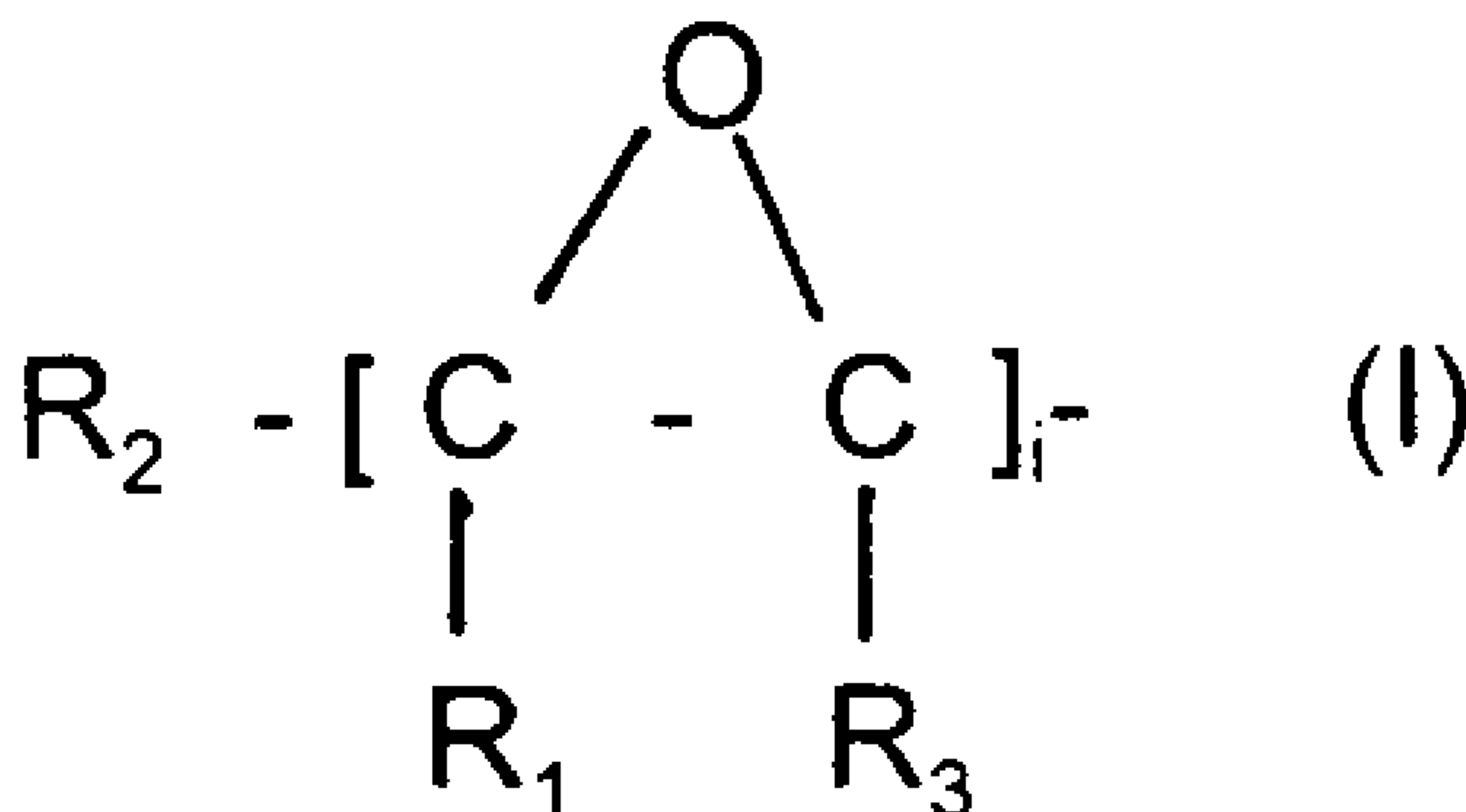




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(54) Titre : INITIATEURS DESTINES A LA POLYMERISATION CARBOCATIONIQUE D'OLEFINES
(54) Title: INITIATORS FOR CARBOCATIONIC POLYMERIZATION OF OLEFINS



