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Editorial

Special Issue: Ceramic and Metallic Biomaterials Nanoparticles for Applications in Medical Sciences

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Nowadays, the development of new materials that can be used to treat, repair, diagnose, replace, or restore a function of the human body represents one of the key research topics for the worldwide scientists and medical industries. For example, metallic nanoparticles are studied for possible applications in biomedicine such as the manipulation of living cells (transportation, displacement, positioning, or cell separation) or cancer detection and treatment. Another important class of compounds that has attracted the attention of the scientific community is represented by ceramic biomaterials, which can be used for the replacement of various types of tissues (as implants or for the repair and reconstruction of various diseased parts of the body). The outperformance of a biomaterial is determined by its crystalline structure, microstructure, (such as grain size or porosity), biocompatibility, corrosion resistance, or mechanical properties. In this context, the development of new biomaterials with improved physical and mechanical properties and a low production cost, high availability, and good esthetics is imperative. This short review aimed to explore the innovative progresses in the field of biomaterials used for biodetections, treatment, or replacement of injured tissues in order to develop practical solutions for clinical practice.

Ceramic biomaterials can be used in a wide range of biomedical procedures, such as tooth replacement or restoration [1,2], knees, ligaments, or tendons [3], bone implants [4], maxillofacial reconstruction [5,6], or particle transport inside the body to the vicinity of the target by applying an external magnetic field [7], etc.

Together with magnetic nanoparticles, ceramic materials can be used to treat cancer diseases by destroying tissues by hyperthermia or magneto-mechanical effects. The advantages to use material in "nano" form for applications in medicine are related to the fact that these materials retain both "bulk" properties, but also gain a number of special properties due to their small size, and large surface area or "aspect ratio" (shape) [8,9]. Interesting new properties of nanoparticles can be obtained by preparing bi-metallic nanomaterials in the form of alloys or core-shell structures. The performance of these types of materials often exceeds those of simple metals. The form and structure of the nanomaterial, as well as its physical and chemical characteristics, vary as the metal components are changed.

The large number of studies presented in the literature related to the synthesis and properties of magnetic nanoparticles demonstrate the importance of nanomaterials whose properties make them useful both in diagnosis and in treatment of many diseases. One of the main characteristic of magnetic nanomaterials is represented by the fact that such materials can be guided (moved) or held in place by a magnetic field. Another important property that makes this type of material suitable to be used in bio-medicine is that magnetic nanomaterials can be heated by an applied magnetic field. Thus, the data presented in the literature show that magnetic nanoparticles can be used to transport drugs in the body, for the treatment of cancer (by hyperthermia or magneto-mechanical effect), and as contrast agents for cancer cell visualization [10–12], etc.

One of the disadvantages of the use of magnetic nanoparticles for biomedical applications is related to the cytotoxicity of these materials and to the fact that these materials can be degraded in the human body. To avoid degradation and toxicity, the surface of the nanomaterials is coated with a layer of organic compound (for example polyethylene glycol (PEG), dextran, or oxide layer [13,14]). The encapsulation of magnetic nanoparticles in an organic compound layer increases the circulation time of nanoparticles in the body, making the nanomaterials biocompatible [15]. However, due to the high reactivity of the organic compounds in the blood, the organic shell can be degraded by the body, the magnetic materials re-becoming toxic to the human body. In order to avoid the biodegradation and reduce their toxicity, a new method has been developed, involving the coat of the nanoparticles with a noble metal shell, which is non-toxic to the human body and manifests a low reactivity in the blood.

Given the limitations described above, biological applications need the employment of magnetic core nanoparticles (with high magnetic moment) encapsulated in a biocompatible shell. The use of magnetic materials with a high magnetic moment leads to a decrease in the applied external magnetic field or an increase in the distance from the external magnet. In this context, nanomaterials containing noble metals and transition simple metals and alloys can be used for biological testing [16–19]. The unique physical properties of nanomaterials to selectively recognize biomolecules can lead to the miniaturization of biological sensors, the literature data showing that magnetic nanomaterials have been extensively studied for various applications in biomedicine, such as: moving, positioning, or separating cells, treating cancer, and so on.

