Back-streaming electron suppression for a D-D neutron generator

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1. Introduction

A high-flux movable D-D neutron generator is being developed at Korea Atomic Energy Research Institute. The fusion reactions take place in a neutron generator by accelerating deuterium into a titanium-coated water cooled copper target which contains deuterium [1,2].

D + D : 3He + n (2.5 MeV)

When deuterium ions hit the target, ionization occurs at the target surface and produce secondary electrons. The released secondary electrons accelerated away from the target by the negative electric potential and the back-streaming electron beam strikes the ion source or insulators inside the vacuum chamber. When the electron beam strikes the components, they may melt and bremsstrahlung x-ray emit. When the electron beam hit insulators, charge build-up occurs and those build-up charges make arc discharge. The back-streaming electrons will also bring a part of current drain on the acceleration high voltage power supply [3].

Figure 1 shows simulated back-streaming electron currents with no secondary electron suppression. So suppression of these back-streaming electrons is important for stable operation of a neutron generator. There are two typical methods for suppressing electrons; using magnetic fields produced by permanent magnets and using an electric field created by installing an electrostatic shroud (shielding case or plate).

If target is plane and magnets are aligned with opposite poles facing each other, creating magnetic field lines parallel with the target surface. The ejected electron spirals around the field lines and back toward the target surface. At this case, the electrons feel magnetic field and also electric field used to accelerate the deuteron ions. This net force results in an E x B drift, so an orthogonal drift of the electrons occur with respect to the magnetic and electric fields.

An electrostatic shroud is a device that suppresses back-streaming electrons by introducing an opposing electric field near the target surface. A shroud around or in front of the target is kept at a more negative potential, the resulting negative potential from the shroud repels electrons from the shroud and make go back to the target.

Usually the electric field suppression method is more effective than magnetic field suppression method because electric fields add energy to the electron while a magnetic field can only change its direction.

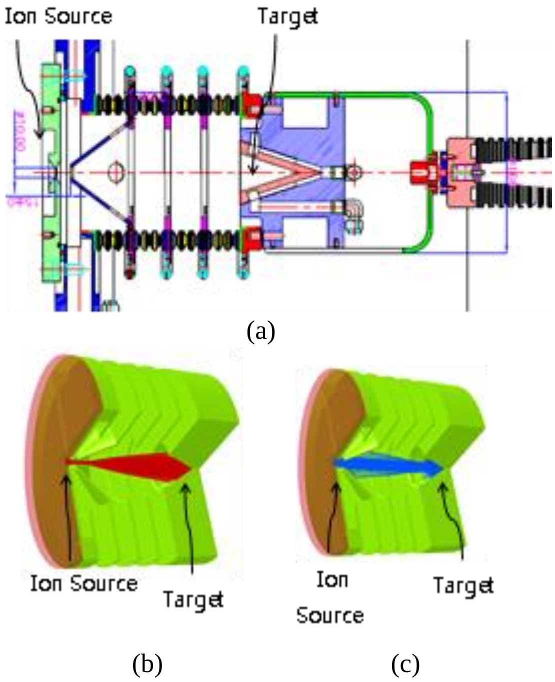


Fig. 1. Designed neutron generator and results of the OPERA simulation for the back-streaming electrons; (a) Cross-sectional diagram of the neutron generator (b) Ion beam currents (11.8 mA, beam energy 200 keV) (c) Back-streaming electron currents (9.9 mA, supposed emitting rate of the secondary electrons : 1).

In this presentation, the methods of the electric field back-streaming electron suppression are summarized and the design of it is introduced briefly.

2. Methods of the electric field suppression

For keeping a shroud around the target more negative than the target potential, active and passive methods could be used. An active method use direct biasing for shroud by an independent power supply floated on the acceleration power supply (Figure 2).

