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Editorial

Magnetic Nanoparticles

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Magnetic nanoparticles are a class of nanoparticle that can be manipulated using magnetic fields. Such particles commonly consist of two components, namely a magnetic material, often iron, nickel, and cobalt, and a chemical component that has functionality, frequently with (bio)catalytic or biorecognition properties. Magnetic nanoparticles, magnetic nanorods, and other magnetic nanospecies have been prepared, and used in many important applications. Particularly, magnetic nanospecies functionalized with biomolecular and catalytic entities have been synthesized and extensively used for many biocatalytic, bioanalytical, and biomedical applications. Different biosensors, including immunosensors and DNA sensors, have been developed using functionalized magnetic nanoparticles for their operation in vitro and in vivo. Their use for magnetic targeting (drugs, genes, radiopharmaceuticals), magnetic resonance imaging, diagnostics, immunoassays, RNA and DNA purification, gene cloning, cell separation, and purification has been developed. Moreover, magnetic nano-objects of complex topology, such as magnetic nanorods and nanotubes, have been produced to serve as parts of various nanodevices, for example, tunable fluidic channels for tiny magnetic particles, data storage devices in nanocircuits, and scanning tips for magnetic force microscopes.

The increasing number of scientific publications focusing on magnetic materials indicates growing interest in the broader scientific community (Figure 1). This Special Issue covers all research areas related to magnetic nanoparticles, magnetic nanorods, and other magnetic nanospecies, as well as their preparation, characterization, and various applications, specifically emphasizing biomedical applications. The review articleswritten by the leading experts cover different subareas of the science and technology related to various magnetic nanospecies—touching upon the multifaceted area and its applications. The different topics addressed in this Special Issue will be of high interest to the interdisciplinary community active in the fields of nanoscience and nanotechnology. It is hoped that the collection of the different review articles will be important and beneficial for researchers and students working in various areas related to bionanotechnology, materials science, biosensor applications, medicine, and so on. Furthermore, the issue is aimed at attracting young scientists and introducing them to the field, while providing newcomers with an enormous collection of literature references.

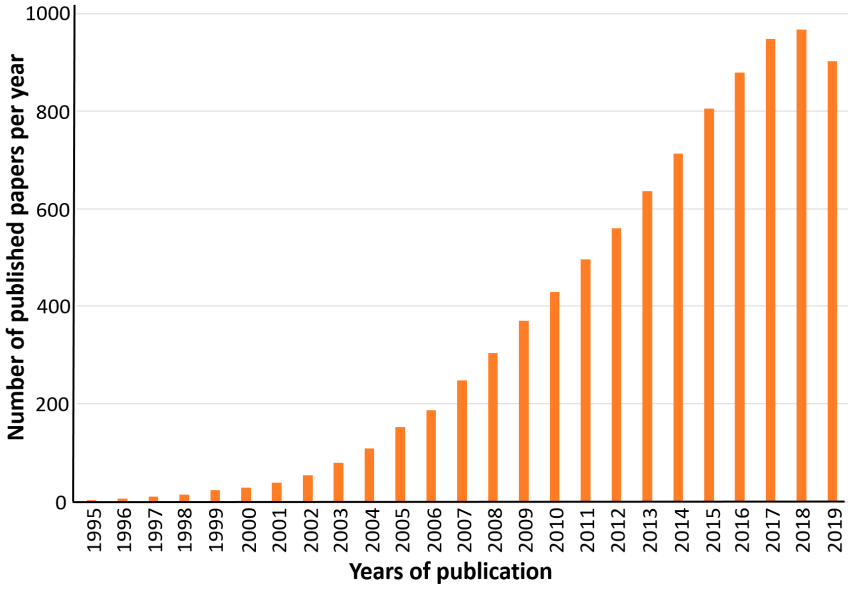

Figure 1. The number of published papers mentioning "magnetic nanoparticles" derived from statistics provided by Web of Science. The search was performed for the key words "magnetic nanoparticles" in the topic. Note the dramatic increase of the publications related to magnetic nanoparticles (the statistics for 2019 was not complete).

