

CLAIMS

1. A process to enable the recycling of a stream of polyester waste material by depolymerising the polyester by alcoholysis, the process comprising at least a first stage
5 of depolymerisation and a separate second consecutive stage of depolymerisation, to which first and second stages the stream of polymer waste material is subjected in a continuous manner, wherein
- in the first stage of the two consecutive stages, the stream of polyester waste
10 material is continuously fed to an extruder operated at a temperature above the melting temperature of the polyester, while a first amount of alcohol is co-fed to the extruder, in order to produce a fluid mixture comprising a melt of the at least partly depolymerised polyester;
 - in the second stage, the said fluid mixture is continuously fed to a continuously
15 stirred tank reactor (CSTR) operated at a temperature above the melting temperature of the polyester, while co-feeding a second amount of alcohol to the CSTR, wherein a residence time in the CSTR is used to provide at the outlet of the CSTR a continuous stream of polyester depolymerised into an oligomeric
20 ester.
2. A process according to claim 1, characterised in that the total amount of alcohol of the first and second amount of alcohol, is between 3 and 12% w/w with respect to the
25 stream of polyester material.
3. A process according to claim 2, characterised in that the first amount of alcohol is between 1 and 5% w/w with respect to the stream of polyester material, and the second amount of alcohol is between 2 and 8% w/w with respect to the stream of polyester
30 material.
4. A process according to any of the preceding claims, characterised in that the first stage comprises first and second separate consecutive sub-stages, wherein each of the first and second substages comprises a corresponding extruder, each operated at a
35 temperature above the melting temperature of the polyester, while co-feeding an amount of alcohol to each extruder, to produce the fluid mixture fed to the CSTR.

5. A process according to claim 4, characterised in that the alcohol fed to the extruder of the first sub-stage, is fed in the distal 20% of the extruder length, preferably in the distal 5-15% of the extruder length, preferably at 10% of the extruder length.
- 5 6. A process according to any of the claims 4 and 5, characterised in that the alcohol fed to the extruder of the second sub-stage, is fed in the middle 30-70% of the extruder length, preferably in the middle 40-60% of the extruder length, preferably at 50% of the extruder length.
- 10 7. A process according to any of the claims 4 to 6, characterised in that the amount of alcohol fed in the extruder of the first sub-stage is between 0 and 2% w/w with respect to the stream of polyester material and the amount of alcohol fed in the extruder of the second sub-stage is between 1 and 5% w/w with respect to the stream of polyester material.
- 15 8. A process according to any of the claims 4 to 7, characterised in that the extruder of the first sub-stage is a twin-screw extruder.
- 20 9. A process according to claim 8, characterised in that the extruder of the first sub-stage is a conical twin-screw extruder.
10. A process according to any of the claims 4 to 9, characterised in that the extruder of the second sub-stage is a single screw extruder.
- 25 11. A process according to any of the preceding claims, characterised in that the two consecutive stages are preceded by a step wherein the stream of polyester waste material is subjected to a drying process to reduce the amount of water in the stream to less than 5000 ppm.
- 30 12. A process according to claim 11, characterised in that the amount of water in the stream between 10 and 1000 ppm, preferably between 20 and 100 ppm, most preferably around 50 ppm.
- 35 13. A process according to any of the preceding claims, characterised in that the amount of alcohol fed in the first stage of the process is controlled by measuring a viscosity of the fluid mixture fed to the CSTR and adjusting the amount of alcohol to

arrive a predetermined value for the said viscosity, which predetermined value is preferably an intrinsic viscosity (IV) between 0.1 and 0.2 dl/g.

14. A process according to any of the preceding claims, characterised in that the amount of alcohol fed in the second stage of the process is controlled by measuring a viscosity of the stream of oligomeric ester and adjusting the amount of alcohol to arrive at a predetermined value for the viscosity, which predetermined value is preferably an intrinsic viscosity (IV) between 0.09 and 0.1.
15. A process according to any of the preceding claims, characterised in that the fluid mixture fed to the CSTR is pumped through a first filter arranged between the first stage and the second stage, the filter preferably having a mesh size between 10 and 80 μm , preferably between 30 and 50 μm , most preferably around 40 μm .
16. A process according to any of the claims 4 to 10, or any of the claims 11 to 14 referring back to claim 4, characterised in that a second filter is arranged between the first sub-stage and the second sub-stage of the first stage, the second filter preferably having a mesh size between 40 and 120 μm , preferably between 60 and 100 μm , most preferably around 80 μm .
17. A process according to any of the preceding claims, characterised in that the stream of oligomeric ester is pumped through a third filter arranged after the CSTR, the third filter preferably having a mesh size below 20 μm , more preferably between 5 and 10 μm .
18. A process according to claim 17, characterised in that active carbon is added to the CSTR, which carbon is removed from the oligomeric ester after this ester has left the CSTR.
19. A process according to any of the preceding claims, characterised in that the alcohol comprises a diol, preferably at least a diol selected from the group of ethylene glycol, 1,3-propanediol, butanediol, cyclohexane dimethanol and neopentyl glycol.
20. A process according to any of the preceding claims, wherein the polyester is polyethylene terephthalate (PET), characterised in that residence time in the CSTR is such that the oligomeric ester for over 50% w/w, preferably over 60, 70, 80 or even 90%

w/w, comprises oligomers of 4 to 16 Bis(2-Hydroxyethyl) terephthalate (BHET) units, preferably 6 to 14 (BHET) units, most preferably, 8 to 10 BHET units.

21. A process according to any of the preceding claims, characterised in that the
5 continuous stream of oligomeric ester is heated to an elevated temperature above the melting temperature of the polyester while subjected to a vacuum below 10 mbar, preferably below 5 mbar, preferably between 0.5 and 2 mbar, most preferably around 1 mbar, to induce repolymerisation, to arrive at a repolymerised amorphous polyester, preferably having an IV between 0.4 to 0.6.

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22. A process according to claims 21 characterised in that the repolymerised polyester is heated to an elevated temperature below the melting temperature of the polyester while subjected to a vacuum or an inert gas, to induce additional repolymerisation, preferably to arrive at an IV above 0.6.

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23. A process according to claim 22, characterised in that the additional repolymerisation step is preceded by a solid state crystallisation step by cooling down the repolymerised amorphous polyester to a temperature between 130 and 180°C to arrive at a solid amorphous polyester, and keeping the solid amorphous polyester at
20 that temperature until the polyester has at least partly crystallised.

24. A system for recycling of a stream of polyester waste material by depolymerising the polyester by alcoholysis, the system comprising an in line arrangement of three consecutive reactors for conducting a continuous process inducing alcoholysis of the polyester, the first reactor being a twin screw extruder having a feeding entrance for feeding an alcohol in the distal 20% of the twin screw extruder length, the second
25 reactor being a single screw extruder having a feeding entrance for feeding an alcohol in the middle 30-70% of the single screw extruder length, and the third reactor being a continuous stirred tank reactor having a feeding entrance for feeding an alcohol.

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