In the passive methods, usually a resistor is inserted between the shroud and the target (Figure 3). When ion beam hits the target, the current flow through the resistor and biases the target a positive potential compared to the shroud. The voltage drop V_d on the resistor R is determined by the beam current I_{beam} ;

$$V_d = I_{beam} \times R$$

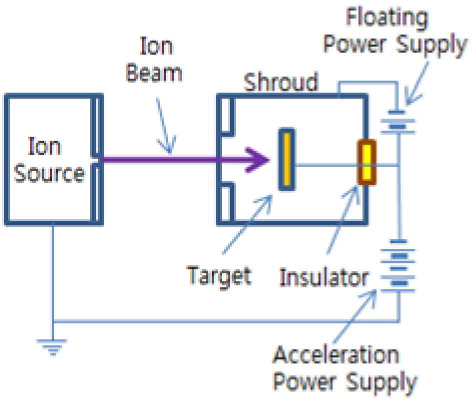


Fig. 2. Active biasing method.

Typical beam current varies and so the voltage V_d also fluctuates. If the voltage is high, that will make sparking between the target and the shroud. If the voltage is low, it can't suppress the secondary electrons.

Also the size of the resistor is very large to install in the neutron generator. For example, if maximum beam current is 50 mA, and optimum suppression voltage is 2 kV, the power on the resistor is 100 W [4].

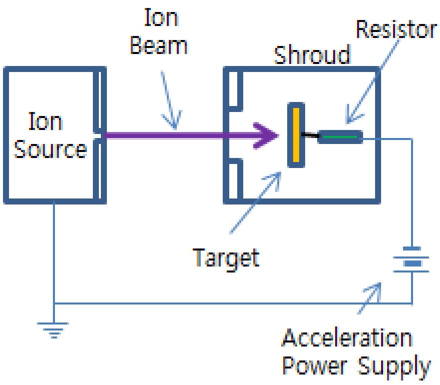


Fig. 3. Linear resistor method.

Instead of the resistor, using a varistor to replace the linear resistor also suggested recently (Figure 4). Varistor could provide constant negative voltage on the shroud whether the ion beam current varies or not. It seems to be attractive but the effect of the varistor is not proved yet [5].

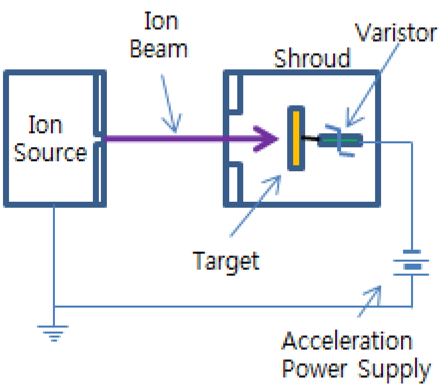


Fig. 4. Varistor method.

Zener diodes also could make negative potential on the shroud (Figure 5). In this case, besides them, high power resistor must be connected between target and ground to ensure a constant current flow through diode stack at all times [3].

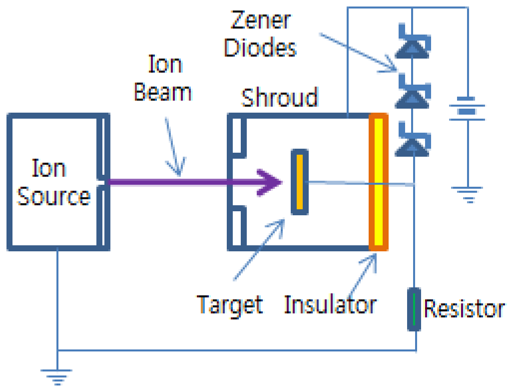
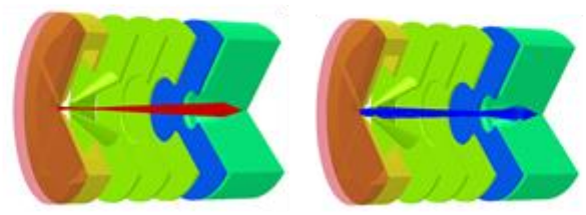


Fig. 5. Zener diode method .

