

Metamaterials as an experimental field for fractional calculus

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In this work we show a novel technology to develop metamaterials and some potential applications. A metamaterial is an engineered material that exhibits unusual physical properties not found in nature, paving the path to new exiting applications, such as negative index of refraction devices [1]. However optical metamaterials require perfect three-dimensional sculpted materials at the nanoscale which is still technologically challenging. This work shows a bottom-up technique based on the electrostatically controlled self-assembly of dielectric nanospheres [2]. The presented approach allows to fabricate high-quality large-scale (up to 50 cm²) colloidal nanostructures with high quality optical behavior that can be produced in just minutes using a largely simplified set-up.

Using nanospheres with diameters ranging from 200 nm to 900 nm and polystyrene and silicon dioxide as dielectric materials, perfectly self-arranged nanostructures are built. The resulting morphology is analysed with Scanning Electron Microscope (SEM) and Focused Ion Beam (FIB) measurements. Not only optical devices as colloidal crystals and inverse opals but other applications as metal insulator metal supercapacitors [3] and sensors are envisaged as well.

Wave propagation and absorption kinetics in these kind of media are typically modelled using fractional calculus [4]. In the chemical case, for example, the existence of preferential flow paths can trigger the fast displacement of dissolved chemical species within the structure, giving rise to superdiffusion, in which case material transport is no longer determined locally, but can depend on concentrations in far locations [5].

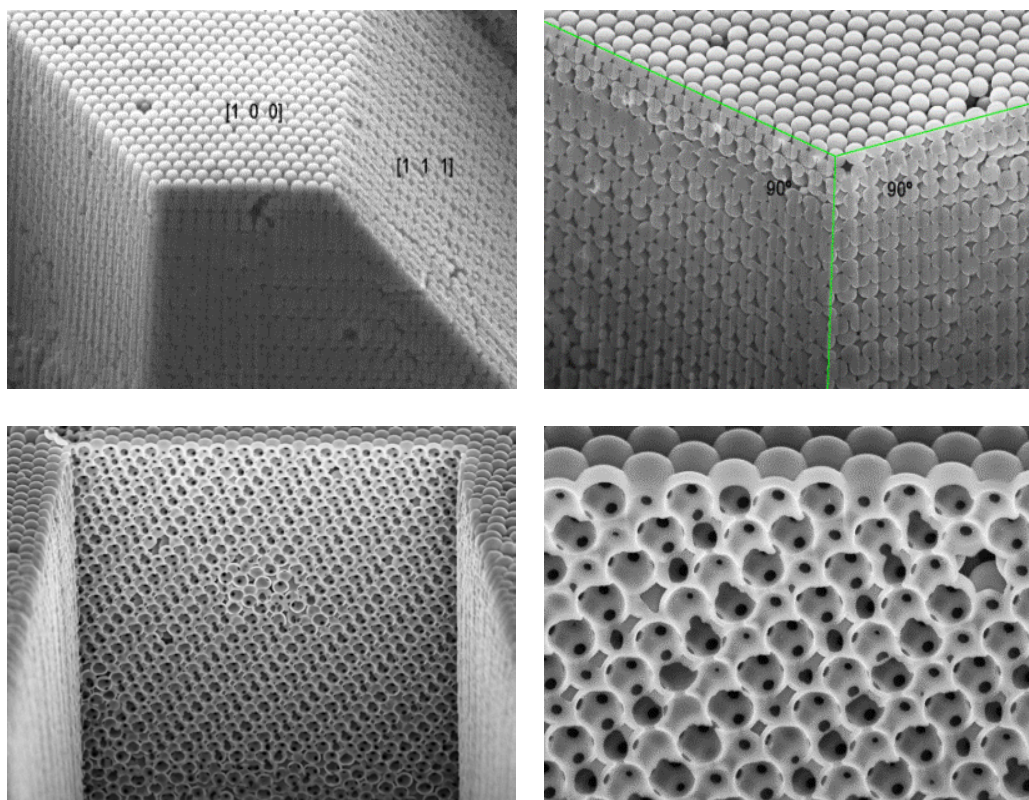


Figure 1: In the top, FIB images of colloidal crystals (opals) and of polystyrene nanospheres; In the bottom, inverse opals of Al₂O₃ and TiO₂.

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