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Featured Letter

Highly tunable liquid crystalline assemblies of superparamagnetic rod-like attapulgite@Fe_3O_4 nanocomposite

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ABSTRACT

The uniform dispersed rod-shape superparamagnetic nanocomposite was prepared by the attachment of Fe_3O_4 particles onto attapulgite. These nanocomposites assemble into magnetically responsive liquid crystal with yellow Bragg reflections under an external magnetic field. The optical properties of the obtained liquid crystal can be controlled by the strength and the direction of the magnetic field as well as the concentration of attapulgite@Fe_3O_4. It was found that a maximum transmittance of light could be available with attapulgite@Fe_3O_4 concentration tuning from 1 mg/mL to 2 mg/mL when the magnet was fixed at a distance of 2 cm from the sample. We demonstrate the use of these nanocomposites to fabricate display and photonic devices.

1. Introduction

Magnetically induced assembly of one-dimensional nanorods has become a powerful tool for the fabrication of ordered array [1,2]. However, as typical building blocks are often non-magnetic, they need the attachment of magnetic nanoparticles to achieve magnetical assembly, such as carbon nanotubes [3], Ag nanowires [4] and Te nanorods [5]. The ordered structures produced by these materials may be useful in liquid crystal and photonic crystal [6–8]. But limited to excessive reactants, byproducts or agglomeration of the resulting 1-D magnetic nanostructures, much less attention has been paid to the application of the nonmagnetic species attached with magnetic nanoparticles and much research work terminated after the magnetic orientation was completed in the past ten years.

Attapulgite (ATP) is a kind of natural one-dimensional nanometer rod-like clay and belongs to hydrous magnesium-aluminum silicate minerals. The exchangeable cations, virgulate morphology and the great specific surface area cause the excellent colloidal properties of ATP, leading to its wide applications in adsorbents and catalyst support. It has long been known that dispersions of anisotropic colloids display liquid crystal phase [9,10]. As an anisotropic nanorod, ATP is a potential candidate of building blocks in liquid crystals. Considering the uncontrollable nature and immature synthetic technology, it is difficult to apply inorganic liquid crystals to reality. Recently, we developed a method for the preparation of superparamagnetic magnetite (Fe_3O_4)-capped ATP [11]. Herein, we report a controlled alignment of nonmagnetic nanorods attached with superparamagnetic nanoparticles, and it is used as building blocks to construct liquid crystal with optical properties that can be controlled by manipulating the composite nanorods orientation using a moderate external magnetic field. As a potential raw material of inorganic liquid crystals, ATP has been instantly and reversibly controlled by a magnetic field. Our findings provide a generic way for common anisotropic materials to prepare controllable liquid crystal. Furthermore, it also provides an alternative route avoiding the complex synthesis process of building blocks and getting low-cost and eco-friendly products.

2. Experimental

Attapulgites@Fe_3O_4 nanocomposites were fabricated by a facile co-precipitation method. The detail can be found in Electronic Supplementary Information. The main chemical composition of the used ATP was listed in Table 1. ATPs@Fe_3O_4 suspension was prepared by dilution of attapulgites@Fe_3O_4 with the appropriate amount of 0.001 M HCl to reach the desired concentration with constant stirring. The pure ATP suspension (10 mg/mL) was homogenized with a high-pressure homogenizer at 30 Mpa [12], and stayed for a month to obtain birefringent tactoids.

3. Results and discussions

As a natural one-dimensional nanoscale clay mineral, the rods of ATP exist with diameter 15–50 nm and length 0.2–1.8 μm as

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Table 1
Chemical compositions of ATP.

Compound	SiO_2	Al_2O_3	MgO	Fe_2O_3	CaO	K_2O	Na_2O	Mass loss
Content (%)	67.21	10.30	13.34	5.18	1.48	1.25	0.13	1.11

shown in Fig. 1(a). The special rod-like morphology makes it possible to act as a carrier, allowing the magnetic nanoparticles to be loaded onto the surface of the nanorods by the nucleation and growth steps of the co-precipitation process. The SEM of the resulting nanostructure is shown in Fig. 1(b) and the TEM of an individual nanorod is shown in Fig. 1(c). The images indicated that small

