Impedans PLASMA MEASUREMENT

Observation of two-temperature electrons in a sputtering magnetron plasma*

STUDY:

Understanding electron transport in sputtering magnetrons is essential for the understanding of the operation of these devices, which are used for sputter etching and thin-film deposition. Several recent experiments have used Langmuir probes to investigate the electron component of a magnetron plasma and mechanisms of electron transport. For instance, Rossnagel and Kaufman reported that the electron temperature and density decrease with distance from the cathode, and noted the presence of a high-temperature electron tail under certain conditions, such as in a He discharge.

In this study, the authors investigate the origin and significance of this electron tail, fitting Langmuir probe data with a two-temperature model.

METHOD

The authors operated an 11Pa He discharge with a copper cathode at a discharge voltage of – 300Vdc. The discharge current in these conditions was found to be 0.32 A, which is a current density at the cathode of 290A/m2 averaged over a collection area of 11cm2.

A cylindrical Langmuir probe placed parallel to the cathode was used to diagnose the discharge. The tungsten probe tip features a diameter of 0.25 mm and a length of 3.5mm. The probe bias Vprobe was given by a programmable bipolar power supply, and the electron current to the probe ie-probe was measured with a resolution of 1 μA

The probe characteristics shows the electrons are non-Maxwellian and were analysed by separating the current below the plasma potential and fitting it to a low temperature Maxwellian and a high temperature Maxwellian. This analysis gives the best fit of the current to a plasma containing two separate electron groups at different temperatures.

FINDINGS:

Outside the magnetic trap, probe characteristics with the signature of two electron temperatures were observed, as plotted below:

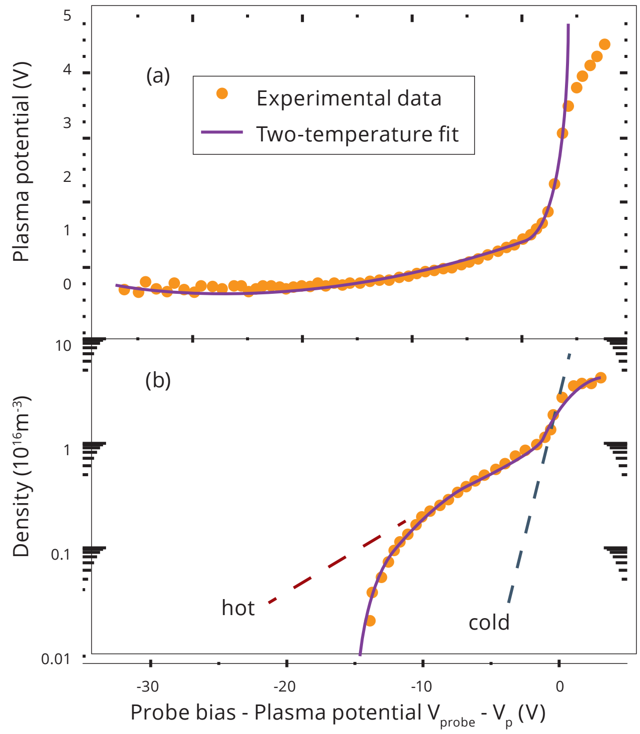

Figure 1: Measured two-temperature probe characteristic taken at r=1.2cm, z=2.5cm. In **(a)** the electron current is plotted on a linear scale and in **(b)** on a logarithmic scale. The two slopes shown by the dashed lines in **(b)** are due to the presence of hot and cold electon components. The solid line gives the fit to a two temperature model for T_e^{cold}=0.47ev, n_e^{cold} = $2.4x10^{16}m^{-3}$, T_e^{hot}=6.8eV and n_e^{hot}=$0.68x10^{16}m^{-3}$.

The axial plasma potential profile, hot and cold electron density profile and temperatures of the hot and cold temperatures are then shown:

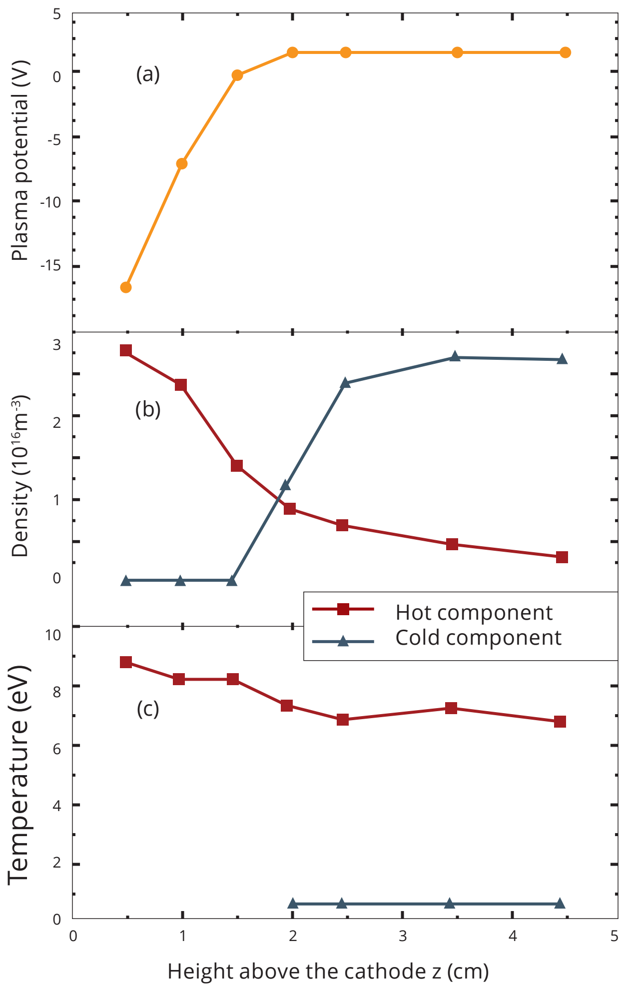

Figure 2 (a) Plasma potential, **(b)** electron density, and **(c)** electron temperature plotted against the height above the cathode, z. There is a steep potential gradient (ie large electric field) in the magnetic trap. The hot electron density is largest in the magnetic trap and decreases as z is increased. In contrast, the cold electron density is large outside the trap and negligible inside. The average hot electron temperature is 7.6eV, while the average cold electron temperature is 0.50eV.

Using Langmuir probes in a – 300Vdc, 0.32-A, I1-Pa He discharge, the authors of this study observed a hot electron component ($T_e^{hot} \approx 7.6$ eV) in a sputtering magnetron's magnetic trap next to the cathode, which leaks out of this trap to the anode. The least energetic electrons in this component are reflected by the anode sheath and become trapped in the plasma, forming a cold electron component ($T_e^{cold} \approx 0.50$ eV). The authors also found that the density of the cold electrons outside the trap was nearly as large as the total density in the trap.

REFERENCES

* TE Sheridan, MJ Goeckner and J Goree. Department of Physics and Astronomy, The University of Iowa, Iowa City. J. Vac. Sci. Technol. A 9, 688 (1991); http://dx.doi.org/10.1116/1.577344

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