Insight into plasma polymerization with a significant contribution of etching to the deposition process

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Abstract: Understanding the role of substrate geometry is crucial for optimizing deposition on non-planar substrates. We investigated the altered transport of film-forming species into two 3D geometries, cavities with a slit opening and a cavity with an undercut, to assess the contribution of ions and to estimate the sticking coefficient of depositing species for the $CO_2/C_2H_4/Ar$ gas mixture.

1. Introduction

Plasma polymer deposition processes are well-studied and optimized for flat substrates. The problem arises when non-planar samples, often required, for example, in bioapplications, need to be coated. An important aspect that must be considered is the substrate's geometry, which can limit direct gas flow and, therefore, the penetration and diffusion of plasma deposition into the structure. Michlíček [3] introduced a concept of understanding the penetration depth of plasma polymerization using different micro and macroporous substrates. With a numerical model, they concluded that there are two film-forming species in the deposition process of amine plasma polymers from Ar/cyclopropylamine gas feed, and determined their sticking coefficients. Interestingly, the aspect ratio of the well structures mainly impacted the deposition rate, whereas the film chemistry was affected only moderately.

2. Methods

For the current study, we selected the deposition in symmetric capacitively coupled plasma (7 Pa) from two CO_2/C_2H_4 mixtures (2:1 and 6:1) that significantly differ by the contributions of film forming and etching processes. The extremely low deposition rate for the CO_2/C_2H_4 = 6:1 reveals that these plasma conditions are close to the balance between the film deposition and etching [2]. We investigated the altered transport of film-forming and etching species into two 3D geometries, cavities with a slit opening and a cavity with an undercut. The details of the experiments are in [3].

3. Results and Conclusion

We observed that the deposition rate inside the cavities with a slit was higher than outside, especially for the CO_2/C_2H_4 = 6:1 mixture, in which etching during the deposition is quite significant (Fig. 1). Thus, the etching species must be lost on their trajectories inside the cavity. We attempted to reproduce the deposition profiles by Monte-Carlo simulations with several types of species.

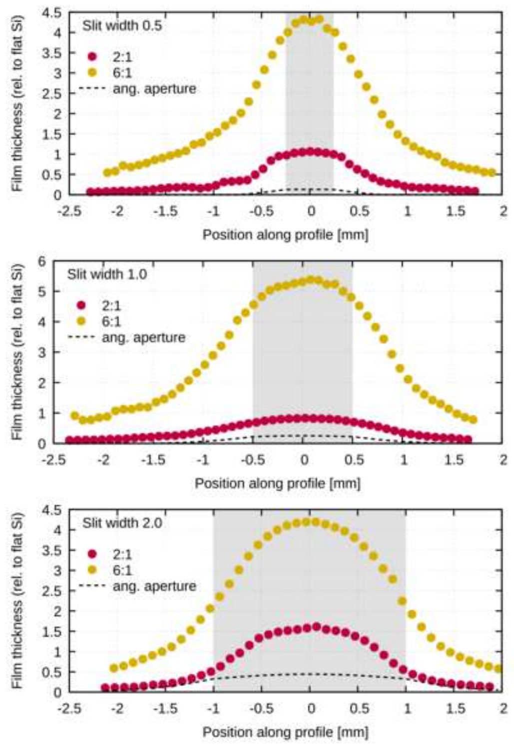

Fig. 1. Deposition thickness profiles in cavities with slit openings 0.5, 1.0 and 2.0 mm normalized to the film thickness on the flat Si. The data obtained by ellipsometry for $CO_2:C_2H_4$ = 2:1 and 6:1 are compared to the thickness profile that is theoretically expected by a geometrical shielding of thermalized particles depicted as a view angle at a given point (``angular aperture"). The slit widths are shown as shaded areas.

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References

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