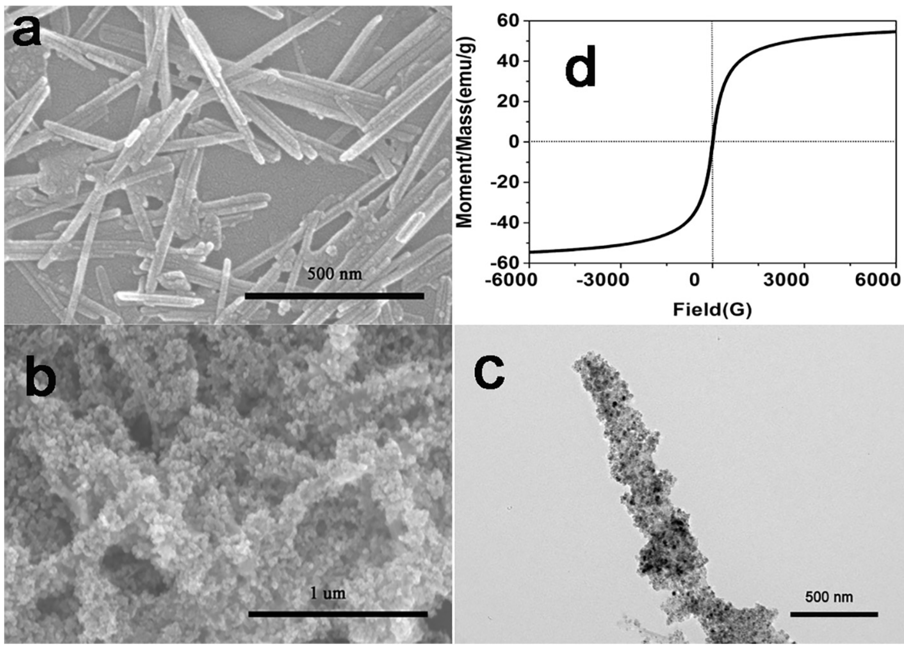

Fig. 1. a) SEM image of ATP. b) SEM image of ATP@Fe_3O_4. c) TEM image of a typical free-standing ATP@Fe_3O_4 rod-like nanocomposite. d) Magnetic hysteresis loop of ATP@Fe_3O_4.

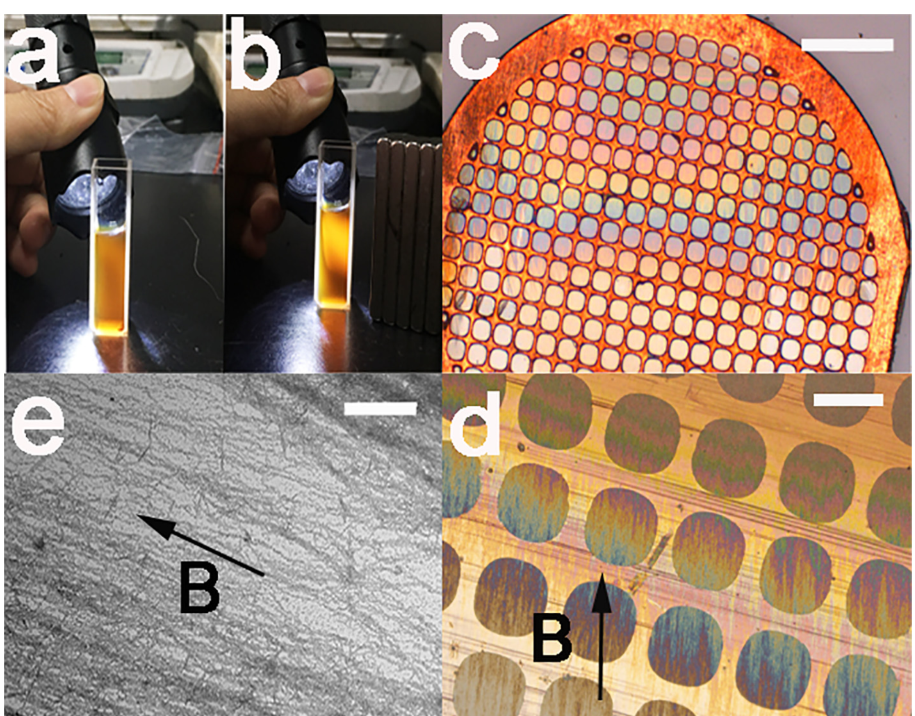

Fig. 2. Real images of ATP-Fe_3O_4 suspensions a) in the absence and b) in the presence of the external magnetic field. c) OM image (in reflected light) of ATP-Fe_3O_4 film on the copper grid. Scale bar: 500 μm. d) Local enlarged drawing of c). Scale bar: 100 μ. e) TEM image of ATP-Fe_3O_4 film. The black arrow indicates the direction of the magnetic field. Scale bar: 2 μ.