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Investigation of the mechanisms involved in one-step nanocomposite thin films synthesis by direct pulsed liquid injection of a colloidal solution in a low-pressure plasma

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Abstract content

Nanocomposite thin films, consisting of nano-objects imbedded in a thin film matrix, have raised growing attention in recent years, due to the great tunability of their properties. Several attempts have been made to provide a reliable process for the growth of nanocomposite thin films. A number of these attempts involve the injection of a liquid nanoparticles-containing colloidal solution in a plasma environment, like atmospheric pressure DBD[1]. Previous research in our lab led to the development of a safe-by-design one-step process coupling low-pressure PECVD and direct liquid injection of a nanoparticles-containing colloidal solution[2]. In this hybrid process, a TiO_2 colloidal solution is injected as droplets in an O_2/HMDSO inductively coupled RF plasma, employed for the growth of the SiO_2 matrix of a nanocomposite thin film. The sudden pressure increase (typically from 3 to 15 mTorr) and new chemical environment brought by the pulsed injection of liquid (pulses of 1 ms with a frequency of 1 Hz) leads to abrupt changes in the plasma parameters, which in turn affects the droplets' evaporation. However, the influence of the different interactions between plasma, solvent and nanoparticles on droplets evaporation is yet to be understood. The aim of the present work is to gain insight on the modifications of the plasma composition upon the injection of the colloidal solution. For this purpose, the plasma is monitored by in situ time-resolved optical emission spectroscopy (OES), actinometry is used to track the time variation of concentration of some of the plasma species (O, H, CO, OH), and film growth is followed through in situ spectroscopic ellipsometry. We investigate the effect of colloidal and solvent-only solutions on interactions involved in the hybrid process, depending on various injection parameters: quantity of liquid injected, frequency of injection, solvent volatility, and concentration of nanoparticles in the colloidal solution. Preliminary results show that injection-induced pressure increase hinders HMDSO fragmentation and therefore SiO_2 deposition, which creates alternating deposition periods for SiO_2 and TiO_2-NP. In addition, the use of solvent of higher volatility seems to favor faster evaporation of the droplets in the plasma.

References

[1] Profili et al. 2016 Plasma Process. Polym. 13, 981 [2] Mitronika et al. 2021 J. Phys. D: Appl. Phys. 54 085206