PLASMA CONFINEMENT SYSTEM AND METHODS FOR USE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/462,779, filed on February 23, 2017, the contents of which are incorporated herein by reference in their entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with government support under Grant Nos. DE-AR0000571, DE-FG02-04ER54756, and DE-NA0001860, awarded by the Department of Energy [DOE]. The government has certain rights in the invention.

BACKGROUND

[0003] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0004] Nuclear fusion is the process of combining two nuclei. When two nuclei of elements with atomic numbers less than that of iron are fused, energy is released. The release of energy is due to a slight difference in mass between the reactants and the products of the fusion reaction and is governed by $\Delta E = \Delta mc^2$. The release of energy is also dependent upon the attractive strong nuclear force between the reactant nuclei overcoming the repulsive electrostatic force between the reactant nuclei.

[0005] The fusion reaction requiring the lowest plasma temperature occurs between deuterium (a hydrogen nucleus with one proton and one neutron) and tritium (a hydrogen nucleus having one proton and two neutrons). This reaction yields a helium-4 nucleus and a neutron.

[0006] One approach for achieving nuclear fusion is to energize a gas containing fusion reactants inside a reactor chamber. The energized gas becomes a plasma via ionization. To achieve conditions with sufficient temperatures and densities for fusion, the plasma needs to be confined.

SUMMARY

[0007] A first aspect of the disclosure is a plasma confinement system that includes an inner electrode, an outer electrode that substantially surrounds the inner electrode, an intermediate electrode that faces the inner electrode, one or more first valves configured to direct gas from within the inner electrode to an acceleration

region between the inner electrode and the outer electrode, two or more second valves configured to direct gas from outside the outer electrode to the acceleration region, a first power supply configured to apply a voltage between the inner electrode and the outer electrode, and a second power supply configured to apply a voltage between the inner electrode and the intermediate electrode.

[0008] A second aspect of the disclosure is a method for operating a plasma confinement system. The method includes directing gas, via one or more first valves, from within an inner electrode to an acceleration region between the inner electrode and an outer electrode that substantially surrounds the inner electrode, directing gas, via two or more second valves, from outside the outer electrode to the acceleration region, and applying, via a power supply, a voltage between the inner electrode and the outer electrode, thereby converting at least a portion of the directed gas into a plasma having a substantially annular cross section, the plasma flowing axially within the acceleration region toward a first end of the inner electrode and a first end of the outer electrode and, thereafter, establishing a Z-pinch plasma that flows between the first end of the outer electrode and the first end of the inner electrode.

[0009] A third aspect of the disclosure is a plasma confinement system that includes an inner electrode, an intermediate electrode that substantially surrounds the inner electrode, an outer electrode that substantially surrounds the intermediate electrode, one or more first valves configured to direct gas from within the inner electrode to an acceleration region between the inner electrode and the intermediate electrode, two or more second valves configured to direct gas from outside the intermediate electrode to the acceleration region, a first power supply configured to apply a voltage between the inner electrode and the intermediate electrode, and a second power supply configured to apply a voltage between the inner electrode and the outer electrode.

[0010] A fourth aspect of the disclosure is a method for operating a plasma confinement system. The method includes directing gas, via one or more first valves, from within an inner electrode to an acceleration region between the inner electrode and an intermediate electrode that substantially surrounds the inner electrode, directing gas, via two or more second valves, from outside the intermediate electrode to the acceleration region, applying, via a first power supply, a voltage between the inner electrode and the intermediate electrode, thereby converting at least a portion of the directed gas into a plasma having a substantially annular cross section, the plasma flowing axially within the acceleration region toward a first end of the inner electrode and a first end of the outer electrode, and applying, via a second power supply, a voltage between the inner electrode and the outer electrode to establish a Z-pinch plasma that flows between the first end of the outer electrode and the first end of the inner

CLAIMS

1. A plasma confinement system comprising:

an inner electrode;

an outer electrode that substantially surrounds the inner electrode;

an intermediate electrode that faces the inner electrode;

one or more first valves configured to direct gas from within the inner electrode to an acceleration region between the inner electrode and the outer electrode;

two or more second valves configured to direct gas from outside the outer electrode to the acceleration region;

a first power supply configured to apply a voltage between the inner electrode and the outer electrode; and

a second power supply configured to apply a voltage between the inner electrode and the intermediate electrode.

2. The plasma confinement system of claim 1, wherein the intermediate electrode is substantially disc-shaped.

3. The plasma confinement system of claim 2, wherein the inner electrode comprises (a) a first end between a first end of the outer electrode and a second end of the outer electrode and (b) an opposing second end further comprising an assembly region within the outer electrode between the first end of the inner electrode and the intermediate electrode.

4. The plasma confinement system of any of claims 1 to 3, wherein the one or more first valves are positioned axially between a first end of the inner electrode and a second end of the inner electrode.

5. The plasma confinement system of any of claims 1 to 4, wherein the one or more first valves are positioned within the inner electrode.

6. The plasma confinement system of any of claims 1 to 5, wherein the two or more second valves are arranged outside of the outer electrode.

7. The plasma confinement system of any of claims 1 to 6, further comprising a first insulator between the outer electrode and the inner electrode.

8. The plasma confinement system of any of claims 1 to 7, further comprising an insulator between an end of the outer electrode and the intermediate electrode.

9. A method for operating a plasma confinement system, the method comprising:

directing gas, via one or more first valves, from within an inner electrode to an acceleration region between the inner electrode and an outer electrode that substantially surrounds the inner electrode;

directing gas, via two or more second valves, from outside the outer electrode to the acceleration region;

applying, via a first power supply, a voltage between the inner electrode and the outer electrode, thereby converting at least a portion of the directed gas into a plasma having a substantially annular cross section, the plasma flowing axially within the acceleration region toward a first end of the inner electrode and a first end of the outer electrode; and

applying, via a second power supply, a voltage between the inner electrode and an intermediate electrode to establish a Z-pinch plasma that flows between the intermediate electrode and the first end of the inner electrode, wherein the intermediate electrode is positioned at a first end of the outer electrode.

10. The method of claim 9, wherein the intermediate electrode is substantially disc-shaped.

11. The method of claim 10, wherein the Z-pinch plasma flows in an assembly region within the outer electrode between the first end of the inner electrode and the intermediate electrode.

12. The method of any of claims 9 to 11, wherein the one or more first valves are positioned axially between a first end of the inner electrode and a second end of the inner electrode.

13. The method of any of claims 9 to 12, wherein directing the gas via the one or more first valves comprises providing a first valve voltage to the one or more first valves followed by providing a second valve voltage to the one or more first valves.

14. The method of any of claims 9 to 13, wherein directing the gas via the two or more second valves comprises providing a third valve voltage to the two or more second valves followed by providing a fourth valve voltage to the two or more second valves.

15. The method of any of claims 9 to 14, wherein the Z-pinch plasma has a radius between 0.1 mm and 5 mm.

16. The method of any of claims 9 to 15, wherein the Z-pinch plasma has an ion temperature between 900 and 2000 eV and an electron temperature greater than 500 eV.

17. The method of any of claims 9 to 16, wherein the Z-pinch plasma has an ion number density greater than 1x1023 ions/m3 or an electron number density of greater than 1x1023 electrons/m3.

18. The method of any of claims 9 to 17, wherein the Z-pinch plasma exhibits sheared flow.

19. The method of any of claims 9 to 18, wherein the Z-pinch plasma exhibits a magnetic field of over 8 T.

20. The method of any of claims 9 to 19, wherein the Z-pinch plasma exhibits stability for at least 10 μs.