

circulated through a reaction column and distillation column and back to the autoclave reactor in order to minimize side-product formation. In a second step, the KOH catalyst is utilized to polymerize EO onto the PO chain ends. This process is complicated and may require finishing step(s) to remove KOH catalyst residues.

**[0009]** Therefore, improvements are sought with respect to producing EO based polyols (such as EO-capped polyols) efficiently in such a way so as to not require a catalyst removal step and/or to changing the selectivity of the Lewis acid catalyst itself, e.g., to improve yield of the desired ethylene oxide-based polyether polyol product (such as the EO capped polyether polyol having a number molecular weight of at least 224 g/mol and EO capping of at least 1 wt% based on a total weight of the resultant polyether polyol). Accordingly, improvements are sought with respect to improving yield of desired products and/or producing non-finishing polyols (i.e., polyols that do not require further finishing).

### Summary

**[0010]** Examples may be realized by providing a method of producing a polyether polyol includes reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, and the low molecular weight initiator has a nominal hydroxyl functionality at least 2. The polymerization catalyst is a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas M is boron, aluminum, indium, bismuth or erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group or a first fluoro/chloro-substituted phenyl group,  $R^3$  includes a third fluoroalkyl-substituted phenyl group or a second fluoro/chloro-substituted phenyl group, and optional  $R^4$  includes a functional group or functional polymer group,  $R^1$  being different from at least one of  $R^2$  and  $R^3$ . The method further includes forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

**[0010a]** In one aspect, the present disclosure refers to a method of producing a polyether polyol, comprising: reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, the low molecular weight initiator having a nominal hydroxyl functionality at least 2 and a molecular weight of less than 5000 g/mol as measured by gel permeation chromatography, and the polymerization catalyst being a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas M is boron, aluminum, indium, bismuth or

erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group that is the same as the first fluoroalkyl-substituted phenyl group,  $R^3$  includes a second fluoro/chloro-substituted phenyl group or a third fluoroalkyl-substituted phenyl group that is different from the first fluoroalkyl-substituted phenyl group, and optional  $R^4$  includes a functional group or functional polymer group, said functional group or functional polymer group being a molecule that contains at least one of the following: water, an alcohol, an alkoxy, a ketone, an ester, an organosiloxane, an amine, a phosphine, an oxime, and substituted analogs thereof; and forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

**[0010b]** In another aspect, the present disclosure refers to a method of producing a polyether polyol, comprising: reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, the low molecular weight initiator having a nominal hydroxyl functionality at least 2 and a molecular weight of less than 5000 g/mol as measured by gel permeation chromatography, and the polymerization catalyst being a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas M is boron, aluminum, indium, bismuth or erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group that is different from the first fluoroalkyl-substituted phenyl group,  $R^3$  includes a third fluoroalkyl-substituted phenyl group that is different from the first fluoroalkyl-substituted phenyl group and the second fluoroalkyl-substituted phenyl group, and optional  $R^4$  includes a functional group or functional polymer group, said functional group or functional polymer group being a molecule that contains at least one of the following: water, an alcohol, an alkoxy, a ketone, an ester, an organosiloxane, an amine, a phosphine, an oxime, and substituted analogs thereof; and forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

**[0010c]** In another aspect, the present disclosure refers to a method of producing a polyether polyol, comprising: reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, the low molecular weight initiator having a nominal hydroxyl functionality at least 2 and a molecular weight of less than 5000 g/mol as measured by gel

permeation chromatography, and the polymerization catalyst being a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_1$ , whereas M is boron, aluminum, indium, bismuth or erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group or a first fluoro/chloro-substituted phenyl group,  $R^3$  includes a third fluoroalkyl-substituted phenyl group or a second fluoro/chloro-substituted phenyl group, and  $R^4$  includes a functional group or functional polymer group, said functional group or functional polymer group being a molecule that contains at least one of the following: water, an alcohol, an alkoxy, a ketone, an ester, an organosiloxane, an amine, a phosphine, an oxime, and substituted analogs thereof,  $R^1$  being different from at least one of  $R^2$  and  $R^3$ ; and forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

**[0010d]** In another aspect, the present disclosure refers to a method of producing a polyurethane product, the method comprising: providing a polyether polyol produced according to the method as disclosed herein and providing an isocyanate.

