

Claims

1. A method of converting particulate lignocellulosic material to produce volatile
5 organic compounds and char, comprising,
forming a mixture of the particulate lignocellulosic material with a catalyst
composition containing polar organic liquid and an acid,
heating the mixture to a temperature sufficiently high and for a period
sufficiently long as to convert a major portion of any remaining solid phase of the
10 mixture to char whilst agitating the mixture, and
separating the volatile organic compounds and the catalyst composition as a
gaseous phase from the solid phase.
2. The method according to claim 1 wherein the temperature is raised to a level
15 sufficient to vaporize the catalyst composition during conversion of the solid phase to
char.
3. The method according to claim 1 or claim 2 wherein the mixture is reacted
under sub-atmospheric pressure.
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4. The method according to claim 3 wherein the mixture is reacted under a
pressure less than 900 millibar.
5. The method according to any one of the preceding claims wherein the polar
25 organic liquid is chosen from room temperature ionic liquids having the general
formula A_xM_y , where A is an organic cation, M is an anion drawn from halide,
sulfate, or organic anions, and x and y are integers, or, a dipolar aprotic liquid.
6. The method according to claim 5 wherein A is dialkyl imidazolium, or alkyl
30 pyridinium and M is halide, sulfate, formate, acetate, trifluoromethanesulfonate or bis
(trifluoromethane)sulfonimide.

7. The method according to claim 5 wherein the dipolar aprotic liquid comprises a dialkyl formamide, N-alkyl morpholine oxide, dialkyl sulfoxide or dialkyl sulfone having the general chemical formula $R_1-SO_2-R_2$ where R_1 and R_2 are alkyl groups containing between one and ten carbon atoms, including cyclic sulfones in which R_1 and R_2 form part of a cyclic polymethylene ring.
8. The method according to any one of the preceding claims wherein the polar organic liquid comprises tetramethylene sulfone.
9. The method according to any one of the preceding claims wherein the acid is chosen from orthophosphoric acid, sulfuric acid, methanesulfonic acid, trifluoromethanesulfonic acid, hydrohalic acids, nitric acid and formic acid.
10. The method according to any one of the preceding claims wherein the acid comprises, 0.1% to 10% by weight of the catalyst composition.
11. The method according to any one of the preceding claims wherein the weight of the catalyst composition in the mixture is one to ten times the weight of the particulate lignocellulosic material.
12. The method according to any one of the preceding claims wherein the mixture is subjected to shearing and compression by any one or more of single of twin-screw presses, rolling mills, crushing mills, shredding mills and hammer mills.
13. The method according to any one of the preceding claims wherein the mixture is heated to a temperature in the range 190°C to 500°C.
14. The method according to claim 14 wherein the heating of the mixture is carried out in a rotating screw reactor having an inlet for the mixture and an outlet for char in which the pressure is maintained within the range 50 to 150 millibar with temperature in the reactor being controlled along the reactor's length such that

temperature of the reactor increases from a lower temperature closer to the inlet to a higher temperature closer to the outlet.

15. Apparatus for converting lignocellulosic materials into volatile organic liquids
5 and char comprising,

a mixing and comminution station for mixing the lignocellulosic material with
a catalyst composition and comminuting the lignocellulosic material,

a reactor arranged to receive mixture from the mixing and comminution
station through an inlet and to discharge char from an outlet located downstream of
10 the inlet,

an evacuation pump arranged to reduce pressure in the reactor,

a feed assembly arranged to move the mixture from the inlet to the outlet so as
to discharge char from the outlet,

a heating assembly for heating the mixture in the reactor to a temperature at
15 which pyrolysis of the mixture occurs as it travels through the reactor, and

a volatiles condensation assembly for recovering catalyst and separating
volatile chemical products from the reactor.

16. The apparatus according to claim 15 wherein the reactor has an elongate
20 tubular section and the feed assembly comprises a screw feeder within the tubular
section.

17. The apparatus according to claim 15 or claim 16 comprising a steam assembly
arranged to inject steam into the reactor at at least one location downstream of the
25 inlet.

18. The apparatus according to any one of claims 15 to 17 comprising a gas-solid
separation system and a fractional distillation system.

