Plasmas in dielectric liquids: a simple process with complex physics to synthesize nanoparticles

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1. Plasmas in dielectric liquids

Plasmas in dielectric liquids display a wide range of phenomena. They are transient, submitted to high pressures and high temperatures, and above all, they may be strongly coupled, like in laser-created plasmas. This means that these plasmas have more in common with a liquid than conventional weakly coupled plasmas, like arcs. In micro-gaps (<100 µm), however, electrical discharges are only weakly coupled, the number of electrons within the Debye sphere being about 0.5 and the Coulomb coupling parameter slightly inferior to 1 (~0.3). This is due to the 'relatively' low energy density deposited by the power supply. However, even if pressure in micro-gap plasmas is typically lower than 10^3 bar, several effects are observed due to their specific behavior like the lowering of the ionization energy which explains, for instance, the lack of H_β-transition at 486 nm in spectra. During the cooling down of the gas, the complexity of the plasma structure appears mainly through the behavior of specific emission lines, like those of aluminum, which are self-reversed, showing the existence of a complex optical path through an inhomogeneous density medium. Nanosecond-resolved ICCD images also illustrate some specific features like shock waves and bubble formation. These specificities are associated by some authors [1] to the different nanostructures morphologies synthesized in the plasma.

2. The two existing strategies to synthetize nanoparticles

Two main ways were adopted to synthesized nanoparticles. The first one deals with low-voltage high-current discharges (typically 100 A and 30 V) ignited by contact between electrodes. These electrodes are used as feed material to produce different types of nanostructures. The largest part of these works is devoted to the so-called "nanocarbons" [1]. This method is efficient to synthesize carbon nanotubes, nanohorns, nanoonions, nanoflowers, nanoclusters, etc. Only a few works (see [2] for instance) were dedicated to the synthesis of nanocarbons with high-current high-voltage discharges (typically 100 A and 10 kV). We investigated the possibility to create nanoparticles with this latter approach. Original nanostructures (figure 1) could be grown by using electrodes of different materials in different liquids like water, heptane and liquid nitrogen.

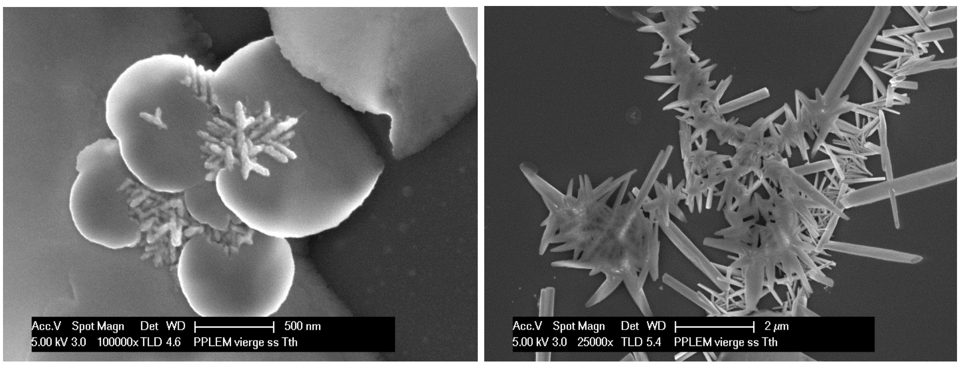

Figure 1: Examples of lead nanostructures grown by discharge in liquid nitrogen

[1] N. Sano, Mater. Chem. Phys., **88**, (2004), 235

[2] N. I. Kuskova, L. Z. Boguslavskii, A. A. Smal'ko, A. A. Zubenko, Surf. Eng. Appl. Electrochem., **43**, (2007), 269