CLAIMS:

1. A method of producing a treated biomass material, the method comprising:

irradiating a biomass material by passing an electron beam through multiple windows into the biomass material, wherein the multiple windows comprise at least

a primary single-type window foil communicating with a high vacuum side of a scanning horn of an electron beam accelerator and

a secondary single-type window foil positioned on an atmospheric side of the scanning horn,

wherein the distance of the secondary window to the biomass material is more than 0.1 cm and less than 10 cm, and the biomass material is selected from the group consisting of cellulosic material, lignocellulosic material, and starchy material.

2. The method of claim 1, wherein one or more of the windows is in the form of a metallic foil.

3. The method of claim 1, wherein ~~irradiating the biomass material reduces the recalcitrance of the biomass material~~the secondary single-type window foil is in communication with atmospheric pressure.

4. The method of claim 1, wherein the multiple window foils comprise a system of gas cooled window foils.

5. The method of claim 4, wherein the system of gas cooled window foils define a gap between the primary and secondary window and

a first flow path providing cooling to the primary window foil; and

a second flow path providing cooling to the secondary window foil.

6. The method of claim 5, wherein the system of gas cooled window foils further comprises where both the primary window foil and the secondary window foil are part of the scanning horn of the electron beam accelerator, where

at least one inlet, which allows a cooling gas to enter the gap defined between the primary and the secondary window and

at least one outlet, to extract cooling gases from the gap defined between the primary and secondary window.

7. The method of claim 6, wherein the system of gas cooled window foils further comprises a cooling chamber, wherein the cooling chamber comprises four walls and the interior volume is approximately rectangular prism in shape.

8. The method of claim 4, wherein the system further comprises a treatment enclosure with a cover surface, where the enclosure is positioned on a side of the secondary single-type window foil opposite the electron beam accelerator.

9. The method of claim 8, wherein the secondary single-type window foil is mounted on the cover surface and is integral to the treatment enclosure.

10. The method of claim 9, wherein the cover surface is perpendicular to the electron beam accelerator.

11. The method of claim 8, wherein the treatment enclosure has a first opening.

12. The method of claim 11, further comprising:
conveying the biomass material through the first opening;
positioning the biomass material under the secondary single-type window foil; and
irradiating the biomass material.

13. The method of claim 11, wherein the treatment enclosure comprises a second opening.

14. The method of claim 12, further comprising:
conveying the treated biomass material out of the treatment enclosure through the second opening.

15. The method of claims 12 or 14, further comprising purging the treatment enclosure with an inert gas or.

~~16. The method of claims 12 or 14, further comprising purging the treatment enclosure with~~ a reactive gas.

~~17~~16. The method of claim 41, being configured in one of the following ways:

___wherein the primary single-type window foil is made from an element selected from the group consisting of: titanium, scandium, vanadium, chromium, nickel, zirconium, niobium, molybdenum, ruthenium, rhodium, palladium, hafnium, tantalum, tungsten, rhenium, platinum, iridium, and alloys or mixtures of any of these.;

___~~18. The method of claim 4,~~ wherein the secondary single-type window foil is made from an element selected from the group consisting of: titanium, scandium, vanadium, chromium, nickel, zirconium, niobium, molybdenum, ruthenium, rhodium, palladium, hafnium, tantalum, tungsten, rhenium, platinum, iridium, beryllium, aluminum, silicon, and alloys or mixtures of any of these.;

___~~19. The method of claim 4,~~ wherein the primary single-type window foil and the secondary single-type window foil are made of the same element, alloy, or mixture.;

___~~20. The method of claim 4,~~ wherein the primary single-type window foil and the secondary single-type window foil are made of different elements, alloys, or mixtures.;

___~~21. The method of claim 4,~~ wherein the primary single-type window foil or the secondary single-type window foil or both are made from an element selected from the group consisting of: titanium, scandium, vanadium, chromium, nickel, zirconium, niobium, molybdenum, ruthenium, rhodium, palladium, beryllium, aluminum, silicon, and alloys or mixtures of any of these.;

___~~22. The method of claim 4,~~ wherein the primary single-type window foil is made from a high Z element and the secondary single-type window foil is made from an element selected from the group consisting of: titanium, scandium, vanadium, chromium, nickel, zirconium, niobium, molybdenum, ruthenium, rhodium, palladium, beryllium, aluminum, silicon, and alloys or mixtures of any of these.