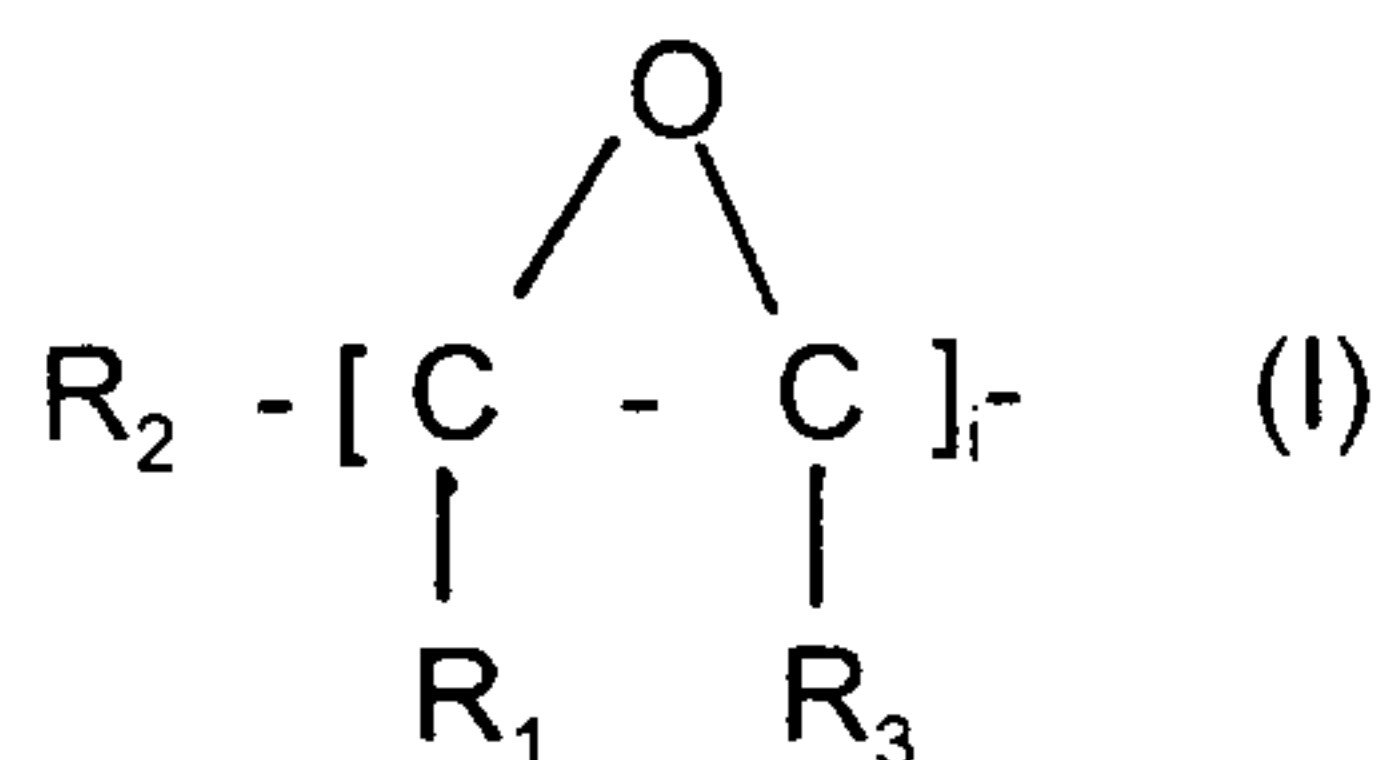
(57) **Abrégé/Abstract:**

A new class of initiators for inducing the cationic polymerization of olefins was discovered. These initiators, in conjunction with Lewis acids as coinitiators, effectively initiate the carbocationic polymerization of olefins. The new initiators are epoxides with the following general formula (I) where R_1 , R_2 and R_3 are hydrogen, alkyl, aryl or aralkyl groups, and can be the same or different, and i is a positive whole number. The Lewis acid has the general formula of MtX_n where M is titanium, aluminum, boron or tin, X is a halogen, an alkyl or an alkoxy or a mixture thereof. The process is a carbocationic process, which can be living or non-living, at a temperature of from about 0 to -80 °C. The polymer produced can be a homo- or copolymer (random or block) carrying hydroxy functional groups. (see formula I)



ABSTRACT

A new class of initiators for inducing the cationic polymerization of olefins was discovered. These initiators, in conjunction with Lewis acids as coinitiators, effectively initiate the carbocationic polymerization of olefins. The new initiators are epoxides with the following general formula (I) where R_1 , R_2 and R_3 are hydrogen, alkyl, aryl or aralkyl groups, and can be the same or different, and i is a positive whole number. The Lewis acid has the general formula of MtX_n where M is titanium, aluminum, boron or tin, X is a halogen, an alkyl or an alkoxy or a mixture thereof. The process is a carbocationic process, which can be living or non-living, at a temperature of from about 0 to -80 °C. The polymer produced can be a homo- or copolymer (random or block) carrying hydroxy functional groups.



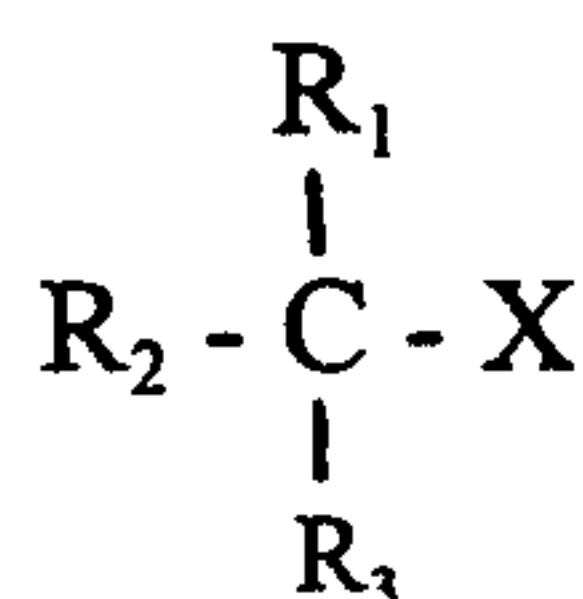
INITIATORS FOR CARBOCATIONIC POLYMERIZATION OF OLEFINS**TECHNICAL FIELD**

This invention relates to carbocationic polymerization of olefins.

BACKGROUND ART

5 The carbocationic polymerization of olefins is well-known and has been studied in detail. These processes can be initiated by systems producing carbocations. These initiating systems include Lewis and Bronsted acids, organic compounds such as halides in conjunction with Lewis acids, etc. (J.P.Kennedy: Cationic Polymerization of Olefins: A Critical Inventory. Wiley-Intersci). These processes produce high or low molecular weight polymers with various halide or olefinic
10 functional groups, and can be further functionalized by post-polymerization reactions.

The living carbocationic polymerization of olefins such as isobutylene and styrene is a relatively new development. Prior art describes living carbocationic polymerizations producing polymers with controlled molecular weights and molecular weight distributions as low as $M_w/M_n = 1.05$ (see United States patent no. 5,169,914). Suitable initiators include compounds with tertiary
15 functional groups of the general formula shown below:



where R_1 , R_2 and R_3 can be hydrogen or aliphatic or aromatic alkyl groups, or aralkyl groups,
20 and X can be a halogen, hydroxyl, ether or ester groups, or peroxides. These initiators, in conjunction with Lewis acids, Electron Pair Donors and Proton Traps, have successfully been used to produce homopolymers and random or block copolymers. The prior art has recently been reviewed in detail (Rubber Chem. Techn. 69, 462 (1996). Multifunctional initiators carrying the

above described tertiary functional groups have also been used to produce branched polymers (J. Polymer Sci., Chem. Oct. 1997).

The above discussed living initiating systems produce halide-functionalized polymers, which can be further modified to yield other functional groups such as hydroxy-or ester. Unfortunately, these initiators are usually not available commercially and have to be synthesized by multistep synthetic routes.

