 independently of another are oxygen, sulphur or a single bond, preferably oxygen or a single bond, and very preferably a single bond, and
R^1, R^2, R^3, R^4, and R^5 independently of another are an organic residue with up to 20 carbon atoms.

18. Metal halide-donor complexes according to Claim 17, wherein the at least one organic compound (II) with at least one ether function is of the general formula R^8-O-R^9 in which the variables R^8 and R^9 are each independently C_1- to C_{20}-alkyl radicals, C_1- to C_{20}-haloalkyl radicals, C_5- to C_8-cycloalkyl radicals, C_6- to C_{20}-aryl radicals, C_6- to C_{20}-haloaryl radicals, or C_7- to C_{20}-arylalkyl radicals.