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(I) Plasma characterization in gaseous and liquid dielectric barrier discharge systems for nanoparticle synthesis and nanostructured thin film deposition

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Atmospheric pressure discharges in a dielectric barrier configuration, resulting in non-local thermodynamic equilibrium (nLTE) plasmas, are used in photovoltaics, photocatalysis, solar cells, water treatments and depollution, as well as for modifying the surface of wood. They can also be used to generate nanoparticles (NPs) and nanocomposites. They can be also integrated for novel approaches in biomedical devices, such as the fabrication of biodegradable systems.

At this moment in their development, the chain of physico-chemical processes occurring between the atmospheric pressure plasma discharges and the molecules of precursors contained in the plasma-treated systems, were yet to be elucidated for the most part. Many attempts to model the chemical reactions occurring in the plasma have shed a new light on these complex processes and their kinetics. At the moment, these theoretical models must be reconciliated with experimental measurements confirming the nature of the chemical and elemental species contained by the plasma, as well as their respective concentrations.

This presentation will describe various atmospheric pressure plasma discharge systems and configurations, as well as their different regimes of operation, as well as different plasma characterization methods adapted to each one of them. Their respective advantages and limitations will be presented.

The first part of the presentation is focused on a plasma-assisted chemical vapor deposition systems based on a dielectric barrier discharge (DBD). This technology was used in both glow and filamentary plasma regimes to generate polymer as well as silica and gold nanoparticle-containing nanocomposites. Frequency Shift Keying (FSK) double modulation was used to successfully deposit polymers and NPs. In each one of these experiments, the nature of polymers and deposited NPs was varied by changing plasma excitation frequency.
Plasma was characterized using FTIR spectroscopy (of the plasma and gas), and the thin films were analyzed by AFM, SEM, profilometry and UV-vis spectrometry. Concurrently, these investigations have shown the importance of the discharge regime on the thickness, polymerization level and homogeneity of the thin film, as well as how the size-dependent nanoparticle transport is controlled by the plasma frequencies.

The second part of the presentation will describe a DBD system used to directly treat fluid surfaces (water). In-solution plasma filamentary discharge has been used for synthesizing metal NPs. It is a reliable method, allowing for the synthesis of surfactant-free NPs. Control of the size and shape of the NPs could be possible by a better optimization of the plasma parameters. In this project, optical emission spectroscopy (OES) was used to measure and analyze electron temperature and density, as well as the concentration of reactive species present in different gas mixture plasma regimes. Power measurements were also performed to correlate the species analysis with the energy that is injected into the system.

In conclusion, using different plasma characterization techniques in conjugation, allows a great control of the parameters of the deposited layers, and created nanoparticles.

Primary authors: MILANIAK, Natalia (Laval University); Ms SAMARD, Lucille (Département de génie des mines, de la métallurgie et des matériaux, Université Laval, Québec, Canada); Mr SAUVAGEAU, Jean-Francois (Département de génie des mines, de la métallurgie et des matériaux, Université Laval, Québec, Canada); Dr NADAL, Elie (Laboratoire PROcédés Matériaux et Énergie Solaire, PROMES CNRS, Tecnosud, 66100 Perpignan, France); Dr MASSINES, Francoise (Laboratoire PROcédés Matériaux et Énergie Solaire, PROMES CNRS, Tecnosud, 66100 Perpignan, France); Prof. LAROCHE, Geatan (Centre de recherche du CHU de Québec, Hôpital St François d'Assise, 10, Rue de l'Espinay, Québec, G1L 3L5, Québec, Canada); Prof. FORTIN, Marc-Andre (Département de génie des mines, de la métallurgie et des matériaux, Université Laval, Québec, Canada)

Presenter: MILANIAK, Natalia (Laval University)

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