DISCLOSURE OF INVENTION

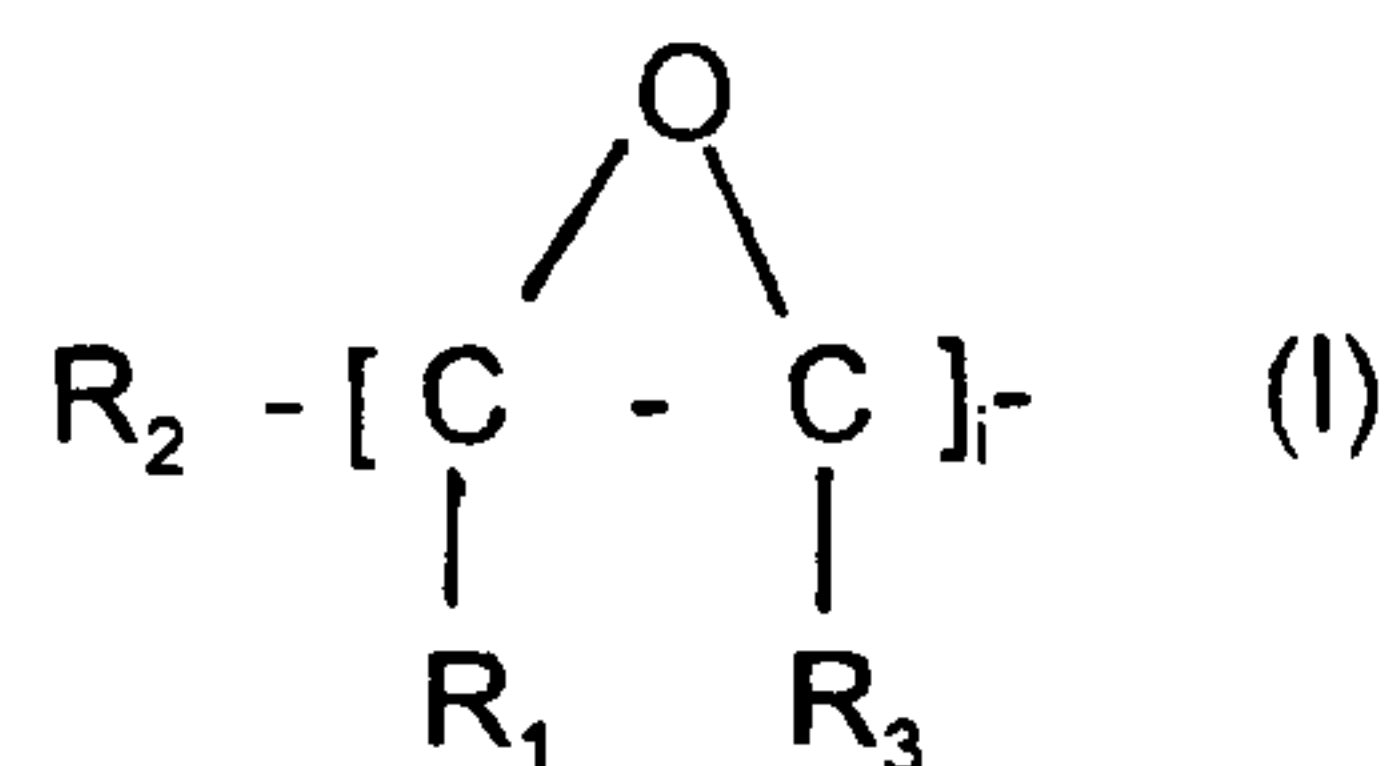
The inventor has discovered that epoxides, when reacted with Lewis acids in the presence of olefins such as isobutylene and styrene, effectively initiate the carbocationic polymerization of those olefins. Epoxides are commercially available or can be synthesized by oxidizing olefins by a simple and fast process (e. g., reacting the olefin with m-Cl-perbenzoic acid in a polar solvent at room temperature, completing the reaction in a few minutes. P. Dreyfuss and J. P. Kennedy: Analytical Chem. 47 (4), 771 (1975)). Epoxides are known to undergo polymerization themselves, by cationic, anionic or coordination mechanism, to yield polyethers containing oxygen in the main chain. Epoxi-ethane undergoes living anionic polymerization yielding a polyether, but substituted epoxides suffer side reactions. (Encyclopaedia of Polymer Science and Engineering, Ed., Mark, Bikales, Overberger, Menges Eds., 14,634, John Wiley&Sons, 1985). In the present invention, epoxides, preferably substituted epoxides, initiate the living polymerization of olefins yielding hydrocarbon polymers, instead of undergoing self- polymerization. Thus the epoxide initiating systems of the present invention produce hydrocarbon polymers with hydroxy functionality; multifunctional epoxides will produce multiple hydroxy functionalities. There is no prior art for using epoxides as initiators for the cationic polymerization of olefins.

Thus according to one aspect of the invention, there is provided a carbocationic polymerization process for producing a polyolefin polymer or copolymer carrying one or more oxygen-containing functional group (s), which comprises introducing a

monomer charge, a Lewis acid as coinitiator and an organic epoxide compound as initiator into a suitable reaction vessel and polymerizing the monomer charge at a temperature of from 0 °C to -120°C. The monomer charge comprises one or more compounds introduced concurrently or sequentially, selected from the group consisting of cationically polymerizable olefins, conjugated diolefins and vinylidene aromatic compounds, and wherein the organic epoxide initiator is charged in an amount of from 10^{-6} to 10^{-1} moles per mole of the olefin.

According to another aspect of the invention, there is provided a living carbocationic polymerization process for producing a polyolefin polymer or copolymer carrying oxygen containing functional groups, which comprises introducing a monomer charge, a Lewis acid as coinitiator and an organic epoxide compound as initiator, a proton trap to prevent protic initiation, and an electron pair donor which may or may not be necessary to achieve living conditions, into a reaction vessel and polymerizing the monomer charge at a temperature of from about 0 degrees to about -120 degrees centigrade, wherein the monomer charge comprises one or more compounds introduced concurrently or sequentially, selected from the group consisting of cationically polymerizable olefins, conjugated diolefins and vinylidene aromatic compounds and the organic epoxide initiator is charged in an amount of from 10^{-6} to about 10^{-1} per mole of the olefin.

