Effect of nanofluid conductivity and humidity on the self-assembly of colloidal crystals by means of electrospray

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1. Abstract

Nowadays nanostructures are gaining importance in several fields due to its high surface area ratio and its optical and electrical properties. The two main approaches for the formation of nanostructures are top-down or bottom-up. Top-down techniques usually require expensive equipment such as electron-beam lithography that is restricted to very small areas and henceforth to sequential processing. On the contrary, bottom-up strategies are able to produce several samples and structures simultaneously. Of course self-assembly of nanoparticles or nanocomponents is mostly welcome as avoids many of the problems of the other conventional techniques. Today colloidal crystals are produced using many of both categories of technologies, but one of the main problems still unsolved is the small size of the areas of the samples (typically few square millimeters) and ordering range of nanoparticles of few micrometers.

Photonic crystals are nanoparticle arrangements with random hexagonal close packed shape (RHCP) order. This 3D periodicity enhances light reflection at wavelength proportional to the size of the nanoparticles. We have recently shown that electrospray of nanofluids has the capability to induce the colloidal crystal formation [3-5] in big areas and with good optical quality and short processing time.

The complexity of the deposition technique requires to adjust fabrication parameters, such as the liquid pumping rate and the electrical conductivity. In our observations, we have identified as one of the key factors the presence of some liquid on the substrate while the nanoparticles are self-assembling.

In the present work we show results of these observations concluding that the value of the nanofluid conductivity has an important effect on the amount of liquid reaching the substrate and the time remaining there before evaporation. At the same time the liquid enables the ordering of nanoparticles. We have seen that several layers of ordered nanoparticles can be produced if the substrate is wet while the absence of water produces monolayers of scattered nanoparticles, but not large area order.

In our interpretation, the several forces that play a significant role in the deposition process, namely, drag force, buoyancy, weight and dielectrophoresis, combine among them to facilitate the self-assembly conditions. While the buoyancy and weight cancel each other in the dimensions of our work, and even if the drag force is very small, the change of the dielectric permittivity of the medium due to the humidity can be fundamental in the process.

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Fig.1. Electrospray setup with some nanofluid accumulated in the sample

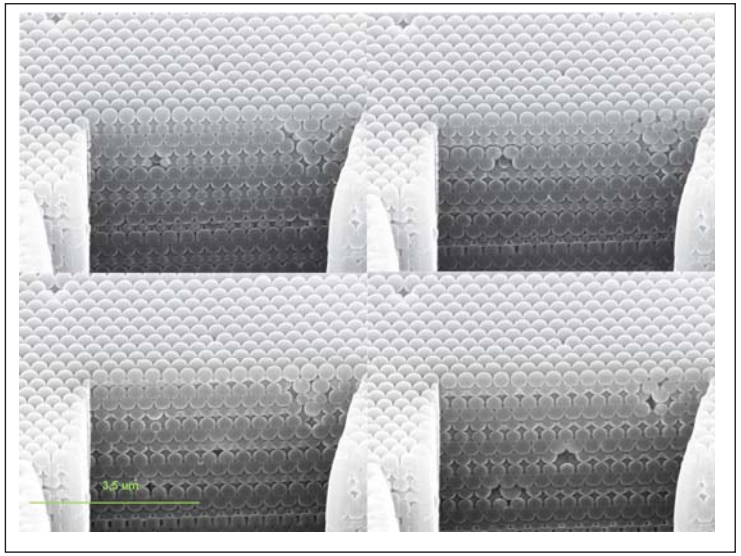

Fig.2. SEM images from the sample with 4 crosssections at 80nm distance