~~23~~17. The method of claim 41, wherein the primary single-type window foil is from 10 to 50 microns thick, or from 15 to 40 microns thick, or from 20 to 30 microns thick.

~~24. The method of claim 23, wherein the primary single-type window foil is from 15 to 40 microns thick.~~

~~25. The method of claim 23, wherein the primary single-type window foil is from 20 to 30 microns thick.~~

~~26~~18. The method of claim ~~23~~17, wherein the secondary single-type window foil is from 5 to 30 microns thick, or from 8 to 25 microns thick, or from 10 to 20 microns thick.

~~27. The method of claim 23, wherein the secondary single-type window foil is from 8 to 25 microns thick.~~

~~28. The method of claim 23, wherein the secondary single-type window foil is from 10 to 20 microns thick.~~

~~29~~19. The method of claim ~~23~~17, wherein the primary single-type window foils are the same thickness or wherein the single-type window foils are different thicknesses.

~~30. The method of claim 23, wherein the single-type window foils are different thicknesses.~~

~~31~~20. The method of ~~claim 1~~any preceding claim, wherein the biomass is selected from the group consisting of paper, paper products, paper waste, wood, particle board, sawdust, agricultural waste, sewage, silage, grasses, wheat straw, rice hulls, bagasse, cotton, jute, hemp, flax, bamboo, sisal, abaca, straw, corn cobs, corn stover, alfalfa, hay, coconut hair, seaweed, algae, and mixtures thereof.

~~32~~21. The method of ~~claim 1~~any preceding claim, wherein the biomass is treated with between 10 and 200 Mrad of radiation, or between 10 and 75 Mrad of radiation, or between 15 and 50 Mrad of radiation, or between 20 and 35 Mrad of radiation.

~~33. The method of claim 32, wherein the biomass is treated with between 10 and 75 Mrad of radiation.~~

~~34. The method of claim 32, wherein the biomass is treated with between 15 and 50 Mrad of radiation.~~

~~35. The method of claim 32, wherein the biomass is treated with between 20 and 35 Mrad of radiation.~~

~~36~~22. The method of ~~claim 1~~any preceding claim, wherein the electron beam comprises electrons having an energy of about 0.5 - 10 MeV, or about 0.8 - 5 MeV, or about 0.8 - 3 MeV, or about 1 - 3 MeV, or about 1 MeV.

~~37. The method of claim 36, wherein the electron beam comprises electrons having an energy of about 0.8 - 5 MeV.~~

~~38. The method of claim 36, wherein the electron beam comprises electrons having an energy of about 0.8 - 3 MeV.~~

~~39. The method of claim 36, wherein the electron beam comprises electrons having an energy of about 1 - 3 MeV.~~

~~40. The method of claim 36, wherein the electron beam comprises electrons having an energy of about 1 MeV.~~

~~41~~23. The method of ~~claim 1~~any preceding claim, wherein the electron beam has a beam current of at least about 50 mA, or at least about 60 mA, or at least about 70 mA, or at least about 80 mA, or at least about 90 mA, or at least about 100 mA, or at least about 125 mA, or at least about 150 mA.