The articles in this Special Issue cover the following specific subareas of the research field:

1. General Information—Preparation, Characterization, Modification, and Usage of Various Magnetic Nanoparticles and Nanorods

Advances in nanotechnology led to the development of nanoparticle systems with many advantages due to their unique physicochemical properties. The review article by Katz [1] serves as a brief introduction to the research area and overviews composition and synthetic preparations of various magnetic nanoparticles and nanorods (Figure 2). Another review by Antone et al. [2] focuses specifically on iron oxide nanoclusters and their preparation and use. A review by Socoliuc et al. [3] describes the design and synthesis of single- and multi-core iron oxide nanoparticles and provides an overview on the composition, structural features, surface, and magnetic characterization of the cores. Biomolecular functionalization of magnetic nanoparticles has allowed their numerous applications. Specifically, the modification of magnetic nanoparticles with cellulose enzyme is reviewed in the article by Khoshnevisan et al. [4].

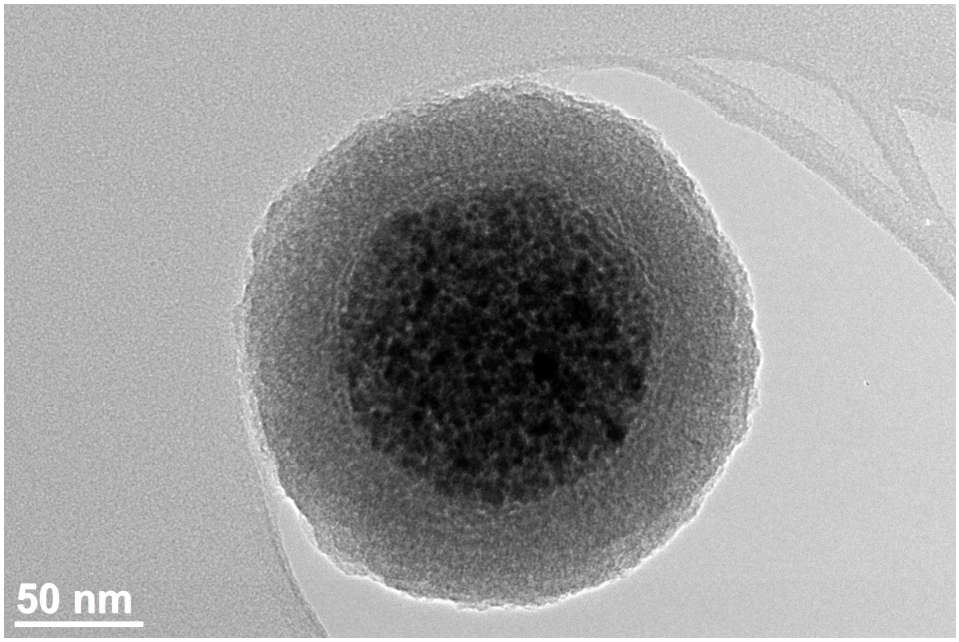

Figure 2. Maghemite silica nanoparticle cluster (scanning electron microscopy (SEM) image): iron oxide (γ-Fe_2O_3) magnetic core and SiO_2 shell—an example of core–shell magnetic nanoparticles. (Adopted from the Wikipedia public domain: https://commons.wikimedia.org/wiki/File:Maghemite_silica_nanoparticle_cluster.jpg).