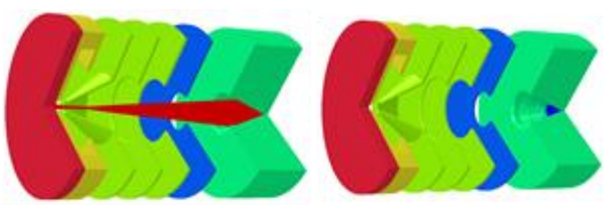
3. Design of the electric field suppression

In design a shroud, factors that affect the performance of it are voltage difference, the distance between the shroud and target, and beam window size.

If voltage difference is high, suppression efficiency is also high, but beam optics may affected. And there are some more possibilities of breakdown between the shroud and the target. The distance between the shroud and the target is long, the efficiency of the suppression is high, too. Figure 6 shows beam currents (left) and back-streaming electrons (right) according to the distance.



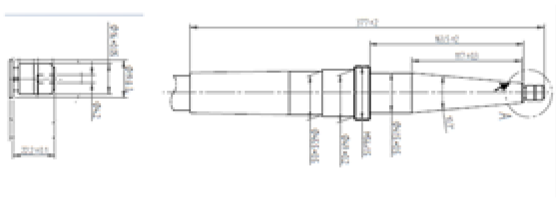
(a)



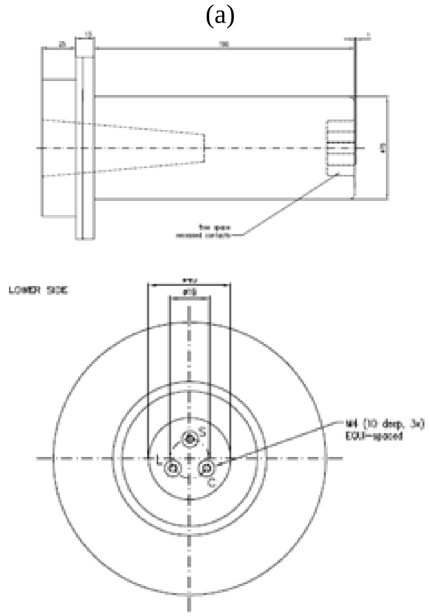
(b)

Fig. 6. Shape of the beam current and back-streaming electron current when (-) 202 kV negative bias is applied on the shroud where target voltage is (-)200 kV, beam window size is 50 mm; (a) the distance between the target and the shroud is 6 mm, (b) 66 mm.

Here we adopt the active suppression method. In the active suppression method, even if it is difficult to make an independent floating power supply for negative shroud potential but could make optimum conditions of shroud potential and beam optics. For connection the power supplies and shroud, target, commercial high voltage cable and receptacle will be use (Figure 7). One of the high voltage cable, produced by Claymount, model CA18-type R28 can be used up to 225 kVDC. It has three core wires in the cable and the maximum voltage between the wires is 2 kV.



(a)



(b)

Fig. 7. (a) High voltage connector (Claymount model CA18-type R28) and (b) receptacle (Claymount model CA18).

4. Conclusions

For stable operation of a neutron generator, suppression of back-streaming electrons is one of important factor. There are two typical methods for suppressing electrons; using magnetic fields and using an electric field created by negative electrostatic shroud. Usually the electric field suppression method is more effective than magnetic field suppression method. For keeping a shroud around the target more negative than the target potential, active and passive biasing methods could be used.

We adopt the active suppression method (Figure 8). In the active suppression method, even if it is difficult to make an independent floating power supply for negative shroud potential but could make optimum conditions of shroud potential and beam optics.

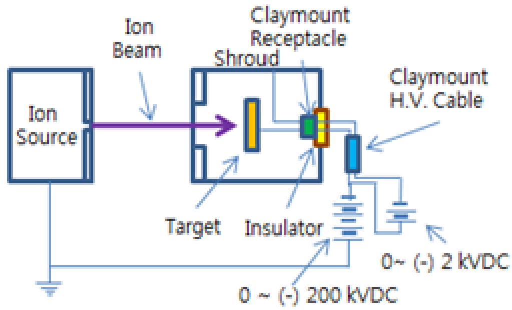


Fig. 8. Designed secondary electron suppression system.

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