Claims

1. A process for producing a polyol block copolymer in a multiple reactor system; the system comprising a first and second reactor wherein a first reaction takes place in the first reactor and a second reaction takes place in the second reactor; wherein the first reaction is the reaction of a carbonate catalyst with CO_2 and epoxide, in the presence of a starter and/or solvent to produce a polycarbonate polyol copolymer and the second reaction is the reaction of a DMC catalyst with the polycarbonate polyol compound of the first reaction and epoxide to produce a polyol block copolymer, wherein (i) the product of the first reaction is fed into the second reactor as a crude reaction mixture, (ii) the epoxide and the polycarbonate polyol compound of the first reaction are fed into the second reactor in a continuous or semi-batch manner, and/or (iii) the product of the first reaction has a neutral or alkaline pH on addition to the second reaction.

2. A process for producing a polyol block copolymer in a multiple reactor system; the system comprising a first and second reactor wherein a first reaction takes place in the first reactor and a second reaction takes place in the second reactor; wherein the first reaction is the reaction of a carbonate catalyst with CO_2 and epoxide, in the presence of a polyfunctional starter, and optionally a solvent, to produce a polycarbonate polyol and the second reaction is the semi-batch or continuous reaction of a DMC catalyst with the polycarbonate polyol compound of the first reaction and epoxide to produce a polyol block copolymer.

3. A process for producing a polyol block copolymer according to claim 2, wherein the starter compound has the formula (III):

$$Z\text{-}(R^Z)_a \quad \text{(III)}$$

wherein Z can be any group which can have 2 or more $-R^Z$ groups attached to it and may be selected from optionally substituted alkylene, alkenylene, alkynylene, heteroalkylene, heteroalkenylene, heteroalkynylene, cycloalkylene, cycloalkenylene, hererocycloalkylene, heterocycloalkenylene, arylene,

heteroarylene, or Z may be a combination of any of these groups, for example Z may be an alkylarylene, heteroalkylarylene, heteroalkylheteroarylene or alkylheteroarylene group;

a is an integer which is at least 2, optionally a is in the range of between 2 and 8, optionally a is in the range of between 2 and 6;

wherein each R^Z may be –OH, -NHR', –SH, -C(O)OH, -P(O)(OR')(OH), –PR'(O)$(OH)_2$ or –PR'(O)OH, optionally R^Z is selected from –OH, -NHR' or -C(O)OH, optionally each R^z is –OH, -C(O)OH or a combination thereof (e.g. each R^z is –OH);

wherein R' may be H, or optionally substituted alkyl, heteroalkyl, aryl, heteroaryl, cycloalkyl or heterocycloalkyl, optionally R' is H or optionally substituted alkyl.

4. A process according to any preceding claim, wherein the DMC catalyst is pre-activated, optionally in the second reactor or separately, optionally wherein the DMC is pre-activated with a starter compound or with the reaction product of the first or second reaction or with a polycarbonate polyol copolymer or with a polyol block copolymer.

5. A process according to any preceding claim, wherein the product of the first reaction is a low molecular weight polycarbonate polyol product having a molecular weight (Mn) in the range 200 to 4000 Daltons as measured by Gel Permeation Chromatography (GPC).

6. A process according to any preceding claim, wherein the product of the first reaction is fed into the second reactor, as a crude reaction mixture, wherein said second reactor contains a pre-activated DMC catalyst, and/or wherein the polycarbonate copolymer is fed into the reaction with the DMC catalyst, as a crude reaction mixture, wherein said reaction contains a pre-activated DMC catalyst.

7. A process according to any preceding claim, wherein the first reaction is carried out under CO_2 pressure of less than 20 bar, more preferably, less than 10 bar, most preferably, less than 8 bar.

8. A process according to any preceding claim, wherein the first reaction is a batch, semi-batch, or continuous process, and/or wherein the second reaction is a continuous process or semi batch process.

9. A process according to any preceding claim, wherein the crude reaction mixture fed into the second reactor includes an amount of unreacted epoxide and/or starter.

10. A process according to any preceding claim, wherein the carbonate catalyst is present in the crude reaction mixture.

11. A process according to any preceding claim, wherein the carbonate catalyst has been removed from the crude reaction mixture prior to the addition to the second reactor.

12. A process according to any preceding claim, wherein the temperature of reaction in the first reactor is in the range about 0°C to 250 °C, preferably from about 40 °C to about 160 °C, more preferably from about 50 °C to 120 °C and/or, wherein the temperature of reaction in the second reactor is in the range from about 50 to about 160°C, preferably in the range from about 70 to about 140°C, more preferably from about 80 to about 130°C.A process according to any preceding claim, wherein the reactors are located in series or wherein the reactors are nested.

13. A process according to any preceding claim, wherein the first and second reactors are effective to provide different reaction conditions, such as temperature and/or pressure, to each other simultaneously.

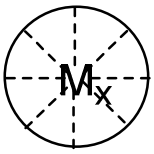
14. A process according to any preceding claim, wherein the epoxides are selected from cyclohexene oxide, styrene oxide, ethylene oxide, propylene oxide, butylene oxide, substituted cyclohexene oxides (such as limonene oxide, $C_{10}H_{16}O$ or 2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane, $C_{11}H_{22}O$), alkylene oxides (such as ethylene oxide and substituted ethylene oxides), unsubstituted or substituted oxiranes (such as oxirane, epichlorohydrin, 2-(2-methoxyethoxy)methyl oxirane (MEMO), 2-(2-(2-methoxyethoxy)ethoxy)methyl oxirane (ME2MO), 2-(2-(2-(2-methoxyethoxy)ethoxy)ethoxy)methyl oxirane (ME3MO), 1,2-epoxybutane, glycidyl ethers, glycidyl esters, glycidyl carbonates,

vinyl-cyclohexene oxide, 3-phenyl-1,2-epoxypropane, 2,3-epoxybutane, isobutylene oxide, cyclopentene oxide, 2,3-epoxy-1,2,3,4-tetrahydronaphthalene, indene oxide, and functionalized 3,5-dioxaepoxides.

15. A process according to any preceding claim wherein the carbonate catalyst is a catalyst capable of producing polycarbonate chains with greater than 76% carbonate linkages.

16. A process according to any preceding claim, wherein the carbonate catalyst is a metal catalyst comprising phenol or phenolate ligands.

17. A process according to any preceding claim wherein the carbonate catalyst is a catalyst of Formula (IV):



(IV)

wherein M is a metal cation represented by M-$(L)_v$;

x is an integer from 1 to 4,

 is a multidentate ligand or plurality of multidentate ligands;

L is a coordinating ligand;

v is an integer that satisfies the valency of M, and/or the preferred coordination geometry of M or is such that the complex represented by formula (IV) above has an overall neutral charge.

18. A process according to any preceding claim, wherein the DMC catalyst is based upon $Zn_3[Co(CN)_6]_2$ (zinc hexacyanocobaltate).

19. A process according to any preceding claim wherein the product of the first reaction is used to pre-activate the DMC catalyst in the second reaction, prior to addition of epoxide.

20. A process according to any preceding claim, wherein the same or different epoxides are used in the first or second reactions.

21. A process according to any preceding claim, wherein the epoxide used in the first or second reaction comprises propylene oxide, ethylene oxide or a mixture of propylene oxide and ethylene oxide.

22. A process according to any preceding claim, wherein the second reaction is carried substantially in the absence of CO_2.

23. A process according to any preceding claim, wherein the polyol block copolymer produced in the second reaction is a polycarbonate block polyether polyol block copolymer.