Spectroscopic diagnostic of microwave plasma at atmospheric pressure applied to the growth of nanopowders

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ABSTRACT

The plasmas at atmospheric pressure have unique properties and showed tremendous potential for various technological applications such as material processing (deposition, etching), spectrochemistry, waste treatment and bio-medical applications. We recently studied the dielectric barrier discharge (DBD) He plasmas applied to the functionalization of wood substrates using optical emission spectroscopy (OES) and collisional radiative models (CRM) [1]. In the present paper we have extended our studies on surface wave sustained (SWD) Ar plasmas in microwave regime, applied to the growth of organosilicon and organotitaniuin nanoparticles, which received serious attentions for these kinds of applications [2]. Being non-invasive, these approaches are very promising and popular. The SWD has flexibility of sustaining over both the RF and microwave domains, without the significant modifications in the electromagnetic field configuration. Furthermore, it offers a very good platform for detailed parametric fundamental studies of the growth kinetics and transport dynamics of nanoparticles in dusty plasmas at atmospheric-pressure. The accurate characterization of these plasmas will surely further improve these applications and the understanding of underlying physics.

Plasma emissions in the wavelength range 200-900nm was recorded at various positions along the direction of propagation of wave. A collisional-radiative (CR) model was developed for Ar 2p (Paschen notation) levels assuming the electron-impact excitations from lower levels as well as energy transfer processes among the 2p manifolds. The electron temperature was determined by comparing the 2p_i \rightarrow 1s_i line emissions with the prediction of the model assuming Te as the only adjustable parameter. Further, the temperature profile was also extracted through fitting of the continuum emission in 400 to 700nm range with the prediction of a theoretical model developed considering various electron-atom and electron-ion processes. Due to low ionization ratio (~10^{-6}), only the former was found to contribute significantly. In addition to these, using Boltzmann plots for the lines originating from higher lying levels (above 2p) the electron temperature was also obtained. The temperatures determined using various approaches were found in good agreement with each other and observed constant over the axial distances with a value \approx 0.45\pm0.04eV. Furthermore, we extended our studies on Ar SWD plasma in the presence of organosilicon and organotitaniuin precursors used for the growth of nanomaterial. The OES analysis revealed a grater precursor dissociation rate compare to the low frequency operated plasmas such as DBD, leading to the formation of powders with much lower precursor concentration fractions. The fragmentation level was observed to decrease with the plasma treatment time due to combined effect of decrease in total number of electrons as well as average electron energy.

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