Another view of the invention is that it provides a new class of initiators for inducing the cationic polymerization of olefins. These initiators, in conjunction with Lewis acids as coinitiators, effectively initiate the carbocationic polymerization of olefins. The new initiators are epoxides with the general formula (I)



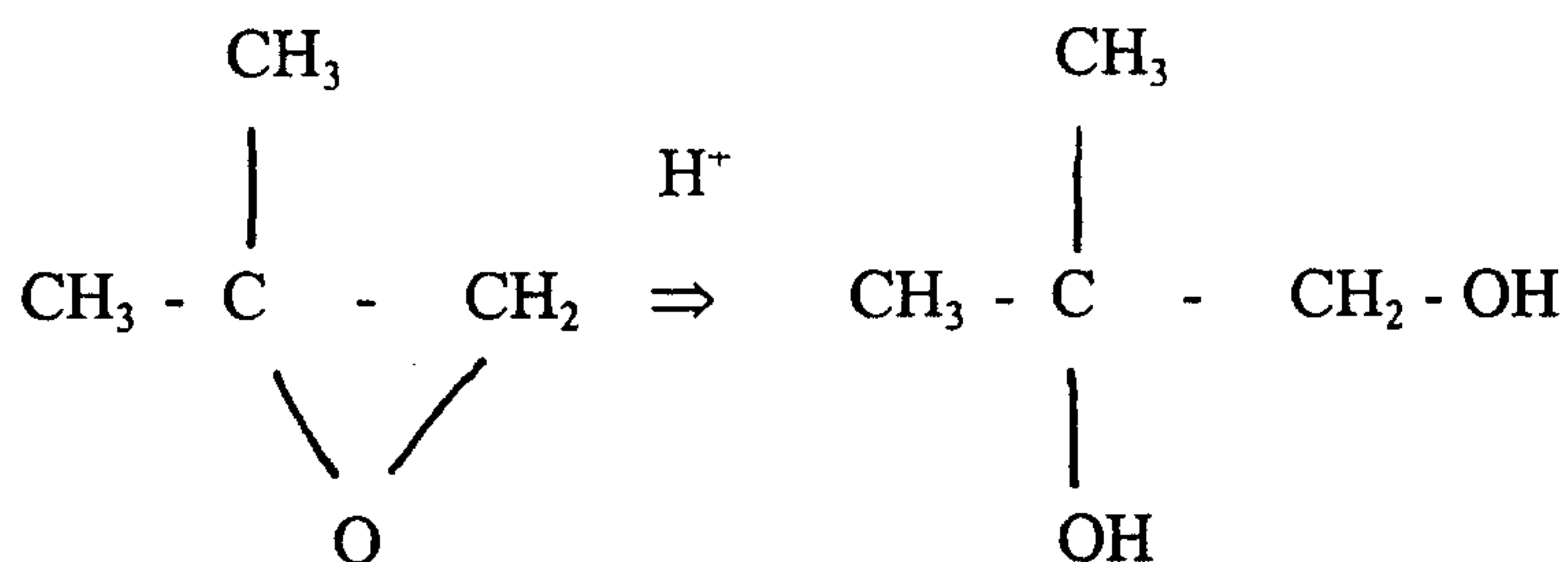
where R_1 , R_2 and R_3 are hydrogen, alkyl, aryl or aralkyl groups, and can be the same or different, and i is a positive whole number. The Lewis acid has the general formula of MtX_n where M is

titanium, aluminum, boron or tin, X is a halogen, an alkyl or an alkoxy or a mixture thereof. The process is a carbocationic process, which can be living or non-living, at a temperature of from about 0 to -80 C. The polymer produced can be a homo- or copolymer (random or block) carrying hydroxy functional groups.

- 5 Further aspects of the invention and additional details and examples will be provided or will become apparent in the detailed description which follows.

BEST MODE FOR CARRYING OUT THE INVENTION

- Tertiary carbocations that are formed by the interaction of an initiator carrying a tertiary functional group, and a Lewis acid such as BCl₃ or TiCl₄, were shown to be effective initiators for the carbocationic polymerization of olefins. Such an initiator is 2,4,4-trimethylpentyl chloride in conjunction with TiCl₄. In her search for commercially available initiators the inventor has theorized that substituted epoxides may be effective initiators for living carbocationic polymerizations. It is taught that epoxides may undergo cleavage under acidic or basic conditions, and the cleavage is oriented in substituted epoxides: (Morrison&Boyd: Organic Chemistry, 6th Ed. , 483 Prentice Hall, 1992)

