Design and characterisation of a plasma chamber for improved radial and axial film uniformity using Impedans' Langmuir probe system

INTRODUCTION

In the ever-developing field of fibre-reinforced composites and other fibre-based material technologies, there is a need to develop methods for modifying the fibre surfaces to improve a wide range of application-specific properties such as adhesion, surface functionalisation, biocompatibility, and wettability. The development of plasma processing for fibre-based materials has been an active field of research for over 40 years.

At low plasma powers, the process can modify the surface chemistry without changing the properties of the bulk material of the fibre. Plasma treatments have also become more popular for industrial use in the last decade, due to environmental concerns which have limited the use of chemical surface treatments with large waste streams.

EXPERIMENTAL SETUP:

The plasma chamber consists of a stainless-steel ISO-200 4-way cross shown in figure 1. The front and rear flanges held two aluminium disc electrodes (D = 170 mm) inside the reactor. The custom-built feedthroughs allowed positioning of the electrodes within the chamber by moving the stainless-steel rods. The plasma was ignited by 13.56 MHz radiofrequency (RF) generators connected to each electrode.

Langmuir probe measurements were performed using a [Langmuir Probe System] with a tip length of

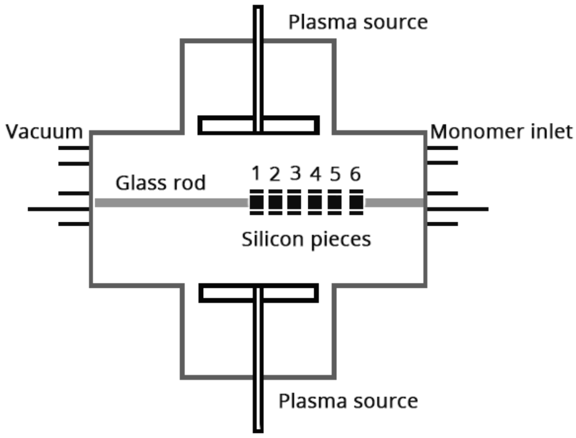

Figure 1. Schematic of the experimental setup.

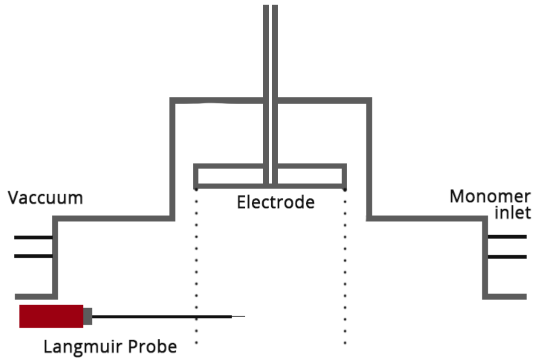

Figure 2. Top view of Langmuir probe setup within the plasma chamber.

with 11 mm and a drive length of 300 mm (Impedans Ltd., Dublin, Ireland). The probe travelled from the outside edge of the chamber to the centre of the chamber along the same proposed path as the fibres, as illustrated in figure 2. The first measurement was taken 50 mm inside the chamber, 200 mm from the centre of the electrode, and then every 20 mm up to the centre of the electrode (x = 0 mm).

As the deposition of acrylic acid coatings would interfere with the probe properties, an air plasma was used to evaluate the plasma characteristics at a constant flow rate of 2 sccm. The electron flux was characterised to determine the influence of plasma power and distance from the electrode on electron density. Three plasma powers (5, 20 and 50 W) at four distances between the Langmuir probe and electrode (15, 30, 40 and 80 mm) were analysed.

RESULTS:

Due to phase differences between the RF sources setting up a beat pattern in the plasma and the knock-on effect this would have on the Langmuir probe data, measurements were performed on a single electrode configuration. For all powers and distances of 30–80 mm between the probe and electrode, the electron flux increased with the decrease in the axial position. The electron flux also increased with the increase in the power for all distances from the electrode. The greatest electron fluxes were observed for distances of 30 and 40 mm from the electrode, and lower fluxes were observed at 80 mm from the electrode.