Thus, a possible application of magnetic nanoparticles is the manipulation of living cells (transport—movement, positioning, or separation of cells). In their paper, Choi et al. developed a technique for transporting and positioning living cells with internalized Ni nanowires using magnetic field alignment. Thus, Ni nanowires were first internalized into neuroblastoma cells and then the latter were placed between two electrodes using a magnetic field. The study allows the creation of an interface between neurons and electronic devices [20].

Hultgren et al. [21] studied cell separation using Ni nanoparticles. The presented results showed a higher efficiency of cell separation when this was carried out using Ni than those obtained by using magnetic beads of comparable volume. Another conclusion of this study showed that the use of Ni nanoparticles allows the production of purer cell populations than the use of spherical nanoparticles. The increase in the efficiency of cell separation when magnetic nanowires are used for this can be attributed, according to the study, to the fact that Ni nanomaterials have a higher magnetic moment. The effectiveness of cell separation with Ni nanoparticles compared to that achieved with magnetic nanoparticles was also studied by Gao et al. [22]. The authors demonstrated that functionalized Ni nanoparticles in the shape of nanowires have a higher cell separation efficiency compared with magnetic nanoparticles with spherical shape, even at a concentration 60 times lower.

Another possible important application of magnetic nanomaterials is the use of these materials for cancer treatment. In the presence of a magnetic field, the magnetic nanomaterials can be heated or rotated so that they can transmit either heat, or a mechanical force to the cells they come in contact with, thus helping to eradicate cancer cells. Due to the shape anisotropy and the increased magnetic moment of materials in shape of nanowires, it is possible to perform hyperthermia at lower field strengths in order to minimize damage to healthy cells.

Another well-defined class of highly exploited metallic materials for biomedical applications is represented by noble metals, especially gold and silver nanoparticles. Currently, the most known route to quickly synthesize colloidal gold is the Turkevich method that uses sodium citrate both as a reduction agent of chloroaurate and stabilizer of the synthesized AuNPs. Moreover, green methods relying on different natural reduction agents, such as plant extracts, algae, and bacteria, are also used to produce stable and non-toxic colloidal gold for biomedical applications [23].

Due to their tunable size, shape, and specific optical properties, AuNPs have been used in biomedical imaging (e.g., X-ray-computed tomography, photo-acoustic imaging, dark field microscopic imaging, magnetic resonance imaging, and fluorescence imaging), immunoassay (ELISA, and lateral flow, which is the most used immunoassay method for SARS-CoV-2 detection), nanomedicine (e.g., drug-targeted drug and gene delivery), photothermal/photodynamic therapy (e.g., cancer treatment), and biosensing (e.g., electrochemical, colorimetric, or fluorescence-based sensing, but also surface plasmon resonance biosensors and surface enhanced Raman scattering based sensors) [23,24].

AuNPs are also the most commonly used in vaccinology. Once administered, they are quickly internalized by macrophages and dendritic cells, inducing their activation [25,26]. AuNPs have attracted huge interest in vaccinology due to their reliable surface functionalization, high biocompatibility, customized dimensions and shapes, and excellent optical properties. Moreover, owing to their inertness, AuNPs can be exploited both as delivery agents and adjuvants in vaccines, being able to boost the immune responses while assuring minimal toxicity [27]. AuNP, with their unique properties, represent ideal platforms towards a new era of vaccinology. Their high surface area and straightforward functionalization allow simultaneous and multivalent antigen presentation and make them excellent candidates for innovative nano-constructs in the field of vaccine development.

Silver nanoparticles are also of interest in medical sciences due to their anti-inflammatory, anti-angiogenesis, antiviral, antifungal, and antibacterial effects, being suitable for catheter modification, dental applications, or wound and bone healing. Moreover, AgNPs showed promising anticancer effects for several human cancerous cell lines [28].

The studies have revealed the importance of AgNPs as suitable means to treat different bacterial diseases, from Malaria leishmaniosis to Escherichia coli infections [29]. As a basic mechanism of action, by releasing silver ions, AgNPs increase the permeability of cell membranes and induce generation of reactive oxygen species, leading to interruption of the replication of the DNA [30].

In conclusion, this special issue aims to provides advances in biomaterials research field for applications in medical sciences. The use of the nanomaterials for biomedical applications has the potential to lead towards increasing life expectancy and improving quality of life.

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