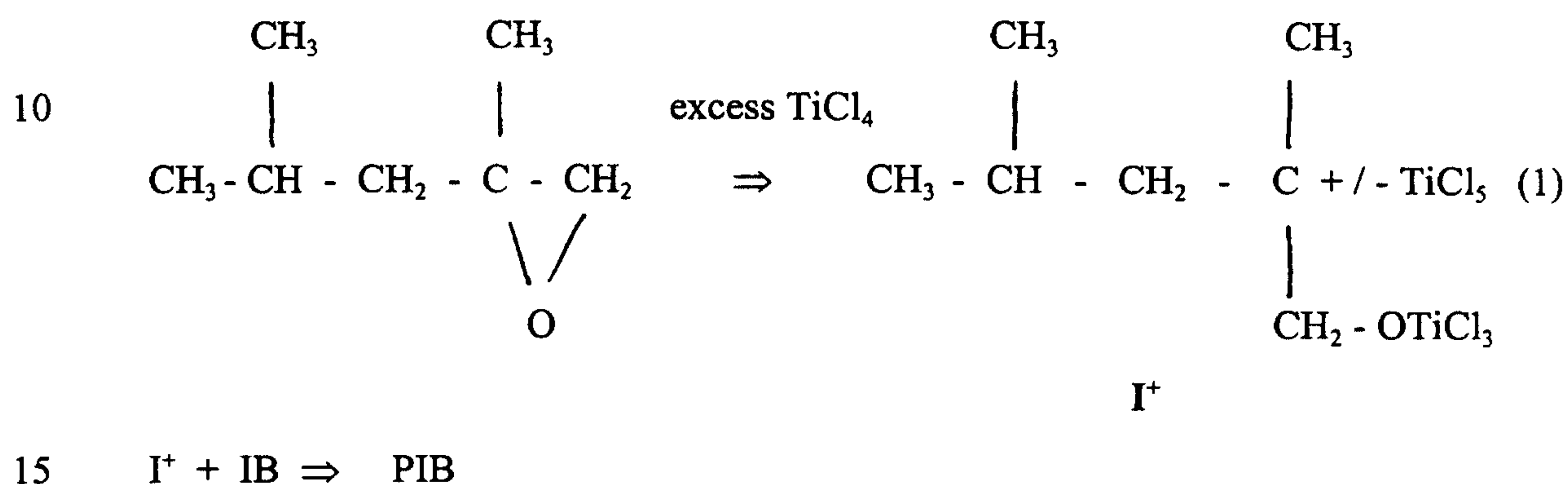


- 20 Epoxides are also known to polymerize to form polyethers. This polymerization reaction forms the base of commodity bonding compounds such as epoxy resins. The challenge was to find conditions under which tertiary carbocations forming from a substituted epoxide in conjunction

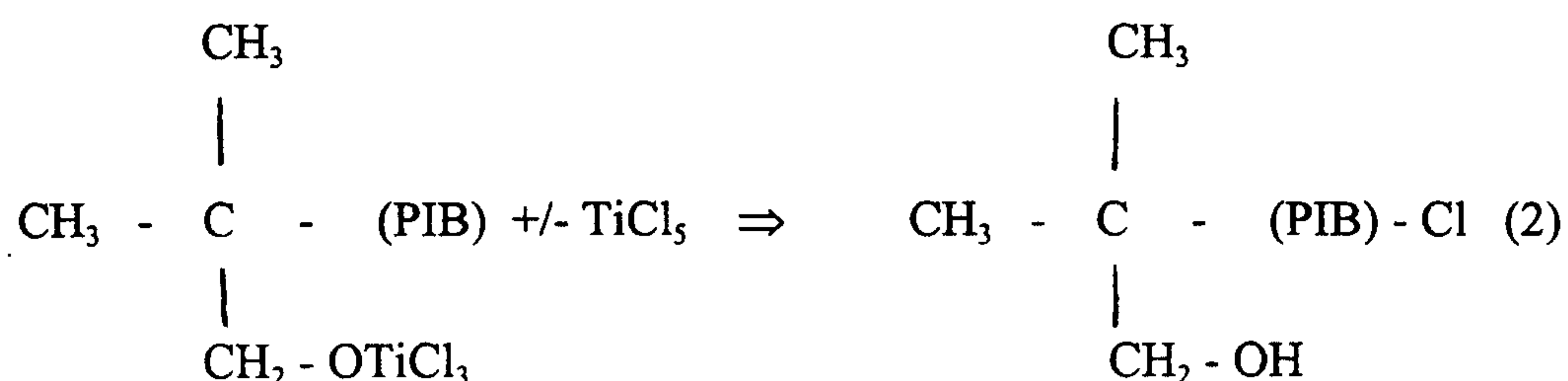
with a Lewis acid would initiate the carbocationic polymerization of olefins instead of undergoing self-polymerization.

The inventor has found that compounds such as 2,4,4-trimethylpentyl-1,2-epoxide, as 2,4,4-trimethylpentyl-2,3-epoxide, alpha-methylstyrene epoxide and squalene epoxide in conjunction
5 with a Lewis acid such as TiCl_4 are effective initiators for the polymerization of olefins such as isobutylene.

Without wishing to be bound by the theory, initiation is proposed to take place by the following sequence of reactions:



The carbocation initiates the polymerization of the olefin, or may undergo competitive self-polymerization. This latter side reaction may decrease the initiator efficiency, but the side product was found not to influence the living nature of the polymerization. Since opening the epoxi ring requires at least one TiCl_4 per epoxide ring, effective initiation was found to require
20 the use of excess Lewis acid. Upon termination of the polymerization by methanol, the following reaction is proposed to take place:



The polymer formed will then contain one hydroxy head group and one chlorine end group. By the use of di- or multifunctional initiators, polymers carrying multiple hydroxi groups can be prepared in one step.

5 The carbocationic polymerization of olefins is carried out at low temperature (-30 to -100 C) in a single solvent or solvent mixture of suitable polarity. Single solvent can be n-butylchloride, while mixed solvents contain a nonpolar component such as hexane and a polar component such as methylchloride. It is also taught by the prior art that internal or external electron pair donors have beneficial effects on the polymerization such as narrowing the molecular weight distribution or preventing side reactions. Without wishing to be bound by the theory it is proposed that the
10 epoxide-based initiating systems behave like internal electron pair donors due to the presence of the oxygen. However, the addition of external electron pair donors such as DMA may be beneficial, but will slow down the polymerization.

The epoxide initiators of the present invention can easily be synthesized from commercially available olefins, polyolefins or terpenes. For instance, 2,4,4-trimethylpentyl-1,2-epoxide was
15 synthesized by reacting m-chloroperbenzoic acid with 2,4,4-trimethylpentene for 10 minutes at room temperature in methylene chloride solvent. Similarly, epoxidized alpha-methylstyrene and hexaepoxy squalene was synthesized by reacting alpha-methylstyrene and squalene with m-chloroperbenzoic acid for 10 minutes at room temperature in methylene chloride solvent. The products were characterized by NMR spectroscopy and were found to be fully epoxidized. The
20 epoxides were found to be stable for a few months when stored in a refrigerator; after 4 months only one epoxide ring cleaved in the hexaepoxi squalene.

These initiators then were used to initiate the carbocationic polymerization of isobutylene.

The following examples describe the present invention. All polymerizations were carried out
25 in a dry box under dry nitrogen, in a three-neck flask equipped with an overhead stirrer, immersed in a cooling bath at -80 C.

EXAMPLE 1.

