Measurement of Electron Flood in Plasma Flood Gun Device

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1. Introduction

An ion implantation process is widely used as a process for manufacturing semiconductors and displays [1, 2]. In the ion implantation process, an ion beam is incident on the target and doped. In this process, the target is electrically charged with charges of the ion beam. These accumulated charges cause discharge and destroy the insulator, making it impossible to achieve the desired process. Therefore, a Plasma Flood Gun (PFG) device that extracts electron flood from plasma source is widely used to neutralize the charge accumulated by the ion beam [3-5]. In this study, we installed a PFG device using a magnetic multi-cusp and measured the electron flood extracted from the PFG device.

2. Plasma Flood Gun device

Our PFG device was built using a magnetic multi-cusp structure [6,7] and thermionic emission by a heated filament [8]. Electrons extracted from the plasma source move along the magnetic field formed through the coil, and then the low energy group of electron flood is measured through the biased mesh.

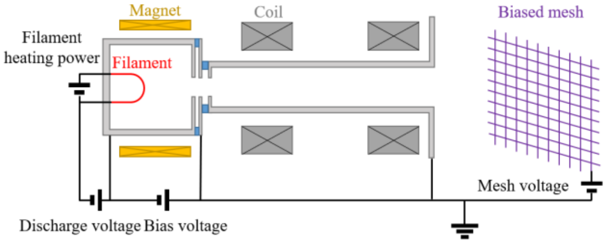

Fig. 1. Schematics of our PFG device including electrical circuit.

Ion beam column for ion beam implantation process is physically transparent, but traps electrons by its electric potential. Therefore, the ion beam column was simulated using a mesh that has a physical transparency close to 100% but can apply an electric potential to trap electrons. The mesh with positive voltage applied measures the number of low electrons that can be trapped to ion beam column. In a vacuum chamber with a base pressure of 10^{-6} Torr, Argon gas was used in the experiment and the extraction hole diameter of the source was made to be 10 mm. To observe the effects of various variables, we conducted experiments while changing three variables: discharge voltage, bias voltage, and gas flow rate. The current of each coil generating the magnetic field was fixed at 20 A, and magnetic field strength 240 G was formed at the center of each two coils. Also, the mesh voltage and discharge current were respectively fixed at 10 V and 1.5 A in all experimental conditions.

3. Experimental results and discussion

We observed the bias current and the mesh current according to the change of the bias voltage, which is the voltage applied between the source and the grounded chamber. The bias current proportional to the electron current extracted from the source increased as the bias voltage was increased. However, the mesh current that simulates the number of electrons trapped in the ion beam column had a maximum value at -2 V. As the bias voltage changed from -2 to -10 V, the mesh current compared to the bias current decreased significantly, so the mechanism of loss of electrons extracted from the source was strengthened. Since the gas flow rate and magnetic field in the experiment were fixed, it is presumed that the potential structure formed by the electron flood has a great influence.

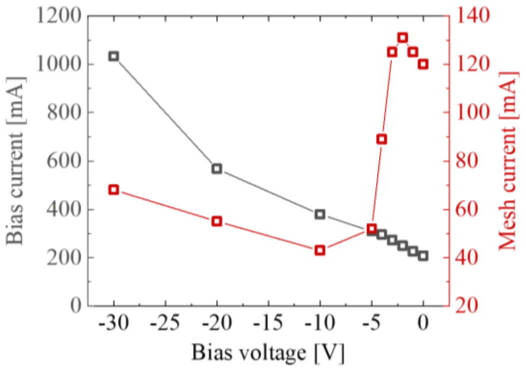

Fig. 2. Variations of bias current and mesh current according to bias voltage. The gas flow rate and discharge voltage of the experiment were 1.4 sccm and 50 V, respectively.

We conducted an experiment to understand the change according to the gas flow rate and discharge voltage. Both discharge voltage and gas flow rate showed results proportional to mesh current and bias current. The discharge voltage determines the energy of beam electrons emitted from the filament, and high energy beam electrons generate low energy secondary electrons through ionization reaction with neutral gas. An increase in the beam electron energy and gas pressure causes an increase in the ionization reaction. This can explain the increase in bias current because it induces the multiplication of electrons, that is, contributes to the increase in bias current compared to discharge current, which is the current of emitted electrons from hot cathode. Surprisingly, since the mesh current increased as much as the increased bias current, most of the low energy electrons due to the ionization reaction that contributed to the increase in bias current seemed to be trapped through the mesh.

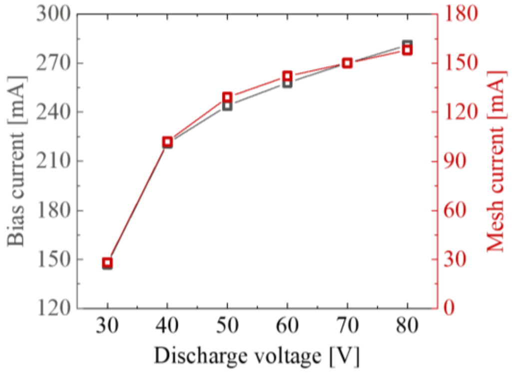

Fig. 3. Variations of bias current and mesh current according to discharge voltage. The gas flow rate and bias voltage of the experiment were 1.4 sccm and -2 V, respectively.

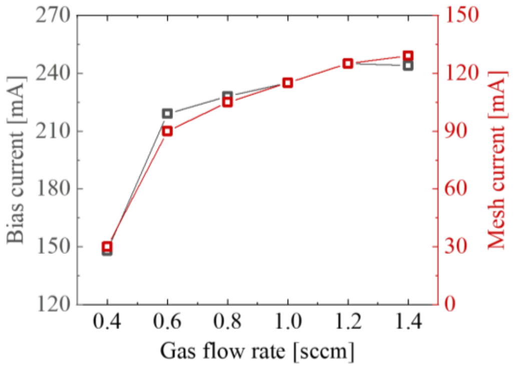

Fig. 4. Variations of bias current and mesh current according to gas flow rate. The discharge voltage and bias voltage of the experiment were 50 V and -2 V, respectively.

4. Summary

We constructed a PFG device using a magnetic multi-cusp plasma source. The mesh simulating an ion beam column that traps electrons with an electric potential has a maximum trapping current value at a bias voltage of -2 V, implying that the potential structure formed by the electron flood is greatly affected by the bias voltage. Also, as the discharge voltage and gas flow rate increased, the mesh current increased as much as the bias current increased. This implies that maximal production of low-energy secondary electrons at a given discharge current, or beam electron current, is critical to the performance of the PFG device.

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