Nanocomposite materials synthesized with an axial DBD plasma jet source with lateral injection

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Abstract: In this contribution, we report on the utilization of an axial DBD plasma jet with lateral injection for the production of SiOCx-Co-based nanocomposite materials with independent control of the nanocomposite phases composition. The results show that the carbon content can be controlled by the oxygen injection, while the Co-based nanoparticles composition is depending both on concentration and flow.

1. Introduction

Atmospheric pressure plasma jets (APPJ) have been copiously studied in the last decades due to their characteristics in terms of discharge regimes, reactive species, interaction with liquids and material synthesis [1, 2]. In particular, nanocomposite materials synthesized using APPJ represent a promising advancement in materials science, enabling their usage in sensors, energy storage or biomedical technologies. At the same time, several challenges with respect to the independent control of the composition of individual components, morphology and stability should be overcome.

In this work, we propose the usage of an APPJ based on an axial DBD discharge to obtain nanocomposites starting from HMDSO as the precursor of the matrix and Cobalt nitrate for the embedded nanoparticles within the material.

2. Methods

An RF (13.56 MHz) driven atmospheric pressure plasma jet generated at 100 W in flowing Ar at 3500 sccm was used to produce the main discharge, in which the HMDSO precursor is introduced laterally in vaporized state through a bubbling system by an additional carrier Ar flow. Oxygen (100 – 500 sccm) is added to control the amount of carbon within the silicon-based matrix. Separately, the cobalt nitrite solution with concentration in the range 0.05 – 50 mM is injected also laterally at flows up to 2 µl/s, in atomized state, to ensure the metallic component in the structure. The deposited material is collected downstream, at a distance of 1 cm from the plasma source, the coating being obtained by the substrate scanning during the plasma jet operation.

The obtained nanocomposites were investigated in terms of morphology, chemical composition and surface properties, in order to understand the influence of synthesis parameters on the overall material properties.

3. Results and Discussion

The results evidenced the obtaining of a polysiloxane-like matrix material containing carbon, with a homogenous granular morphology with typical dimension around 200 nm, that diminishes by oxygen injection. At the same time, the compositional maps illustrate the Co presence on the entire investigated surface. XPS investigations pointed out that the nanocomposites chemical composition is strongly influenced by the addition of the cobalt nitrate during synthesis process, showing that Co can be present as oxide, nitride remained unreacted from the precursor, but also cobalt carbide formed upon interaction with matrix.

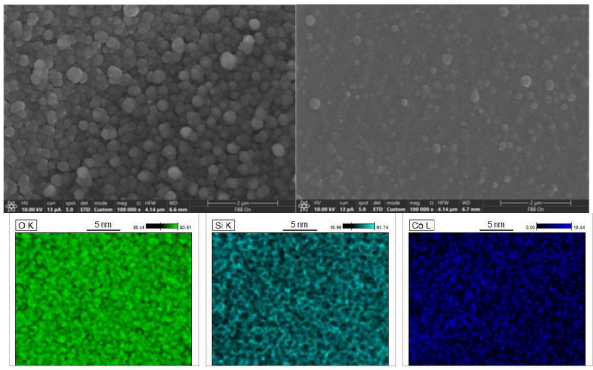

Fig. 1. **Upper line** -SEM images of the samples obtained a) with no additional O_2; b) with 100 sccm O_2. **Lower line** -compositional map illustrating the homogeneous distribution of the components in the nanocomposite material with an elemental composition of O–63.07at%, Si–32.02at%, and Co–4.73 at%.

4. Conclusion

The usage of a DBD axial plasma jet with lateral independent injection of precursors allows the obtainment of nanocomposites material with independent control of the phases composition, while ensuring the homogeneity of components within the material.

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