The reaction vessel was charged with 50 ml hexane and cooled to -80 C. 54.9 ml condensed methyl chloride was added, followed by the addition of 0.07 ml (4×10^{-4} mol) alpha-methylstyrene epoxide as an initiator, 0.16 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent protic initiation, and 16 ml isobutylene (IB) as a monomer. The polymerization was started with the addition of 0.36 ml TiCl_4 . The monomer conversion was 70% in 120 minutes, yielding a polyisobutylene (PIB) with $M_n = 43,000$ and $M_n/M_w = 1.2$. The incorporation of the aromatic initiator was verified by SEC coupled with UV spectroscopy. The polymerization was living; the M_n increased linearly with conversion, and M_n/M_w decreased as expected. Table 1 lists the data.

Table 1. IB polymerization initiated with epoxidized alpha-methylstyrene

Time	M_n	M_n/M_w
5	3900	1.7
10	6100	1.7
15	8000	1.6
20	10,500	1.5
30	15,000	1.4
60	27,000	1.3
120	43000	1.2

EXAMPLE 2.

The reaction vessel was charged with 50 ml hexane and cooled to -80 C. 33.4 ml condensed methyl chloride was added, followed by the addition of 0.73 ml (5.4×10^{-4} mol) 2,4,4-trimethylpentyl-1-epoxide as an initiator, 0.2 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent protic initiation, and 13.8 ml isobutylene (IB) as a monomer. The polymerization was started with the addition of 0.13 ml TiCl_4 . The monomer conversion was complete in 40 minutes, yielding a polyisobutylene (PIB) with $M_n = 64,000$ and $M_n/M_w = 1.1$.

EXAMPLE 3.

The reaction vessel was charged with 50 ml hexane and cooled to -80 C. 33.4 ml condensed methyl chloride was added, followed by the addition of 0.07 ml (4×10^{-4} mol) alpha-methylstyrene epoxide as an initiator, 0.2 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent protic initiation, and 16 ml isobutylene (IB) as a monomer. The polymerization was started with the addition of 0.5 ml TiCl_4 . The monomer conversion was 80 in 30 minutes, yielding a polyisobutylene (PIB) with $M_n = 66,000$ and $M_n/M_w = 1.3$. The polymerization was living; M_n increased linearly with conversion and M_n/M_w decreased as expected. Table 2 summarizes the data:

Table 2. IB polymerization initiated with epoxidized alpha-methylstyrene

Time	M_n	M_n/M_w
2	15,000	1.6
4	25,000	1.4
6	35,000	1.3
8	43,000	1.3
10	49,000	1.3
20	64,000	1.3
30	66,000	1.3

EXAMPLE 4.

The reaction vessel was charged with 50 ml hexane and cooled to -80 C. 34 ml condensed methyl chloride was added, followed by the addition of 0.7 ml (4×10^{-3} mol) alpha-methylstyrene epoxide as an initiator, 0.16 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent protic initiation, and 16 ml isobutylene (IB) as a monomer. The polymerization was started with the addition of 0.72 ml TiCl_4 . The monomer conversion was 70% in 30 minutes, yielding a polyisobutylene (PIB) with $M_n = 11,000$ and $M_n/M_w = 1.2$. The incorporation of the aromatic initiator was verified by SEC coupled with UV spectroscopy. This polymer was also subjected

to GC-MS analysis, which yielded oxygen-containing aromatic residues. This indicates that the headgroup of the polymer contains oxygen as shown in reaction (2).

EXAMPLE 5.

The reaction vessel was charged with 153 ml methylcyclohexane and cooled to -80 C. 60 ml
5 condensed methyl chloride was added, followed by the addition of 5×10^{-4} mol hexaepoxy
squalene as an initiator, 0.32 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent
protic initiation, and 60 ml isobutylene (IB) as a monomer. The polymerization was started with
the addition of 3×10^{-2} mol TiCl_4 . The monomer conversion was 100% in 20 minutes, yielding
a polyisobutylene (PIB) with $M_n = 115,000$ and $M_n/M_w = 1.2$ by SEC-Multiangle Light
10 Scattering (MLS) analysis. The slope of the radius of gyration vs molecular weight plot was
found to be 0.33, indicating that the polymer has a star-branched structure (spherical shape).
Assuming six arms, each arm would have $M_n = 20,000$.

EXAMPLE 6.

The reaction vessel was charged with 153 ml methylcyclohexane and cooled to -80 C. 60 ml
15 condensed methyl chloride was added, followed by the addition of 4.5×10^{-5} mol hexaepoxy
squalene as an initiator, 0.32 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent
protic initiation, and 43 ml isobutylene (IB) as a monomer. The polymerization was started with
the addition of 2×10^{-2} mol TiCl_4 . The monomer conversion was 55% in 480 minutes, yielding
a polyisobutylene (PIB) with $M_n = 174,000$ and $M_n/M_w = 1.2$ by SEC-MLS. The radius of
20 gyration vs molecular weight plot yielded a slope of 0.32, indicating a spherical shape star-
branched polymer. Assuming 6 arms, each arm would have an $M_n = 30,000$.

EXAMPLE 7.

The reaction vessel was charged with 153 ml methylcyclohexane and cooled to -80 C. 60 ml condensed methyl chloride was added, followed by the addition of 5×10^{-4} mol hexaepoxy squalene as an initiator, 0.32 ml 2,6-di-tert-butylpyridine (DtBP) as a proton trap to prevent
5 protic initiation, and 43 ml isobutylene (IB) as a monomer. The polymerization was started with the addition of 3×10^{-2} mol TiCl_4 . The reaction was allowed to proceed for 250 minutes, at which point 0.32 ml DtBP and 0.001 mol dimethyl acetamide DMA as an Electron Pair Donor ED were added to the mixture, followed by the addition of the prechilled mixture of 9.6 g distilled styrene and 10 g methylcyclohexane. The reaction was allowed to proceed for 20 minutes, at which point
10 methanol was added to terminate the polymerization. NMR analysis of the product showed the presence of 10.2 mol% (17.4 wt%) styrene in the block. The isobutylene conversion was found to be 78% in 35 minutes. The polyisobutylene (PIB) had $M_n = 106,700$ and $M_n/M_w = 1.4$, measured just before the styrene incorporation by standard SEC with universal calibration. The final product had $M_n = 125,000$ and $M_n/M_w = 1.2$, measured by SEC-MLS. The radius of
15 gyration vs molecular weight plot yielded a slope of 0.4, indicating a star-branched block copolymer with spherical shape. Assuming six arms, each arm should have a polyisobutylene section with $M_n = 18,000$ and a polystyrene section with $M_n = 2900$.

