CLAIMS

1. A method comprising:

exposing a biomass material, in particulate form, to ionizing radiation in the form of a scanning electron beam, and

during exposure to the electron beam, conveying the biomass material upon a vibratory conveyor in a direction, x, such that the vibratory conveyor vibrates the particles of the biomass material during irradiation to cause the biomass particles to move in any combined directions and magnitudes of x, y and z vectors,

wherein y is the direction transverse to x and z is the direction perpendicular to and orthogonal to the directions x and y, and wherein displacement of the vibratory conveyor in the z direction is between 0 and 3 inches (7.62 cm),

wherein the biomass material defines a substantially uniform average bed thickness across the width of the vibratory conveyor of between about 0.0312 inches (0.0792 cm) and 5 inches (12.7 cm) on the conveyor as it is being exposed to the ionizing radiation.

2. The method of claim 1, wherein 75% or more of the biomass material is distributed to be at the level of the average bed thickness.

3. The method of claim 1, further comprising distributing the biomass material prior to conveying the biomass material upon the vibratory conveyor and exposing the biomass to the ionizing radiation.

4. The method of claim 3, wherein distributing the biomass material utilizes a feeder conveying system.

5. The method of claim 4, wherein the feeder conveying system comprises a second vibratory conveying system.

6. The method of claim 1, further comprising comminuting the biomass prior to exposing the biomass to the ionizing radiation.

7. The method of claim 6, wherein comminuting is selected from the group consisting of shearing, chopping, grinding, hammermilling and combinations thereof.

8. The method of claim 6, wherein comminuting produces a biomass material with particles, and more than 80 % of the particles have at least one dimension that is less than about 0.25 inches (0.635 cm).

9. The method of claim 6, wherein comminuting produces a biomass material with particles, and no more than 5% of the particles are less than 0.03 inches (0.0762 cm) in their greatest dimension.

10. The method of claim 1, wherein the source of the ionizing radiation is selected from the group consisting of an electron beam, an ion beam, ultraviolet light with a wavelength of between 100 nm and 280 nm, gamma radiation, X-ray radiation and combinations thereof.

11. The method of claim 1, wherein the source of the ionizing radiation is an electron beam.

12. The method of claim 11, wherein the electron beam is supplied by an electron accelerator equipped with a scanning horn disposed above the conveyor and configured to direct the electron beam onto the biomass upon the vibratory conveyor.

13. The method of claim 1, wherein the biomass is irradiated with 10 to 200 Mrad of radiation.

14. The method of claim 1, wherein the biomass material comprises a cellulosic or lignocellulosic material.

15. The method of claim 14, wherein the cellulosic or lignocellulosic material comprises a lignocellulosic material selected from the group consisting of wood, paper, paper products, cotton, grasses, grain residues, bagasse, jute, hemp, flax, bamboo, sisal, abaca, corn cobs, corn stover, coconut hair, algae, seaweed, straw, wheat straw and mixtures thereof.

16. The method of claim 1, wherein at least a portion of the conveyor comprises an enclosure.

17. The method of claim 16, wherein the enclosure comprises a window foil integrated into a wall of the enclosure, and wherein the window foil is disposed beneath the ionizing radiation and allows passage of the ionizing radiation through the window foil and onto the biomass material.

18. The method of claim 1, wherein the biomass material is conveyed at a rate of at least about 1000 lb/hr (454 kg/hr).

CLAIMS

1. A method comprising:

exposing a biomass material to ionizing radiation while the biomass material is being conveyed upon a vibratory conveyer.

2. The method of claim 1, wherein the biomass material defines a substantially uniform thickness bed on the conveyor as it is being exposed to the ionizing radiation.

3. The method of claim 1 or 2, further comprising distributing the biomass material prior to conveying the biomass material upon the vibratory conveyer and exposing the biomass to the ionizing radiation.

4. The method of claim 3, wherein distributing the biomass material utilizes a feeder conveying system.

5. The method of claim 4, wherein the feeder conveying system comprises a second vibratory conveying system.

6. The method of any one of claims 1-3, wherein 75% or more of the biomass material is distributed to be at the level of the average bed thickness.

7. The method of any one of claims 1-3, wherein 80% or more of biomass material is distributed to be at the level of the average bed thickness.

8. The method of any one of claims 1-3, wherein 85% or more of the biomass material is distributed to be at the level of the average bed thickness.

9. The method of any one of claims 1-3, wherein 90% or more of the biomass material is distributed to be at the level of the average bed thickness.

10. The method of any one of claims 1-3, wherein 95% or more of the biomass material is distributed to be at the level of the average bed thickness.

