Film deposition on pin-backed glass dielectrics of pin-to-plate dielectric barrier discharges in Ar-hexamethyldisilane

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Abstract: The paper reports results of experimental and modeling studies on plasma deposition of thin films from ambient-pressure Ar-hexamethyldisilane discharges in pin-to-plate setups with a dielectric plate covering the pin. The analysis of the measured radial film thickness profiles at the dielectric surface together with results of spatially two-dimensional fluid-Poisson modeling reveal the mechanisms responsible for the film deposition.

1. Introduction

New insights into physico-chemical mechanisms of plasma-activated chemical vapor deposition (PACVD) of thin films from ambient-pressure dielectric-barrier discharges (DBDs) are enabled by DBDs with short gas residence times, largely preventing contributions from neutral plasma-chemical products to film formation and minimizing gas-phase compositional changes [1-3]. Pin-to-plate DBD setups with a glass plate covering the pin as the single barrier were used to study film formation from small admixtures x_M of hexamethyldisilane (HMDS) in Ar on the glass plate's surface facing the conducting plate. The report focuses on the analysis of peculiar radial film profiles to identify the discharge mechanisms responsible for their formation.

2. Methods

The principal experimental setup was already described in ref. [1]. In this work, the length L of the powered pin was 1, 3, and 50 mm, respectively, the gap width 2.5 mm, and the borosilicate dielectric's thickness 1.25 mm. Ar-HMDS mixtures with $50 \le x_M/\text{ppm} \le 2000$ were flowing through the gap with an average velocity $v_{av} = 50$ cm/s. The amplitude of the applied sinusoidal voltage (19 kHz) was 500 V above the extinction voltage, $U_{a,0} = U_{ext,0} + 500$ V. Experimental investigations of radial film profiles at the dielectric surface were performed by means of profilometry and infrared spectroscopy. In addition, a time-dependent, spatially two-dimensional (2d-t) fluid-Poisson model considering a 13-species reaction kinetic model for the Ar-HMDS mixture implemented within a cylindrical coordinate system was employed for the modeling of the DBD source.

3. Results and Discussion

Film thickness profiles $d(r,L)$, normalized to $d(0,L) = 1$, are shown in Figure 1 for three pin electrode lengths. It is found that these profiles apparently consist of two symmetrical bell-shaped profiles with significantly different full widths at half maximum. Analysis of time-integrated cation fluxes towards the glass surface during one voltage period obtained by 2d-t modeling indicates that these symmetrical profiles may correspond to two discharge modes, differing in their time-integrated radial distribution of ion fluxes to the dielectric's surface. Infrared spectra taken at various radii along the deposit show significant differences. This suggests different mechanisms at work during film formation by deposition and neutralization of incoming cations.

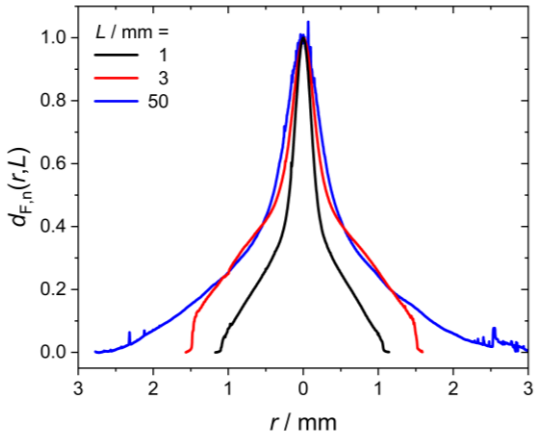

Fig. 1. Normalized film thickness profiles $d_{F,n}(r,L) \equiv d(r,L)/d(0,L)$ on the glass dielectric for different lengths L of the powered pin electrode, obtained with 50 ppm HMDS in Ar and $U_{a,0}$ = 2.9, 2.2, 1.7 kV for L = 1, 3, 50 mm.

4. Conclusion

A pin-to-plate DBD with a glass plate covering the pin as the single barrier in Ar-HMDS fed discharges is used to study the film formation on the glass plate's surface. Radial film thickness profiles and calculated cation fluxes at the glass surface indicate that deposition occurs by two different mechanisms, likely associated with different discharge modes.

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References

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