INDUSTRIAL APPLICABILITY

The invention provides an improved process for producing polyolefin polymers or copolymers
20 carrying one or more oxygen-containing functional groups, and such polyolefin polymers or copolymers themselves.

CLAIMS

1. A carbocationic polymerization process for producing a polyolefin polymer or copolymer carrying oxygen-containing functional group (s), which comprises introducing a monomer charge, a Lewis acid as coinitiator and an organic epoxide compound as initiator into a reaction vessel and polymerizing the monomer charge at a temperature of from about 0 degrees to about -120 degrees centigrade, wherein said monomer charge comprises one or more compounds introduced concurrently or sequentially, selected from the group consisting of cationically polymerizable olefins, conjugated diolefins and vinylidene aromatic compounds and said organic epoxide initiator is charged in an amount of from 10^{-6} to about 10^{-1} moles per mole of said olefin.
2. The process of Claim 1, wherein said monomer charge is polymerized at a temperature of from about - 40 to about - 80 °C.
3. The process of Claim 2 wherein said organic epoxide compound is selected from the group of substituted epoxides.
4. The process of Claim 3 wherein said substituted epoxide is selected from the group of epoxidized aliphatic olefins.
5. The process of Claim 4 wherein said epoxide compound is 2,4,4-trimethyl-pentyl- epoxide.
6. The process of Claim 3 wherein said substituted epoxide is selected from the group of epoxidized aralkyl compounds.
7. The process of Claim 6 wherein said epoxide is alpha-methylstyrene epoxide.
8. The process of Claim 3 wherein said substituted epoxide is selected from the group of epoxidized polyolefins.
9. The process of Claim 8 wherein said epoxide is squalene hexaepoxide.

10. The process of Claim 3 wherein said conjugated diolefins comprises a C₄ to C₈ diolefin in an amount of up to 60% of the monomer charge.
11. The process of Claim 3 wherein said vinylidene aromatic compounds comprises a C₈ to C₂₀ vinylidene aromatic compound in an amount of up to 100% of the monomer charge.
12. The process of Claim 11 wherein said vinylidene aromatic monomer is selected from the group of styrene, p-methylstyrene and indene.
13. The process of Claim 3 wherein said Lewis acid is selected from the group consisting of BCl₃, TiCl₄, AlCl₃, VCl₄, FeCl₃, SnCl₄, SbF₆, ZnCl₂, and BF₃.
14. The process of Claim 13 wherein said Lewis acid is TiCl₄.
15. The process of Claim 3, conducted in the presence of a diluent.
16. The process of Claim 15 where said diluent is selected from the group consisting of C₁ to C₆ halogenated hydrocarbons, C₃ to C₈ aliphatic hydrocarbons, C₅ to C₁₀ cyclic hydrocarbons, mixtures of said halogenated hydrocarbons and one of said aliphatic hydrocarbons, and mixtures of said halogenated hydrocarbons and one of said cyclic hydrocarbons.
17. The process of Claim 16, wherein said diluent is selected from methyl chloride, methylene chloride, n-butylchloride, hexane, methylcyclohexane and mixtures thereof.
18. The process of Claim 3, wherein said monomer charge comprises the sequential or concurrent addition of isobutylene and a second or subsequent monomer (s) selected from the group consisting of isoprene, styrene, p-methylstyrene and indene, the amount of second or subsequent monomer (s) being up to 100% of the charge, said Lewis acid is TiCl₄, said organic epoxide compound is selected from the group consisting 2,4,4-trimethyl-pentyl-epoxide, alpha- methylstyrene epoxide and squalene hexaepoxide, said Lewis acid being from about 2 to about 100 moles per mole of epoxi compound, and

the diluent selected from the group of consisting methyl chloride, hexane, methylcyclohexane and mixtures thereof.

19. The process of claim 1 wherein said oxygen-containing functional group (s) is/are selected from the group consisting of hydroxyl and aldehyde.

20. The process of Claim 8 wherein said epoxidized polyolefins are selected from the group consisting of synthetic and natural polyisoprenes (terpenes).

21. A living carbocationic polymerization process for producing a polyolefin polymer or copolymer carrying oxygen containing functional groups, which comprises introducing a monomer charge, a Lewis acid as coiniciator and an organic epoxide compound as initiator, a proton trap to prevent protic initiation, and an electron pair donor which may or may not be necessary to achieve living conditions, into a reaction vessel and polymerizing the monomer charge at a temperature of from about 0 degrees to about -120 degrees centigrade, wherein said monomer charge comprises one or more compounds introduced concurrently or sequentially, selected from the group consisting of cationically polymerizable olefins, conjugated diolefins and vinylidene aromatic compounds and said organic epoxide initiator is charged in an amount of from 10^{-6} to about 10^{-1} per mole of said olefin.

22. The process of Claim 21, wherein said monomer charge is polymerized at a temperature of from about -40 to about -80 °C.