### Listing of the Claims:

1. A method of producing a polyether polyol, comprising:

reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, the low molecular weight initiator having a nominal hydroxyl functionality at least 2 and a molecular weight of less than 5000 g/mol as measured by gel permeation chromatography, and the polymerization catalyst being a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas M is boron, aluminum, indium, bismuth or erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group that is the same as the first fluoroalkyl-substituted phenyl group,  $R^3$  includes a second fluoro/chloro-substituted phenyl group or a third fluoroalkyl-substituted phenyl group that is different from the first fluoroalkyl-substituted phenyl group, and optional  $R^4$  includes a functional group or functional polymer group, said functional group or functional polymer group being a molecule that contains at least one of the following: water, an alcohol, an alkoxy, a ketone, an ester, an organosiloxane, an amine, a phosphine, an oxime, and substituted analogs thereof; and

forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

2. A method of producing a polyether polyol, comprising:

reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, the low molecular weight initiator having a nominal hydroxyl functionality at least 2 and a molecular weight of less than 5000 g/mol as measured by gel permeation chromatography, and the polymerization catalyst being a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas M is boron, aluminum, indium, bismuth or erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group that is different from the first fluoroalkyl-substituted phenyl group,  $R^3$  includes a third fluoroalkyl-substituted phenyl group that is different from the first fluoroalkyl-substituted phenyl group and the second fluoroalkyl-substituted phenyl group, and optional  $R^4$  includes a functional group or functional polymer group, said functional group or functional polymer group being a molecule that contains

at least one of the following: water, an alcohol, an alkoxy, a ketone, an ester, an organosiloxane, an amine, a phosphine, an oxime, and substituted analogs thereof; and

forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

3. A method of producing a polyether polyol, comprising:

reacting a low molecular weight initiator with ethylene oxide in the presence of a polymerization catalyst, the low molecular weight initiator having a nominal hydroxyl functionality at least 2 and a molecular weight of less than 5000 g/mol as measured by gel permeation chromatography, and the polymerization catalyst being a Lewis acid catalyst having the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_1$ , whereas M is boron, aluminum, indium, bismuth or erbium,  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  are each independent,  $R^1$  includes a first fluoroalkyl-substituted phenyl group,  $R^2$  includes a second fluoroalkyl-substituted phenyl group or a first fluoro/chloro-substituted phenyl group,  $R^3$  includes a third fluoroalkyl-substituted phenyl group or a second fluoro/chloro-substituted phenyl group, and  $R^4$  includes a functional group or functional polymer group, said functional group or functional polymer group being a molecule that contains at least one of the following: water, an alcohol, an alkoxy, a ketone, an ester, an organosiloxane, an amine, a phosphine, an oxime, and substituted analogs thereof,  $R^1$  being different from at least one of  $R^2$  and  $R^3$ ; and

forming a polyether polyol having a number average molecular weight of greater than the number average molecular weight of the low molecular weight initiator in the presence of the Lewis acid catalyst.

4. The method as claimed in claim 3, wherein the Lewis acid catalyst has the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_1$ , whereas  $R^2$  is the first fluoro/chloro-substituted phenyl group and  $R^3$  is the second fluoro/chloro-substituted phenyl group that is the same as the first fluoro/chloro-substituted phenyl group.

5. The method as claimed in claim 3, wherein the Lewis acid catalyst has the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas at least one of  $R^2$  and  $R^3$  is a fluoro/chloro-

fluoroalkyl-substituted phenyl group, difluoro/chloro-fluoroalkyl-substituted phenyl group, trifluoro/chloro-fluoroalkyl-substituted phenyl group, or tetrafluoro/chloro-fluoroalkyl-substituted phenyl group.

6. The method as claimed in any one of claims 1 to 5, wherein the Lewis acid catalyst has the general formula  $M(R^1)_1(R^2)_1(R^3)_1(R^4)_{0 \text{ or } 1}$ , whereas at least one of  $R^1$ ,  $R^2$ , and  $R^3$  is a 3,4- or 3,5-bis(fluoroalkyl)-substituted phenyl group.

7. The method as claimed in claim 3, wherein  $R^4$  is a cyclic ether having 3-10 carbon atoms.

8. The method as claimed in claim 3, wherein  $R^4$  is a ketone having 3-10 carbon atoms.

9. The method as claimed in any one of claims 1 to 8, wherein the polyether polyol has a yield of at least 60% based on actual yield of an ethylene oxide capped polyol and a theoretical yield of the ethylene oxide capped polyol.

10. The method as claimed in any one of claims 1 to 9, wherein the low molecular weight initiator is a polyether diol or triol derived from at least one selected from propylene oxide, ethylene oxide, and butylene oxide.

11. A method of producing a polyurethane product, the method comprising:  
providing a polyether polyol produced according to the method as claimed in any one of claims 1 to 10, and  
providing an isocyanate.