~~42. The method of claim 41, wherein the electron beam has a beam current of at least about 60 mA.~~

~~43. The method of claim 41, wherein the electron beam has a beam current of at least about 70 mA.~~

~~44. The method of claim 41, wherein the electron beam has a beam current of at least about 80 mA.~~

~~45. The method of claim 41, wherein the electron beam has a beam current of at least about 90 mA.~~

~~46. The method of claim 41, wherein the electron beam has a beam current of at least about 100 mA.~~

~~47. The method of claim 41, wherein the electron beam has a beam current of at least about 125 mA.~~

~~48. The method of claim 41, wherein the electron beam has a beam current of at least about 150 mA.~~

4924. The method of claim 41, wherein the electron beam comprises electrons having an energy of about 1 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 30 centimeters, or less than 20 centimeters, or less than 10 centimeters.

~~50. The method of claim 49, wherein the electron beam comprises electrons having an energy of about 1 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 20 centimeters.~~

~~51. The method of claim 49, wherein the electron beam comprises electrons having an energy of about 1 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 10 centimeters.~~

5225. The method of claim 41, wherein the electron beam comprises electrons having an energy of about 5 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 75 centimeters, or less than 60 centimeters, or less than 50 centimeters, or less than 40 centimeters, or less than 30 centimeters, or less than 20 centimeters.

~~53. The method of claim 52, wherein the electron beam comprises electrons having an energy of about 5 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 60 centimeters.~~

~~54. The method of claim 52, wherein the electron beam comprises electrons having an energy of about 5 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 50 centimeters.~~

~~55. The method of claim 52, wherein the electron beam comprises electrons having an energy of about 5 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 40 centimeters.~~

~~56. The method of claim 52, wherein the electron beam comprises electrons having an energy of about 5 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 30 centimeters.~~

~~57. The method of claim 52, wherein the electron beam comprises electrons having an energy of about 5 MeV, and the spacing between the primary single-type window foil and the secondary single-type window foil is less than 20 centimeters.~~

~~58~~26. The method of claim 41, where the method further comprises a beam stop.

~~59~~27. A system for cooling multiple single-type window foils of an electron beam accelerator comprising:

a first flow path for providing a first cooling gas across a primary single-type window foil and second flow path for providing a second cooling gas across a secondary single-type window foil, wherein the secondary single-type window foil is positioned on an atmospheric side of a scanning horn of the electron beam accelerator; and

the primary and secondary single-type window foils are positioned with a gap of less than about 9 cm between them and the secondary single-type window foil functions as a sacrificial window to protect the primary window.

28. The system of claim 27, wherein the primary single-type window foil is in communication with a high vacuum side of a scanning horn of the electron beam accelerator.

29. The system of claim 27 or 28, wherein the secondary single-type window foil is in communication with atmospheric pressure.

~~60~~30. A method for cooling multiple single-type window foils of an electron beam accelerator, the method comprising:

passing a first cooling gas across a primary single-type window foil and passing a second cooling gas across a secondary single-type window foil, wherein the secondary single-type window foil is positioned on an atmospheric side of a scanning horn of the electron beam accelerator; and

the primary and secondary single-type window foils are positioned facing each other with a gap of less than about 9 cm between them and the secondary single-type window foil functions as a sacrificial window to protect the primary window.

31. The method of claim 30, wherein the primary single-type window foil is in communication with a high vacuum side of a scanning horn of the electron beam accelerator.

32. The method of claim 30 or 31, wherein the secondary single-type window foil is in communication with atmospheric pressure.

~~61~~33. The method of claim ~~58~~26, where the beam stop is moveable to absorb different amounts of the electron beam.

~~62~~34. The method of claim ~~58~~26, where the beam stop absorbs at least 20 % of the incident electrons, or at least 40 % of the incident electrons, or at least 60 % of the incident electrons, or at least 80 % of the incident electrons.

~~63. The method of claim 58, where the beam stop absorbs at least 40 % of the incident electrons.~~

~~64. The method of claim 58, where the beam stop absorbs at least 60 % of the incident electrons.~~

~~65. The method of claim 58, where the beam stop absorbs at least 80 % of the incident electrons.~~