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CHARACTERIZATION OF A HIGH PRESSURE CYLINDRICAL CATHODE/MOVEABLE ANODE SOURCE

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Cylindrical tube discharges are used in a wide variety of applications in plasma processing and show a promising approach to technology advancements in biomedical applications [1]. High pressure tubular cathode plasmas with molecular (e.g. C_2H_2, CH_4) or atmospheric gases have potential applications in 3D thin film coatings [2], plasma gas sensors [3] and nanoparticle generation. Determining the optimal design for reliable operation, ignition and control requires considerable development for each application. Here we present aspects of electrical and optical characterisation of a plasma device with potential in all three applications areas.

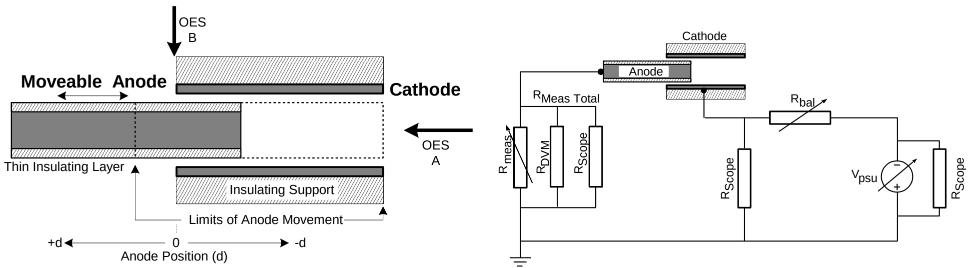

Figure 1: Source schematic and electrical circuit

The plasma source Fig (1) was DC driven and operated at static argon pressures >100mTorr. It consists of a 10mm long stainless steel cylindrical tube cathode of 2.6mm OD & 1.8mm ID, housed in an insulating support. The anode is a 1mm OD stainless steel rod with a thin insulating layer on the outer curved surface. This reduces long path breakdown and spatially defines the plasma by restricting the current path to the exposed metal front face. A linear actuator is used to give accurate remote control of anode position (d), and thus gap. Axial resolution of +/-12μm is achievable over a wide range (1mm > d > 10mm).

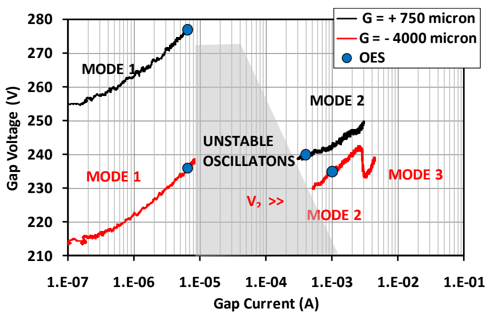

Figure 2: Discharge Modes

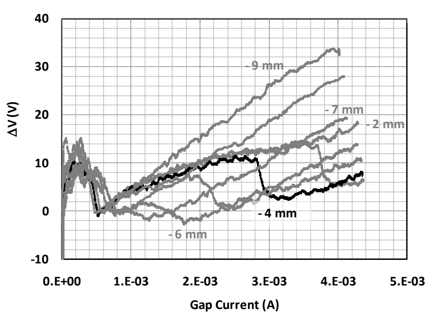

Figure 3: Mode 3 onset

The VI measurements Fig (2) clearly show distinct modes of discharge operation. At gap current Igap < 10 μA, VI curves exhibit positive slopes differing only by a shift in breakdown voltages for external and internal anodes [4], and are shown as Mode 1. For 10 μA < Igap < 300 μA, an unstable oscillating regime [5] is observed. Above this current, stable operation is possible in Mode 2, where Igap rises with Vgap for both anode positions.

However, the internal anode VI characteristic exhibits a sudden change at ~ 3 mA. This onset of "Mode 3" occurs at progressively lower gap currents as the anode position approaches the far end of the cathode (Fig (3)). Thus Mode 3 is associated with the cathode end and Mode 2 can reach all along the cathode, its length a function of current and/or voltage.

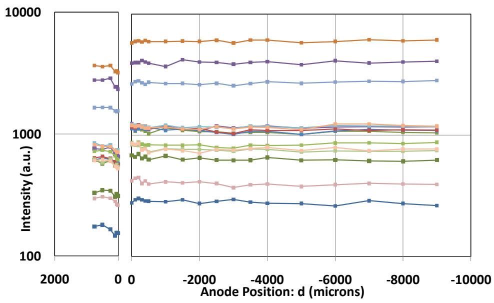

Figure 4: Line Intensities vs Anode Position

OES of Mode 2 discharges were performed at fibre optic positions A and B, Fig (1), for a wide range of d. Gap currents were 0.4 mA (d > 0) and 1.0 mA (d < 0). The total intensity at position A (I_A) was near constant for all d whereas the intensity at B (I_B) dropped markedly for 750 μm > d > **-** 500 μm. I_A ~ 3 I_B at maximum I_B. Individual argon line intensities for this range of d are shown in Fig (4). Again there is very little variation in Mode 2 for internal anode positions. External anodes display similar argon emission line ranking but with a drop in intensity for anode positions close to the cathode. The difference in intensities between external and internal data is because of the increase in Igap.

Visual observation of the discharge geometry and extent is limited to the cathode face at d=0 mm, however these do offer some indication of discharge geometries for external anodes. In Mode 1 an annular-cone shaped discharge is visible linking the anode and cathode faces/edges and in Mode 2 a disk shaped discharge is seen at the entrance to the cathode. The Mode 2 VI characteristics, Fig (3), suggest that the discharge can extend through the cathode, and one might expect it to be visible at the cathode face at d = **-** 10 mm. As previously noted, this face is not visible.

From these observations we can propose likely discharge geometries inside the cathode tube where direct observation is not possible. For Igap < 10 μA, we assume the Mode 1 anular cone discharge becomes ring shaped for d < 0 mm. The disk seen for Igap > 300 μA, Mode 2, is assumed to extend longitudinally with increasing Igap, towards the cathode face at d = **-**10 mm where the transition to Mode 3 may occur. Possible explanations of the observed discharge behaviour are being considered including: longitudinal and radial diffusion of charged particles (initial calculations suggest electron densities of ~10^{14} cm^{-3}) and the formation of a virtual anode. Further characterisation and investigations into several of these interesting source aspects, including: OES of Mode2/3 onset, determination of excitation [6,7] and gas temperature, the use of a perforated cathode tube for radial OES access are ongoing. Other configurations including geometry and drive will allow comparative studies.

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