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Editorial

Synthesis, Properties, and Applications of Multifunctional Magnetic Nanostructures 2018

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Magnetic nanostructures have emerged as the novel class of materials being used in a variety of applications such as ultra-high-density magnetic recording media, drug delivery, magnetic resonance imaging (MRI), sensing, hyperthermia, water treatments, and catalysts. Recent advances in multifunctional nanostructured design, synthesis, and characterization techniques have led to the realization of various magnetic nanostructures exhibiting several physical and chemical properties that are unique and interesting. Magnetic nanostructures with varied geometries are complex and manifest diverse properties differing from their parent bulk compound because the energies associated with the various physical parameters are comparable to the nanostructure dimensions. Controlling these properties, thus, enables researchers to understand and develop new concepts that would potentially result in novel applications. This annual special issue is comprised of a wide range of original research articles as well as review papers on the topic of synthesis, properties, and applications of new designed multifunctional magnetic nanostructures.

In this special issue, a total of nine manuscripts were accepted for publication out of fourteen manuscripts. These articles covered a broad variety of topics related to magnetic nanomaterials. We hope that these articles will give the readers useful information and pathway for futuristic scientific applications. In the following, we will summarize the results from accepted manuscripts.

B. Bai et al. investigated magnetic Fe_3O_4@chitosan carbon microbeads (MCM), which were synthesized by a simple thermal cracking process under a nitrogen atmosphere at 350°C. Based on the XRD, SEM, and FT-IR characterization results, a possible mechanism for the formation of MCM was proposed. The application of MCM composites for the adsorptive removal of doxycycline (DC) was evaluated using a fixed-bed column. The results showed that pH, initial concentration, flow rate, and bed depth are found to be important factors to control the adsorption capacity of DC. The Thomas and Yoon-Nelson models showed a good agreement with the experimental data and could be applied for the prediction of the fixed-bed column properties and breakthrough curves. More importantly, the saturated fixed bed can be easily recycled by H_2O_2 which shows excellent reusability for the removal of doxycycline. Thus, the combination of the adsorption advantage of chitosan carbon with catalytic properties of magnetic Fe_3O_4 nanoparticles might provide a new tool for addressing water treatment challenges.

S. Sun et al. studied avidin-immobilized magnetic nanoparticles (AMNPs) as a novel targeted drug delivery system

to deliver iminobiotinylated daunomycin (IDAU). In their study, an IDAU was connected to AMNPs based on the avidiniminobiotin binding system. The drug loading capacity and release behavior were then determined through adsorption dissociation kinetics experiments, and the inhibitory effects of IDAU on liver tumour cell DLKP growth were also evaluated. Therapeutic efficacy and the regulation of drug release can be improved by using selective targeting drug delivery systems. TEM, XRD, VSM, and FTIR were employed for the physicochemical characterization of the drug-loaded MNPs. The binding of IDAU had little effect on sizes of AMNPs (~35 nm), but the stability and dispersibility of the nanoparticles were improved. The study also found that the loading capacity and efficiency of nanoparticles were mainly dependent on affinity interaction between IDAU and AMNPs. The optimal loading capacity and efficiency of MNPs for IDAU were measured according to the reversed-phase high-performance liquid chromatography (RP-HPLC) data. Under the conditions of pH 6.8 and 1 mmol/L of biotin, the drug-loaded MNPs released rapidly at the beginning and then maintained at a certain controllable release level. The effect of IDAU on DLKP proliferation was also tested. These findings indicated that AMNPs hold tremendous potential as an effective drug delivery system.

The article "Investigation of the Magnetic Properties of Ferrites in the CoO-NiO-ZnO Using Simplex-Lattice Design" by L. Frolova and O. Khmelenko is devoted to the analysis of changes in the magnetic characteristics of spinel ferrite in the CoO-NiO-ZnO system by the simplex method. In this study, ferrites of Ni-Zn, Co-Zn, and Co-Ni were synthesized in the form of nanoparticles (20-40 nm) using a new method for processing contact nonequilibrium low-temperature plasma (CNP). The effect of the mutual influence of the content of different bivalent cations on the saturation magnetization and the coercive field was investigated. The Ni-Zn ferrites show low magnetization values compared to the entire Co-Zn, Co-Ni ferrite series. The EPR spectra of ferrites are analyzed by superexchange interaction, which shows that the value of the resonant field and line width corresponds to the value of magnetic saturation and is due to the arrangement of cations on sublattices, i.e., the distribution between the tetrahedral and octahedral sites.

Q. Yin et al. reported a study introducing a measurement system specifically designed and constructed for surface profile measurement of triangular microstructures generated on the surface of flat workpieces. Microstructures with the shape of an equilateral right triangle were employed as the measurement specimen. The surface profile measurement of triangular microstructures was carried out by employing two methods to correct errors caused by the specimen inclination and the radius of the stylus tip. The shape, depth, and period of the measured microstructures were also detected based on the results of surface profile measurement. Also, the proposed measurement system was experimentally tested. Experimental results demonstrate the feasibility of the proposed surface profile measurement for microstructures with complex surface topographies.