2. Biomedical Applications of Magnetic Nanoparticles

The comprehensive review by Hepel [5] provides a very broad view on the use of magnetic nanoparticles for various applications in nanomedicine, (Figure 3). Another review by Piñeiro et al. [6] concentrates on the use of magnetic nanoparticles in medical biosensing, theranostics, and tissue engineering. The use of iron oxide magnetic nanoparticles in pharmaceutical areas has increased in the last few decades. The article by Luciano Bruschi et al. [7] reviews conceptual information about magnetic nanoparticles, methods of their synthesis, properties useful for pharmaceutical applications, advantages and disadvantages, strategies for nanoparticle assemblies, and use in the production of drug delivery, hyperthermia, theranostics, photodynamic therapy, and as antimicrobial substances. Biocatalysis and biomedical perspectives of magnetic nanoparticles as versatile carriers are highlighted in the review by Bilal et al. [8]. Another review article by Obaidat et al. [9] overviews the use of magnetic nanoparticles for hyperthermia, which is a non-invasive method that uses heat for cancer therapy where high temperature has a damaging effect on tumor cells. Magnetic hyperthermia uses magnetic nanoparticles exposed to alternating magnetic fields to generate heat in local regions (tissues or cells). While this therapeutic method is highly important for cancer treatment, the paper is mostly focused on the physical properties of the magnetic nanoparticles, and the intrinsic and extrinsic parameters required for the medical use of magnetic nanoparticles. The implication of magnetic nanoparticles in cancer detection, screening, and treatment is reviewed in the article by Hosu et al. [10]. This review summarizes studies about the implications of magnetic nanoparticles in cancer diagnosis, treatment, and drug delivery as well as prospects for future development and challenges of magnetic nanoparticles in the field of oncology. The review article by Stergar et al. [11] is concentrated on potential biomedical applications of NiCu magnetic nanoparticles. While the most frequently used magnetic nanoparticles are composed of iron oxide (Fe_3O_4), NiCu magnetic nanoparticles, which are not common for biomedical applications, demonstrate some advantages due to their unique features. The article by Tada and Yang [12] is a review of iron oxide labeling and tracking of extracellular vesicles. Extracellular vesicles are essential tools for conveying biological information and modulating functions

of recipient cells. Therefore, their visualization (imaging), particularly with magnetic nanoparticles, is highly important and the reviewed method is expected to be applicable and useful in clinical analysis.

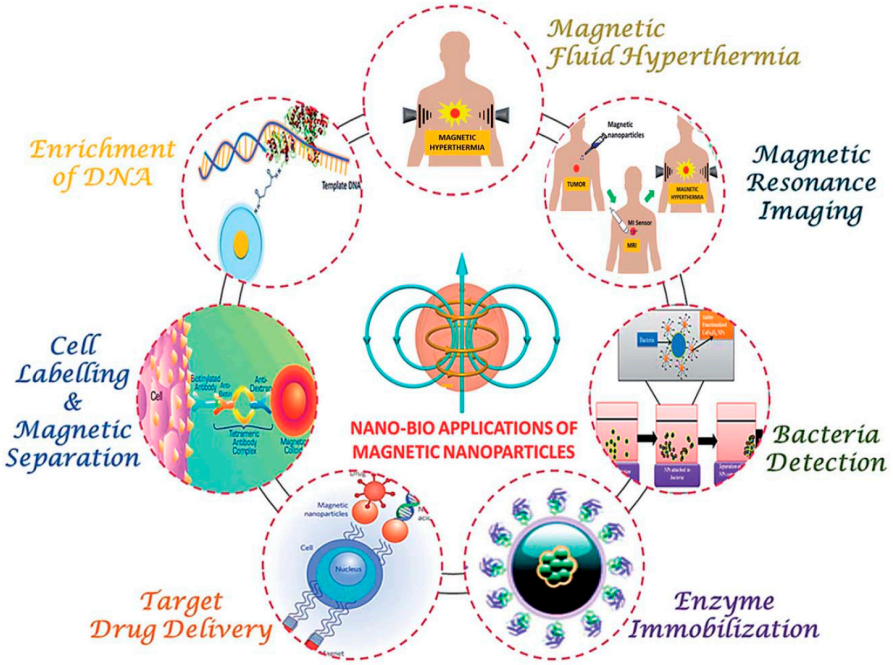

Figure 3. Different biomedical applications of magnetic nanoparticles—schematic presentation. (Adopted from *RSC Adv.* **2016**, *6*, 43989–44012 with permission.)

