Ion and fast atom beams in an End-Hall ion source: a numerical study

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An End-Hall ion source is a cylindrical magnetized device of few centimeters in length able to generate an ion beam with a current of typically 1 A and ion energies in the range of 100 eV. The large divergence of the generated ion beam makes this very simple source suitable for ion assisted deposition processes without acceleration grids. At this conference, a self-consistent two-dimensional quasi-neutral model of an end-Hall ion source will be presented and used to understand the parameters controlling the characteristics of the extracted beam when a point source is used as electron emitter.

Hall-effect ion sources can be classified in the gridless ion sources category, since the extraction of the ion beam does not involve grids. In fact, the use of an external magnetic field, which is generally generated by magnets or coils, across the discharge current, lowers the local electron conductivity across the magnetic field lines. This lowering of the electron conductivity leads to the formation of gradient in the plasma potential in the region of strong magnetic field. Ions are accelerated and extracted from the source by the gradient of plasma potential. The advantage of the gridless ion source, relative to the gridded one, is that the extracted ion beam current is not limited by the space charge (Child-Langmuir law's); and much larger ion current can be extracted for same device dimensions.

Two main categories of Hall-effect ion sources exist, both with a cylindrical geometry that lets the ExB electron drift in the azimuthal direction. The magnitude of magnetic field strength (~ 100 G) is chosen to strongly magnetize electrons but not ions. The first category has been extensively studied and used since the 1970's for space propulsion systems [1]. The Hall Effect (HET) or closed-drift thruster is a device where the plasma is generated in an annular region (channel between two concentric, dielectric cylinders). The discharge voltage is applied between the anode (through which the gas is injected) and the cathode located outside the thruster channel. The magnetic field configuration whose direction is mainly radial (perpendicular to the channel walls) is designed to minimize the divergence of the ion beam. HETs have also been used for deposition [2], and polymer processing [3], [4]. The low divergence of the ion beam offers the disadvantage of a relatively small area of surface treatment. Nevertheless, the ion beam energy in the range of 200 eV can exceed the requirements for the industry of ophthalmic coatings where an ion beam energy below 100 eV is necessary for coating materials [5]. The second category of Hall-effect ion sources is the End-Hall (EH) ion source where the geometry of the anode is conical, and the magnetic field lines are parallel to the anode. The gas is injected at the rear of the source through a back plate (see Fig. 1). EH ion source characteristics are suitable for Ion Assisted Deposition – IAD (also referred to Ion Beam Assisted Deposition - IBAD), etching and deposition [6]. The advantages of EH ion sources are the following: 1) the high current density leads to high deposition rate; 2) at ion energies in the range of 100 eV, the sputtering of coating materials is relatively low (preventing destructions and/or changes in the optical thin film properties) and a low (preferable) temperature of the substrate can be achieved; 3) a highly divergent ion beam induced by the device geometry and magnetic field lines shape can be achieved to treat large material surfaces.

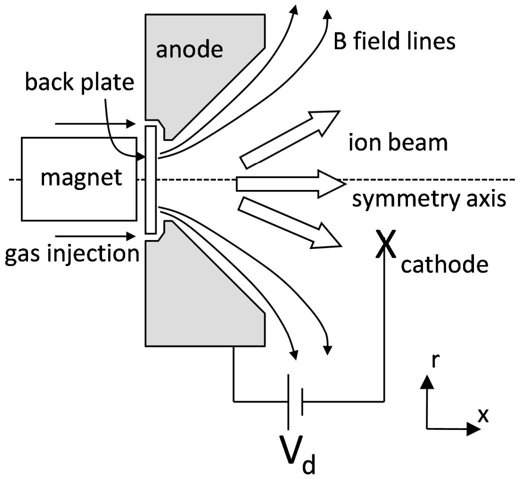

Fig. 1: Geometry of the End-Hall ion source.

A two-dimensional hybrid model with a fluid description of electrons and particle description for ions and neutrals has been developped [7]. This model includes the ion source and the plume outside the conical channel. The 2D model results on the parameters and mechanisms that control the characteristics of the ion and fast atom beams generated by the EH ion source will be discussed. Comparisons with experimental results will be also shown.

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