T. A. Dontsova et al. investigated the effect of the nanomagnetite modification on textural characteristics of clay matrices, adsorption properties, and parameters of the spent sorbent separation. The nitrogen adsorption-desorption method has shown that the obtained magnetic nanocomposite sorbents have large specific surface areas (in 1.2–2 times more) than the initial clays due to the formation of the secondary porous structure on the surface and in macropores of clay matrices. The best adsorption properties concerning dyes belong to magnetic sorbents with nanomagnetite content of 7 wt.%. The additional modification of the third phase of graphene-like molybdenum disulphide into magnetic sorbents leads to the significant increase in the sorption capacity of both cationic (up to 1100 mg/g) and anionic (up to 1830 mg/g) dyes. The conducted investigations of the total acidity and acid-base sites on the surface of clay, magnetite-modified clay, and molybdenum disulfide-modified magnetic sorbent indicate the significant influence of the Lewis base sites on the adsorption properties of these materials. In their research, data are presented on the change in the adsorption and textural characteristics of clay matrices depending on the magnetite content, the amount of the modifier on the magnetic separation process and the moisture content of waste sorbents, and the influence of the third-phase presence (nanomolybdenum disulphide) in the magnetic mineral sorbent on its adsorption and textural properties. Thus, authors attempted to analyze the possibility of directed modification of the adsorption and textural properties of various clay matrices modified with nanomagnetite by a simple impregnation method.

K. Badreddine et al. studied the effect of Sm doping with different concentrations up to 10% on the structural, morphological, optical, and magnetic properties of the ZnO nanoparticles. The $Zn_{1-x}Sm_xO$ ($0.00 \leq x \leq 0.10$) nanoparticles were prepared by coprecipitation technique that provides nanopowders with good quality despite the low cost and simplicity of this method. XRD analysis showed the hexagonal wurtzite structure of ZnO and absence of any residual Sm_2O_3 phase, indicating that Sm dissolved completely into ZnO lattice. The fluctuating lattice parameters (a and c) with an increase of Sm doping indicated that the structure of ZnO was perturbed by the doping of Sm. TEM micrographs revealed that the size and the shape of the ZnO nanocomposites were changed by modifying the doping level of Sm. The band gap energy and Urbach energy were calculated for $Zn_{1-x}Sm_xO$. The band energy gaps of pure and Sm-doped ZnO samples are in the range 2.6–2.98 eV. Pure ZnO exhibited a room temperature ferromagnetic behavior along with diamagnetic and paramagnetic contributions. Ferromagnetic behavior was reduced for the doped samples with $x = 0.01$ and $x = 0.04$. The samples with $x = 0.02$ and $0.06 \leq x \leq 0.10$ tend to be superparamagnetic.

T. Saiki et al. estimated the density of the unpaired electrons by ESR technique in sintered nanopolycrystalline Si. Reduction in the skin effect for the sintered Si nanopolycrystalline body as an electricity conductor at a high frequency due to its nanostructure was studied. Singular disappearance of electrical resistances near a local high magnetic harmonic frequency of a few MHz was observed. This phenomenon has not been observed for conventional ferromagnetic metals. The measured electrical resistances changed to

almost 0 mΩ at room temperature. At the same time, negative resistance of the sintered Si nanopolycrystalline body was observed. It will apply to electronic transmittance lines or semiconductors. The numerical calculation was also performed on the electrical resistance with frequency dependency while considering the electric field and magnetic field in the sintered Si nanopolycrystalline body. The experimental and calculated results were compared. The calculation could explain the variation of the relative permittivity of the Si nanopolycrystalline body and the phenomenon for the theoretical disappearance of the resistivity at the MHz frequency. Reduced Si nanoparticles from SiO_2 powder were synthesized by laser ablation in liquid. A Si nanopolycrystalline body made of the reduced Si nanoparticles was fabricated. It was found by measuring the magnetization property of the sintered Si nanopolycrystalline body which is ferromagnetic. Dangling bonds (unpaired electrons) have long been known to occur due to defects in Si crystals. Perfect Si without defective crystals has no dangling bonds. However, Si nanoparticles have many dangling bonds. High-density dangling bonds cause the sintered Si nanopolycrystalline body to have ferromagnetism.

X. Song et al. report *in vitro* safety evaluation and *in vivo* imaging studies of superparamagnetic iron oxide nanoparticles (SPION) through biomimetic modification. Magnetic resonance imaging (MRI) is an advanced medical imaging diagnostic technique that utilizes different resonance signals generated by the signal strength of water content and the relaxation time of protons in water molecules under the influence of an external magnetic field. This technique requires contrast agents, such as Gd-DTPA and Gd-DOTA, which could increase the risk of renal fibrosis in patients with severe renal insufficiency. The magnetic moment or susceptibility of SPION is higher than that of other paramagnetic substances and could significantly reduce the dosage of the contrast agent required. Animal acute toxicity test also had proved its high safety in vivo. In this work, c(RGDyK)-PDA-SPION was further studied for the cell toxicity and effect on HepG2 cells in vitro, and the MRI imaging of this contrast agent in HepG2 tumour-bearing mice was also studied. The results showed that it possessed high safety and enrichment phenomenon on HepG2 cells in vitro. Animal experimental data preliminarily prove that the contrast agent could enhance the MRI *T2*-weighted imaging capability of HepG2 carcinoma in tumour-bearing mice and could be a potential *T2* contrast agent.

Finally, the review conducted by M. Bohra et al. features on "well-known" Verwey transition of Fe_3O_4, particularly in nanoscale dimensions. Considering sharp changes occur in the physical properties of Fe_3O_4 near Verwey transition, numerous potential applications based on spin/charge transport, multiferroicity, exchange bias, and spin Seebeck effect have been reviewed. They briefly reviewed recent research work on the origin of Verwey transition though it is still debatable. The size and shape effect on the Verwey transition of various geometries and their synthesis methods have been discussed in length. The Verwey transition is a low-temperature transition around 120 K; various artificial ways are summarized on how to shift this transition at higher temperature end. Authors also discussed the best growth and characterization methods which are being currently employed to investigate Verwey transition of nanostructured Fe_3O_4 material because conventional methods have their limitations. Authors also highlighted a pathway for futuristic spintronics and nanotechnology applications wherein Verwey transition-based applications can be potentially employed.

We hope that this special issue will contribute to the nanomagnetic society of their current understanding.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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