Influence of the substrate on the properties of the thin film deposited from a dielectric barrier discharge in HMDSO/N₂

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1. Introduction

Using an atmospheric pressure dielectric barrier discharge process is becoming an efficient way to deposit various kinds of thin films. Particularly, the protection against corrosion thanks to the deposition of organosilicon films is one of the most interesting aimed applications with such processes.

A DBD in a HMDSO/N₂ mixture (15 ppm of HMDSO) was used to deposit a thin film on two different substrates namely glass and copper. The influence of the substrate on the properties of the deposited coatings as well as the gas phase was studied.

2. Experimental setup

The reactor was designed in a plane-to-plane electrode geometry. Two glass plates, 1 mm thick, were used as dielectric material and placed on each electrode. The inter electrode distance was fixed at 1.0 mm. The deposition process was operated in a static mode. The external voltage was fixed at 7.0 kV, and the frequency at 13 kHz. The dissipated power was measured at 1.0 ± 0.1 W/cm², with Lissajous method [1]. The first substrate used was a 15 µm thick sodocalcic glass, the roughness of which was around 80 nm. The copper substrate was electrodeposited and was 105 µm-thick with a roughness of about 1.3 µm. The thin films were characterized by scanning electron microscopy (SEM), FT-IR, XPS and nanoSIMS-50.

3. Results

The deposition process was firstly realized on the glass substrate. The discharge operated in a Townsend regime, with the presence of only a few streamers, randomly distributed on the surface. The thin film was observed by SEM. The result is presented in figure 1.

Fig.1 Thin film deposited on the glass substrate (x10,000)

With the same experimental conditions, the film was deposited on the copper substrate where much more streamers were present in the discharge. Moreover, their distribution was fixed; each filament seemed to initiate at the same position on the surface. The SEM picture of the film is presented in figure 2.

Fig.2 Thin film deposited on the copper substrate (x1,000)

SEM analysis showed brighter areas, the diameter of which was around 50 µm. By magnifying the photographs a specific disposition was observed as displayed in figure 3.

Fig.3 Thin film deposited on the copper substrate (x10,000)

A nanoSIMS-50 analysis showed that the substrate was covered by a SiOCN film, with the presence of copper in the brightest areas (Fig.3). So the substrate was covered with an organosilicon film that contained holes at positions where streamers were initiated. Indeed the holes were apparently randomly distributed in the area exposed to the streamer.

By reducing the gap to 0.5 mm, the discharge established was always in the Townsend regime and no holes were observed in the deposited coating, whatever the substrate was (copper or glass).

4. Conclusion

The presence of holes in the film is due to the development of streamers in the discharge, which remain fixed at the same positions on the copper substrate. We correlated these observations with the results obtained with OES, reported in [2]. The phenomenon responsible for the production of these holes, the size of which was about a few tenths of micrometer still needs to be determined, as the streamer diameter is 50 times bigger.

5. References