NEW METAMATERIALS BY PROTEIN GUIDED CRYSTALLIZATION OF NANOPARTICLES

(приглашенный доклад)

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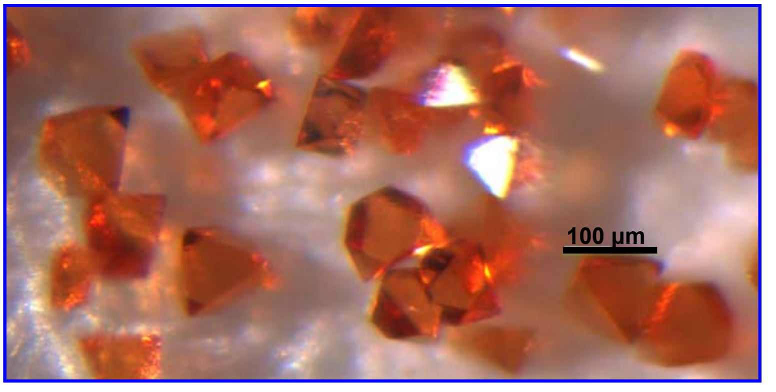
A new class of smart materials- metamaterials, emerged in the last decade, is an exciting and intense area of research in physics and nanotechnology. In this field, nanoparticles, contrary to atoms in conventional solids, are used as a building blocks, to form this new type of materials. Particular interest from fundamental point of view is focused on understanding of underlying physical phenomena, associated with ordered periodic arrangement of nanoparticles in 3D array. Among questions that remain to be answered are questions about collective behaviour of nanoparticles within the 3D array and whether or not this behaviour is responsible for unique physical properties on the mesa scale.

It is challenging enough to produce high quality 2D arrays of nanoparticles, let alone their three dimensional arrangement. Here we report a successful demonstration of application of protein crystallization technique to prepare a three dimensionally ordered array of magnetic nanocrystals. This method is a breakthrough in nanofabrication. It is generic, flexible and allows us to produce a new type of metamaterials with unique properties. We utilise protein ferritin cages for a template constrained growth of, for instance superparamagnetic nanoparticles of magnetite/maghemite Fe_3O_4-γ-Fe_2O_3 (Magnetoferritin), followed by thorough nanoparticles bioprocessing and purification, and finally by protein crystallization. Protein crystallization is driven by natural response of proteins to the supersaturation of the electrolyte, which leads to spontaneous nucleation and 3D-crystal growth. Within short period of time (hours to days) we were able to grow functional crystals on the mesa scale, with sizes in the order of tens, up to few hundred microns. This is the first of its kind demonstration, as an alternative to reported earlier colloidal and supra-crystals [1, 2].

In our previous study [3, 4] we successfully demonstrated that isolated, stable and well characterised magnetic nanoparticles encapsulated into protein is a credible physical model system to probe spin dynamics effects. We used nanoparticles of magnetoferritin in well-dispersed and aggregated states to study the effects of magnetostatic interactions on magnetic thermal relaxation from saturation. Clear $T\ln(t/\tau_0)$ scaling enabled us to calculate the (effective) energy barrier distribution in each case. Our result, in contrast to reported earlier, is the first clear experimental demonstration of the theoretically predicted behaviour [5]. We found that interactions lead to both a decrease in the peak energy and to a broadening of the energy barrier distribution.

By making 3D-ordered arrays of magnetic nanocrystals we are able to extend our study of fundamental magnetic interactions on nanoscale. We aim to uncover the effect of interparticles separation on magnetic interactions and therefore on fundamental magnetic characteristics of such materials. Here we present the results of structural characterisations of the first of its kind magnetic crystals by Small Angle X-ray Scattering (SAXS) and their magnetic behaviour by SQUID.



Optical image: each crystal is an F.C.C-array of ~8 nm diameter ferrimagnetic nanoparticles.

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