Whilst neutrons are eminently useful, there are difficulties around their cheap, reliable, safe and on-demand production. Historically, Californium-252 neutron sources have been the standard, but the constant uncontrollable emission of neutrons imposes complex operational safety requirements. Additionally, the half-life of the material being 2.5 years implies a short lifetime of the source as well as inherent disposal complications and costs.

An alternative technology that is currently available is an advanced tube neutron generator, or compact linear accelerator. Typically, this takes the form of a Deuterium ion source which is linearly accelerated into a concentrated beam by an electric field into a solid or gaseous Tritium target to induce fusion reactions and neutron production. Such systems have been commercialised, but their use is limited due to large upfront and running costs. This is mainly due to the infrastructure needed to run the accelerator, unintentional activation of materials from stray energetic deuterium fluence as well as erosion or burnup of the Tritium target requiring regular replacement. This also implies the system is not continuously operable for long periods.

Description of Prior Art

Particle generator devices are discussed in WO03019996. The generators in WO03019996 are described with focus on the differences from a linear geometry long-life plasma-gas target line source topology particle generating device.

WO03019996 discloses a cylindrical IEC device of low neutron production rate and high reliability and simplicity. This document also suggests the use of Aluminium for the anode wall because it emits electrons when exposed to intense ultraviolet radiation which encourages the ionization processes discussed above.

Summary of the Invention

In accordance with some implementations of the present disclosure, there is provided a particle producing apparatus of the inertial electrostatic confinement type, comprising: a vessel; an anode structure; a cathode structure, wherein the anode structure and cathode structure are positioned within the vessel; and a first enriched surface, the first enriched surface being enriched with fusible isotope species. The first enriched surface is at least a part of a surface of the anode structure or a surface of the cathode structure. The vessel comprises a central axis, the anode and cathode structures are positioned such that the anode structure and cathode

structure are substantially coaxial with the vessel, the anode structure having a mean distance from the central axis that is larger than the mean radius from the central axis of the cathode structure, the anode and cathode structures are substantially concentric along at least a part of their lengths and configured such that, in operation, an electric field is provided between the anode and cathode structures and the first enriched surface is electron screened. The enriched surface is enriched with deuterium and/or tritium by electrolysis with a deuterated and/or tritiated heavy water solution containing conductive salts for electrolysis. The enriched surface may prompt lattice confinement fusion.

Claims

1. A particle producing apparatus of the inertial electrostatic confinement type, comprising:

a vessel;

an anode structure;

a cathode structure, wherein the anode structure and cathode structure are positioned within the vessel; and

a first enriched surface, the first enriched surface being enriched with fusible isotope species wherein the first enriched surface is at least a part of a surface of the anode structure or a surface of the cathode structure;

wherein the vessel comprises a central axis, the anode and cathode structures are positioned such that the anode structure and cathode structure are substantially coaxial with the vessel, the anode structure having a mean distance from the central axis that is larger than the mean radius from the central axis of the cathode structure, the anode and cathode structures are substantially concentric along at least a part of their lengths and configured such that, in operation, an electric field is provided between the anode and cathode structures and the first enriched surface is electron screened;
and wherein the enriched surface is enriched with deuterium and/or tritium by electrolysis with a deuterated and/or tritiated heavy water solution containing conductive salts for electrolysis.

2. A particle producing apparatus as claimed in Claim 1, wherein the apparatus is configured to contain an ion and neutral gas mixture and, in operation, to cause the ion and neutral gas mixture to form a plasma.

3. A particle producing apparatus as claimed in any of the preceding claims, wherein the vessel has a substantially constant cross-section coaxially along the length of the cathode structure.

4. A particle producing apparatus as claimed in any of the preceding claims, wherein the anode structure is formed of a plurality of anode units.

5. A particle producing apparatus as claimed in any of the preceding claims, wherein the first enriched surface is formed of basic or transition metals.

6. A particle producing apparatus as claimed in Claim 5, wherein the metal is an element with an atomic number greater than or equal to 40.