23. The process of Claim 22 wherein said organic epoxide compound is selected from the group of substituted epoxides.

24. The process of Claim 23 wherein said substituted epoxide is selected from the group of epoxidized aliphatic olefins.

25. The process of Claim 24 wherein said epoxide compound is 2,4,4-trimethyl- pentyl-epoxide.

26. The process of Claim 23 wherein said substituted epoxide is selected from the group of epoxidized aralkyl compounds.
27. The process of Claim 26 wherein said epoxide is alpha-methylstyrene epoxide.
28. The process of Claim 23 wherein said substituted epoxide is selected from the group of epoxidized polyolefins.
29. The process of Claim 28 wherein said epoxide is squalene hexaepoxide.
30. The process of Claim 23 wherein said conjugated diolefins comprises a C₄ to C₈ diolefin in an amount of up to 60% of the monomer charge.
31. The process of Claim 23 wherein said vinylidene aromatic compounds comprises a C₈ to C₂₀ vinylidene aromatic compound in an amount of up to 100% of the monomer charge.
32. The process of Claim 31 wherein said vinylidene aromatic monomer is selected from the group of styrene, p-methylstyrene and indene.
33. The process of Claim 23 wherein said Lewis acid is selected from the group consisting of BCl₃, TiCl₄, AlCl₃, VCl₄, FeCl₃, SnCl₄, SbF₆, ZnCl₂, and BF₃.
34. The process of Claim 33 wherein said Lewis acid is TiCl₄.
35. The process of Claim 23, conducted in the presence of a diluent.
36. The process of Claim 35 where said diluent is selected from the group consisting of C₁ to C₆ halogenated hydrocarbons, C₃ to C₈ aliphatic hydrocarbons, C₅ to C₁₀ cyclic hydrocarbons, mixtures of said halogenated hydrocarbons and one of said aliphatic hydrocarbons, and mixtures of said halogenated hydrocarbons and one of said cyclic hydrocarbons.

37. The process of Claim 36, wherein said diluent is selected from methyl chloride, methylene chloride, n-butylchloride, hexane, methylcyclohexane and mixtures thereof.

38. The process of Claim 23 wherein said proton trap is 2,6-di-tert.-butylpyridine.

39. The process of claim 23 wherein said electron pair donor is selected from the group consisting of dimethylacetamide, dimethylformamide, pyridine and substituted pyridines.

40. The process of Claim 23, wherein said monomer charge comprises the sequential or concurrent addition of isobutylene and a second or subsequent monomer (s) selected from the group consisting of isoprene, styrene, p-methylstyrene and indene, the amount of second or subsequent monomer (s) being up to 100% of the charge, said Lewis acid is TiCl_4 , said organic epoxide compound is selected from the group consisting 2,4,4-trimethyl-pentyl-epoxide, alpha- methylstyrene epoxide and squalene hexaepoxide, said Lewis acid being from about 2 to about 100 moles per mole of epoxi compound, and the diluent selected from the group of consisting methyl chloride, hexane, methylcyclohexane and mixtures thereof.

41. The process of claim 21 wherein said oxygen-containing functional group (s) is/are selected from the group consisting of hydroxyl and aldehyde group.

42. The process of Claim 28 wherein said epoxidized polyolefins are selected from the group consisting of synthetic and natural polyisoprenes (terpenes).

43. A polyisobutylene polymer produced by the process of Claim 27, containing one oxygen containing group attached to the aromatic alpha-methylstyrene initiator moiety at one end and one tertiary chloride group at the other end of the polymer.

44. The polyisobutylene polymer according to Claim 43, wherein the oxygen containing group is a primary hydroxy group.
45. A star-branched polyisobutylene polymer produced by the process of Claim 29, containing six oxygen containing groups attached to the squalene multifunctional initiator moiety at the core of the polymer, and six tertiary chloride groups at the end of the arms of the star polymer.
46. The star-branched polyisobutylene polyisobutylene polymer according to Claim 45, wherein the oxygen containing groups are primary hydroxy groups.
47. A star-branched polyisobutylene-poly (vinylidene aromatic) block copolymer produced by the process of Claim 29, containing six oxygen containing groups attached to the squalene multifunctional initiator moiety at the core of the polymer, and six tertiary chloride groups at the end of the arms of the star block copolypolymer.
48. The star-branched polyisobutylene-poly (vinylidene aromatic) block copolymer according to Claim 47, wherein the oxygen containing groups are primary hydroxy groups.
49. A polyisobutylene polymer containing one oxygen containing group attached to the aromatic alpha-methylstyrene initiator moiety at one end and one tertiary chloride group at the other end of the polymer.
50. The polyisobutylene polymer according to Claim 49, wherein the oxygen containing group is selected from the group consisting of primary hydroxy and aldehyde.
51. A star-branched polyisobutylene polymer containing six oxygen containing groups attached to the squalene multifunctional initiator moiety at the core of the polymer, and six tertiary chloride groups at the end of the arms of the star polymer.

52. The star-branched polyisobutylene polymer according to Claim 51, wherein the oxygen containing groups are selected from the group consisting of primary hydroxy and aldehyde.
53. A star-branched polyisobutylene-polystyrene block copolymer containing six oxygen containing groups attached to the squalene multifunctional initiator moiety at the core of the polymer, and six tertiary chloride groups at the end of the arms of the star block copolypolymer.
54. The star-branched polyisobutylene-polystyrene block copolymer according to Claim 53, wherein the oxygen containing groups are selected from the group consisting of primary hydroxy and aldehyde.
55. A polyisobutylene polymer containing one oxygen containing group attached to the aromatic alpha-methylstyrene initiator moiety at one end and one tertiary chloride group at the other end of the polymer with an Mn from about 500 to about 5×10^6 , and a molecular weight distribution MWD from about 1.01 to about 3.
56. The polyisobutylene polymer according to Claim 55 wherein the oxygen containing group is selected from the group consisting of primary hydroxy and aldehyde.
57. A six-arm star-branched polyisobutylene polymer containing six oxygen containing groups attached to the squalene multifunctional initiator moiety at the core of the polymer, and six tertiary chloride groups at the end of the arms of the star polymer with an Mn from about 500 to about 5×10^6 , and a molecular weight distribution MWD from about 1.01 to about 3.
58. The six-arm star-branched polyisobutylene polymer according to Claim 57 wherein the oxygen containing groups are selected from the group consisting of primary hydroxy and aldehyde.
59. A six-arm star-branched polyisobutylene-polystyrene block copolymer containing six oxygen containing groups attached to the squalene multifunctional initiator moiety at the core of the polymer, and six tertiary

chloride groups at the end of the arms of the star block copolymer, with an Mn from about 500 to about 6×10^6 , and a molecular weight distribution MWD from about 1.01 to about 3.

60. The six-arm star-branched polyisobutylene-polystyrene block copolymer according to Claim 59 wherein the oxygen containing groups are selected from the group consisting of primary hydroxy and aldehyde.