Claims

1. A method of converting particulate lignocellulosic material to produce volatile organic compounds and char, comprising,
 - 5 forming a mixture of the particulate lignocellulosic material with a catalyst composition containing polar organic liquid and an acid,
 - heating the mixture to a temperature sufficiently high and for a period sufficiently long as to convert a major portion of any remaining solid phase of the mixture to char whilst agitating the mixture and subjecting it to shearing and
 - 10 compression in the presence of steam, and
 - separating the volatile organic compounds and the catalyst composition as a gaseous phase from the solid phase.
2. The method according to claim 1 wherein the temperature is raised to a level
- 15 sufficient to vaporize the catalyst composition during conversion of the solid phase to char.
3. The method according to claim 1 or claim 2 wherein the mixture is reacted under sub-atmospheric pressure.
- 20 4. The method according to claim 3 wherein the mixture is reacted under a pressure less than 900 millibar.
5. The method according to any one of the preceding claims wherein the polar
- 25 organic liquid is chosen from room temperature ionic liquids having the general formula A_xM_y , where A is an organic cation, M is an anion drawn from halide, sulfate, or organic anions, and x and y are integers, or, a dipolar aprotic liquid.
6. The method according to claim 5 wherein A is dialkyl imidazolium, or alkyl
- 30 pyridinium and M is halide, sulfate, formate, acetate, trifluoromethanesulfonate or bis (trifluoromethane)sulfonimide.

7. The method according to claim 5 wherein the dipolar aprotic liquid comprises a dialkyl formamide, N-alkyl morpholine oxide, dialkyl sulfoxide or dialkyl sulfone having the general chemical formula $R_1-SO_2-R_2$ where R_1 and R_2 are alkyl groups containing between one and ten carbon atoms, including cyclic sulfones in which R_1 and R_2 form part of a cyclic polymethylene ring.
8. The method according to any one of the preceding claims wherein the polar organic liquid comprises tetramethylene sulfone.
9. The method according to any one of the preceding claims wherein the acid is chosen from orthophosphoric acid, sulfuric acid, methanesulfonic acid, trifluoromethanesulfonic acid, hydrohalic acids, nitric acid and formic acid.
10. The method according to any one of the preceding claims wherein the acid comprises, 0.1% to 10% by weight of the catalyst composition.
11. The method according to any one of the preceding claims wherein the weight of the catalyst composition in the mixture is one to ten times the weight of the particulate lignocellulosic material.
12. The method according to any one of the preceding claims wherein the mixture is subjected to shearing and compression by any one or more of single or twin-screw presses, rolling mills, crushing mills, shredding mills and hammer mills.
13. The method according to any one of the preceding claims wherein the mixture is heated to a temperature in the range 190°C to 500°C.
14. The method according to claim 13 wherein the heating of the mixture is carried out in a rotating screw reactor having an inlet for the mixture and an outlet for char in which the pressure is maintained within the range 50 to 150 millibar with temperature in the reactor being controlled along the reactor's length such that

temperature of the reactor increases from a lower temperature closer to the inlet to a higher temperature closer to the outlet.

15. Apparatus for converting lignocellulosic materials into volatile organic liquids
5 and char comprising,

a mixing and comminution station for mixing the lignocellulosic material with
a catalyst composition and comminuting the lignocellulosic material,

- a reactor arranged to receive mixture from the mixing and comminution
station through an inlet and to discharge char from an outlet located downstream of
10 the inlet,

an evacuation pump arranged to reduce pressure in the reactor,

a feed assembly arranged to move the mixture from the inlet to the outlet so as
to discharge char from the outlet whilst subjecting the mixture to shearing and
compression,

- 15 a heating assembly for heating the mixture in the reactor to a temperature at
which pyrolysis of the mixture occurs as it travels through the reactor,

a steam assembly arranged to inject steam into the reactor at at least one
location downstream of the inlet, and

- a volatiles condensation assembly for recovering catalyst and separating
20 volatile chemical products from the reactor.

16. The apparatus according to claim 15 wherein the reactor has an elongate
tubular section and the feed assembly comprises a screw feeder within the tubular
section.

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17. The apparatus according to any one of claims 15 to 16 comprising a gas-solid
separation system and a fractional distillation system.