7. A particle producing apparatus as claimed in Claim 6, wherein the element is one of Zirconium, Palladium, or Erbium.

8. A particle producing apparatus as claimed in any of the preceding claims, wherein the first enriched surface is provided as a coating on the anode structure or cathode structure.

9. A particle producing apparatus as claimed in any of Claims 1-7, wherein the first enriched surface is formed integrally with the electrode that it forms at least part of the surface of.

10. A particle producing apparatus as claimed in any of the preceding claims, wherein the apparatus is configured such that, in operation, the apparatus produces nucleons.

11. A particle producing apparatus as claimed in Claim 10, wherein the nucleons are neutrons.

12. A particle producing apparatus as claimed in Claim 10, wherein the nucleons are protons.

13. A particle producing apparatus as claimed in Claim 12, wherein the apparatus further comprises fluid conducting structures proximate to the anode structure.

14. A particle producing apparatus as claimed in Claim 13, wherein the fluid conducting structures are composed of a metal alloy.

15. A particle producing apparatus as claimed in any of Claims 13 or 14, wherein the fluid conducting structures comprise corrugations along a length of the fluid conducting structures.

16. A particle producing apparatus as claimed in any of the preceding claims, wherein the first enriched surface covers a portion of the surface area of the anode structure or cathode structure such that in operation the produced particles have a localised flux with a predetermined geometry.

17. A particle producing apparatus as claimed in any of the preceding claims, wherein the first enriched surface is at least a part of the surface of the anode structure, and a second enriched surface is at least a part of the surface of the cathode structure, the second enriched surface being enriched with fusible isotope species.

18. A system comprising a plurality of particle producing apparatuses, wherein at least one particle producing apparatus is a particle producing apparatus as claimed in any of the preceding claims, the system being configured such that a single power supply can serve several particle producing apparatuses.

19. A system according to claim 18 comprising a plurality of particle producing apparatuses according to any of claims 1 to 17, wherein each said particle producing apparatus is arranged in a parallel configuration in which inner anode surfaces face an irradiation area are enriched thereby providing localised enrichment of a portion of the surface area of the anode such that in operation the produced particles have a localised flux with a predetermined geometry.

20. A Positron Emission Tomography (PET) scanner comprising a particle producing apparatus as claimed in any of Claims 1 to 10 and 12 to 19.

21. Use of the particle producing apparatus of any one of claims 1-10 or 12-17, or the system of claim 18 or claim 19, as a proton generator to produce PET medical radioisotopes.

22. Use of the particle producing apparatus of any one of claims 1-11 or 13-17, or the system of claim 18 or claim 19, as a neutron generator for:

(i) diagnostics and imaging or neutron activation applications, or

(ii) pulsed mode neutrons for detection of explosives and fissile material.

23. A method of manufacturing a particle producing apparatus according to any one of claims 1-17, the method comprising providing a particle producing apparatus of the inertial electrostatic confinement type, comprising:

a vessel;

an anode structure; and

a cathode structure;

wherein the vessel comprises a central axis, the anode and cathode structures are positioned such that the anode structure and cathode structure are substantially coaxial with the vessel, the anode structure having a mean distance from the central axis that is larger than the mean radius from the central axis of the cathode structure, the anode and cathode structures are substantially concentric along at least a part of their lengths and configured such that, in operation, an electric field is provided between the anode and cathode structures;

and wherein the method additionally comprises enriching at least a part of a surface of the anode structure or a surface of the cathode structure with deuterium and/or tritium by electrolysis with deuterated and/or tritiated water.

24. A method according to claim 23, wherein the step of enriching at least part of a surface of the anode structure or a surface of the cathode structure with deuterium and/or tritium comprises:

(i) filling the vessel with a Deuterated or Tritiated heavy water solution containing conductive salts for electrolysis,

(ii) inserting another cathode, and

(iii) applying a voltage to form hydride across the enriched surface.

25. A method according to claim 23 or claim 24, wherein chemical etching of the surface to be enriched is performed prior to the enriching step.