11. The method of any one of the preceding claims, further comprising comminuting the biomass prior to exposing the biomass to the ionizing radiation.

12. The method of claim 11, wherein comminuting is selected from the group consisting of shearing, chopping, grinding, hammermilling and combinations thereof.

13. The method of claim 11 or 12, wherein comminuting produces a biomass material with particles, and more than 80 % of the particles have at least one dimension that is less than about 0.25 inches.

14. The method of claim 13, wherein greater than 90 % of the particles have at least one dimension that is less than about 0.25 inches.

15. The method of claim 13, wherein greater than 95 % of the particles have at least one dimension that is less than about 0.25 inches.

16. The method of any one of claims 13-15, wherein no more than 5 % of the particles are less than 0.03 inches in their greatest dimension.

17. The method of any one of the preceding claims, wherein the source of the ionizing radiation is selected from the group consisting of an electron beam, an ion beam, ultraviolet light with a wavelength of between 100nm and 280nm, gamma radiation, X-ray radiation and combinations thereof.

18. The method of any one of the preceding claims, wherein the source of the ionizing radiation is an electron beam.

19. The method of claim 18, wherein the biomass is irradiated with 10 to 200 Mrad of radiation.

20. The method of claim 18 wherein the biomass is irradiated with 10 to 25 Mrad of radiation.

21. The method of claim 18, wherein the biomass is irradiated with 10 to 75 Mrad of radiation.

22. The method of claim 18, wherein the biomass is irradiated with 15 to 50 Mrad of radiation.

23. The method of claim 18, wherein the biomass is irradiated with 20 to 35 Mrad of radiation.

24. The method of any one of claims 18-23, wherein the energy of the electron beam is between 0.3 and 2 MeV.

25. The method of any one of claims 18-24, wherein the electron beam is supplied by an electron accelerator equipped with a scanning horn disposed above the conveyor and configured to direct the electron beam onto the biomass upon the vibratory conveyor.

26. The method of any one of the preceding claims, wherein the biomass material receives a substantially uniform level of ionizing radiation.

27. The method of any one of the preceding claims, wherein the biomass material comprises a cellulosic or lignocellulosic material.

28. The method of claim 27, wherein the cellulosic or lignocellulosic material comprises a lignocellulosic material selected from the group consisting of wood, paper, paper products, cotton, grasses, grain residues, bagasse, jute, hemp, flax, bamboo, sisal, abaca, corn cobs, corn stover, coconut hair, algae, seaweed, straw, wheat straw and mixtures thereof.

29. The method of any one of the preceding claims, wherein at least a portion of the conveyor comprises an enclosure.

30. The method of any one of the preceding claims, wherein exposing the biomass material to ionizing radiation reduces the recalcitrance of the biomass material.

31. The method of any one of the preceding claims, wherein the vibratory conveyer conveys the biomass material at an average speed of 3 to 100 ft/min.

32. The method of claim 31, wherein the vibratory conveyer conveys the biomass material at an average speed of 9 to 50 ft/min.

33. The method of claim 31, wherein the vibratory conveyer conveys the biomass material at an average speed of 12 to 25 ft/min.

34. The method of any one of the above claims, wherein the biomass material is irradiated with an irradiator with a power output of at least 50 kW.

35. The method of any one of the above claims, wherein the biomass material is conveyed at a rate of about 1000 to about 8000 lb/hr.

36. The method of any one of the above claims, wherein the biomass is exposed to ionizing radiation more than one time.

37. An apparatus for producing a treated biomass material, comprising:

an ionizing radiation source; and

a vibratory conveying system, wherein the vibratory conveying system is capable of conveying biomass material past the ionizing radiation source.

38. The apparatus of claim 37, further comprising an enclosure surrounding the biomass material when the biomass material is proximate to the radiation source.

39. The apparatus of claim 38, wherein the enclosure comprises a window foil integrated into a wall of the enclosure, and wherein the window foil is disposed beneath the radiation source and allows passage of the electrons through the window foil and onto the biomass material.

40. The apparatus of any one of claims 37-39, further comprising a feeder conveying system upstream from the vibratory conveying system, wherein the feeder conveying system is configured to spread the biomass material to form a bed of biomass material of substantially uniform depth, and where the feeder conveying system feeds the biomass material to the vibratory conveying system upstream of the radiation field.

41. The apparatus as in claim 40, wherein the feeder conveying system is a vibratory conveying system.

42. The apparatus as in any one of claims 37-41, wherein the conveyor system comprises structural materials including steel.