A plasma sheath region could be observed through the view port into the chamber, and at a distance of 15 mm the Langmuir probe appeared to be partially inside the plasma sheath region. The size of the plasma sheath is directly related to the applied power and pressure. An increase in power and a decrease in pressure results in a greater electron mobility and a larger sheath region. Such behaviour was observed for a distance of 15 mm from the electrode, where the electron flux decreased with the decrease in the axial position from 140 to 80 mm. These decreases were greater as the power was increased from 5 to 20 W and then 50 W.

For a plasma power of 5 W, the electron flux nearest the chamber wall, at an axial position of 200 mm, was close to zero for all distances between the probe and the electrode. While at the centre of the plasma a maximum of approximately 90 A/m^2 was found at 30 and 40 mm with the flux at both 15 and 80 mm having dropped to approximately 50 A/m^2. These values all rise as the power is increased with the maximum flux (approximately 200 A/m^2) being at 30 mm with 50W.

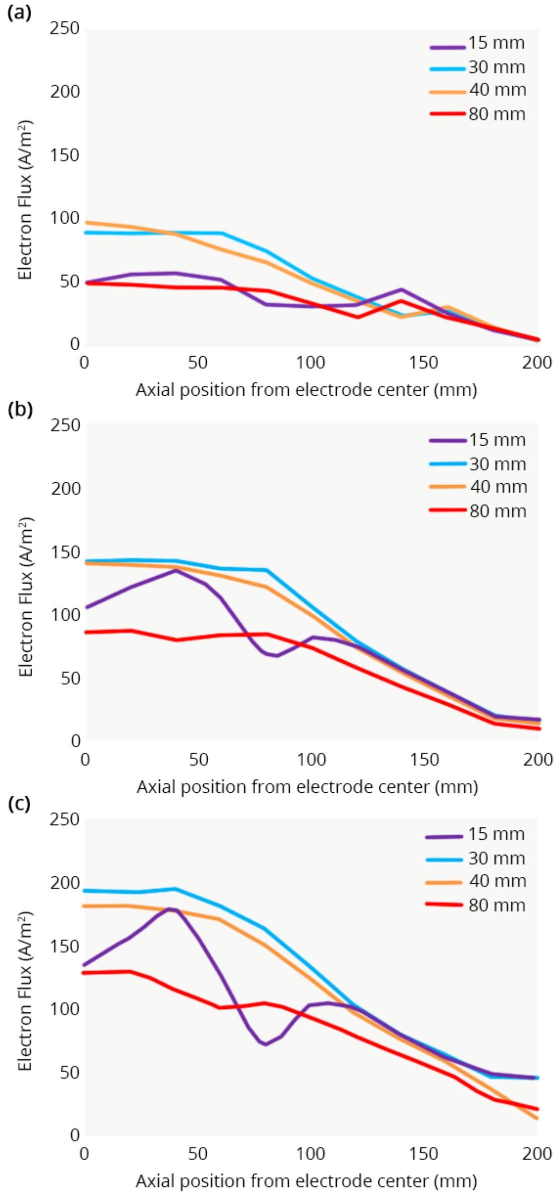

Figure 3. Electron flux measured using the Langmuir probe for RF powers of (a) 5 W, (b) 20 W and (c) 50 W at distances of 15, 30, 40 and 80 mm from the electrode.

CONCLUSION:

The Langmuir probe measurements provided insight into the electron density distribution within the chamber. The electron flux showed a plateau region directly in front of the electrode and decreasing electron flux away from the electrode toward the chamber walls. For distances from the electrode of 30–80 mm and shorter probe travel distances, the electron flux decreases indicate reduced electron collisions further away from the electrode. The decrease in the electron flux as the probe travels closer to the electrode at 15 mm is due to the probe traveling through the plasma sheath region, which is deficient of energetic electrons.

REFERENCE:

*Radjef, R. et al, “Design and characterisation of a plasma chamber for improved radial and axial film uniformity”

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