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Synthesis and characterization of inorganic anisotropic nanoparticles

Abstract

Nanoparticles with an anisotropic shape have shown great potential in innovative applications. For example, when magnetic anisotropic nanoparticles are subjected in a magnetic field, they will align with the field, resulting in a torque ($\tau_m = m \times H$), that can be transferred to the surrounding. Therefore, the effect is interesting for new magnetically responsive application such as magneto-optics and magneto-viscous fluids. Moreover, the magneto-mechanical effect could be also used in medicine for the cancer treatment. In particular, magnetic nanoplatelets that display a high uniaxial magnetocrystalline anisotropy with an easy axis perpendicular to the platelet can be especially appropriate. One of materials that exhibits the hard-magnetic properties is the barium hexaferrite platelets (HF). The effect of the magnetic field – torque is proportional to platelet magnetic moment, which is product of magnetization (M) and platelet volume (V). One way to increase the effect of the field on the nanoplatelet is to increase the magnetization. This could be achieved by combining hard-magnetic material with soft-maghemite (γ -Fe₂O₃) one. Such composite nanoparticles could be produced with simple co-precipitation method [1]. HRTEM and HAADF STEM revealed that the composite displayed incredibly uniform structure, where hexaferrite is positioned in between equally thick epitaxial maghemite layers. The composites display single phase hysteresis loop, confirming that the components are rigidly exchange coupling. Importantly, the composite nanoplatelets retain the out-of-plane easy axis of the cores, while substantially enhancing the saturation magnetization (MS). However, the MS is accompanied by relative decrease of HC due to the epitaxial stress in the structure [2].

On the other hand, in last few years, the topological insulators (TIs) became one of the most interesting materials. Among them, the most investigated is anisotropic bismuth selenide (Bi₂Se₃). Due to its topological surface states (TSS) it displays special electronic and optical properties, which makes it a good candidate for a variety of important applications, e.g. spintronics, photodetectors, ultrafast lasers, cancer treatment, thermo-electronics, etc. [3]. In most of the envisaged applications above mentioned, Bi₂Se₃ has to be directly contacted with another semiconductor or a metal in heterostructures [4]. According to the literature, the Bi₂Se₃ nanoplatelets could only be synthesized using a solvothermal method [5]. The drawback of this method is the use of toxic and expensive organic solvents. Moreover, after the solvothermal synthesis, the particles are coated with a thin amorphous layer that impedes the direct contact between Bi₂Se₃ and the other materials of the heterostructure. In this context, we investigated the possibility to synthesize the Bi₂Se₃ nanoplatelets with simple hydrothermal method. It was found, that Bi₂Se₃ can be synthesized with hydrothermal method at similar conditions as with solvothermal method. Moreover, the hydrothermally synthesized Bi₂Se₃ nanoplatelets display unique optical properties compared to solvothermally synthesized counter-particles.

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