3. Biosensors Based on Magnetic Nanoparticles

Magnetic nanoparticles conjugated with various biomolecules offer a versatile approach to biosensors, particularly in biomedical applications (Figure 4), as discussed in the review article by Krishnan and Yugender Goud [13]. Another comprehensive review by Üzek et al. [14] focuses on optical biosensing systems based on magnetic nanoparticles. The optical biosensors on the platform of biomolecular-functionalized magnetic nanoparticles are broadly categorized into four types—surface plasmon resonance (SPR), surface-enhanced Raman spectroscopy (SERS), fluorescence spectroscopy (FS), and near-infrared spectroscopy and imaging (NIRS)—that are commonly used in various bioanalytical applications. The use of biosensors based on magnetic nanoparticles specifically for food safety monitoring is highlighted in the review by Khan et al. [15]. Due to the expanding occurrence of marine toxins, and their potential impact on human health, there is an increased need for tools for their rapid and efficient detection. The use of magnetic nanoparticles in marine toxin detection is explained in the review article by Gaiani et al. [16]. Magnetic Janus nanoparticles bring together the ability of Janus particles to perform two different functions at the same time in a single particle with magnetic properties enabling their remote manipulation, which allows headed movement and orientation. The article by Campuzano et al. [17] reviews the preparation procedures and applications in the (bio)sensing field of static and self-propelled magnetic Janus nanoparticles. The main progress in the fabrication procedures and the applicability of these nanoparticles are critically discussed, also giving some clues on challenges to be dealt with and future prospects.

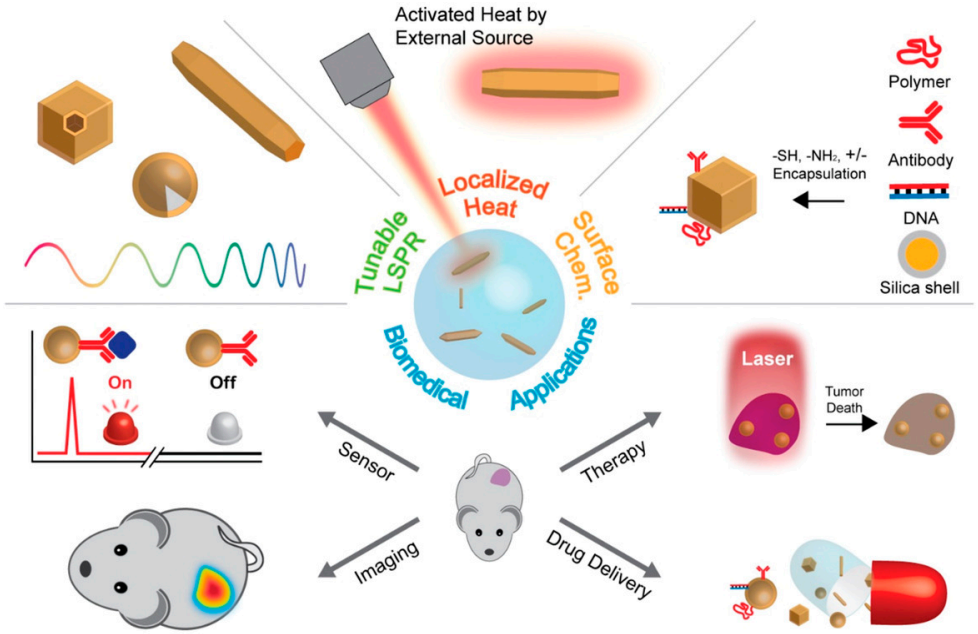

Figure 4. Biomedical applications of magnetic nanoparticles—schematic presentation [18]. (Adopted from *Adv.Sci.* **2019**, *6*, 1900471; open access article under the terms of the Creative Commons Attribution License, which permits use, distribution, and reproduction in any medium.)

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