A-I24 AAPPS-DPP2020

4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Development of sub-100 eV broad-beam ion source system

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Dry- and wet-based processes have been continuously developed to synthesize and modify materials with nanometer precision. Among these methods, plasma-based processes have been routinely used for material synthesis, modification, and characterization. Nanostructuring of material surfaces involves the use of precise ion energies in order to tailor specific material characteristics and responses. Depending upon the intended use, incident beams of ions with narrow energy distribution are preferred for different applications such as layer-by-layer deposition, shallow junction formation, and surface modification. This process becomes crucial as particle energy is around the 100 eV range.

While a glow discharge can be used for a majority of materials science and engineering applications, the broad energy distribution of the discharge may induce unwanted effects on the surface. The high-energy tail of the discharge, despite being almost negligible, can still make a major effect on the material property and performance especially when nanometer precision is critical. Usually, the energy distribution of the incident particles must be narrow to achieved the desired results. Hence, an ion beam with a narrow energy spread is preferred over typical glow discharges. Thus, development of low-energy ion beam systems has gained renewed interest due to its practical applications in material synthesis and modification.

Recently, a low-energy ion source system has been fabricated capable of extracting ion beams with energies around 100 eV (Fig. 1). The ion beam has a 4-cm diameter cross section. The source is composed of an ion reservoir, a two-electrode extraction system, and a downstream chamber. The ion source chamber can assume different multicusp magnetic field configurations. To produce a quiescent discharge, the source uses two thermionically-heated tungsten wires. The extraction electrode is made of tungsten wires arranged parallel to each other. The entire system is evacuated by a turbomolecular pump coupled to a rotary pump. The base pressure was below 10^{-3} Pa. Argon (Ar) gas was introduced into the system with operating pressures ranging from 0.3 to 1.2 Pa. Operating parameters such as discharge voltage, discharge current, and extraction potential were varied.

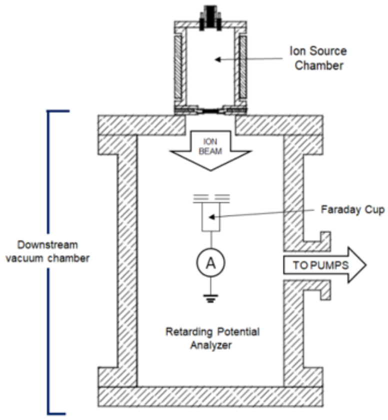

Figure 1. Schematic diagram of the ion source system.

A custom-built Langmuir probe was inserted in the ion source and the plasma characteristics such as electron temperature, plasma density, and plasma potential were determined from the I-V curve measured by the probe. In addition, a custom-designed retarding potential analyzer was used to determine the energy distribution of the Ar ions in the downstream region provided the ions are singly ionized. An example ion energy distribution function is shown in Fig. 2.

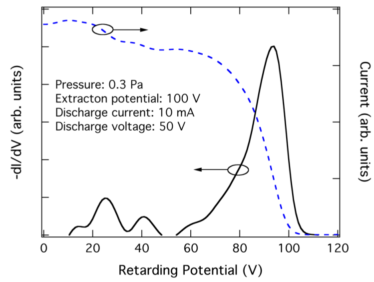

Figure 2. A representative IEDF of an Ar ion beam.

Acknowledgments
The author acknowledge the Department of Science and Technology Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST PCIEERD) Project No. 03058.

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