Magnetic nanocomposites based on mesoporous silica for biomedical applications

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Abstract: Multifunctional nanocarriers, integrating diagnostic and therapeutic functions, have attracted increasing scientific attention recently. Magnetic-mesoporous silica nanocomposite materials are emerging as one of the most appealing candidates to produce novel nanodevices[1] for personalized medicine, theranostic carriers, celular and diagnostic MRI in vivo, magnetofection, hyperthermia, magnetic bioseparation, molecular diagnostics, magnetic-controlled drug release systems and osseous regeneration devices[2,3]. The main driving force for this trend is connected to the possibility of combining synergistic magnetic, mesoporous, and biological entities and functions in a well-defined host matrix[1], also looking for tissue engineering constructs capable of combining the replacement of damaged parts with local cancer treatment[2]. The synthesis of mesoporous silica materials with controlled physicochemical characteristics like large pore volume, high surface area, narrow pore size distribution, tunable pore size and high hydrothermal stability, is of large interest due to its inert, harmless, and inexpensive character and their ever-expanding list of applications [4]. The incorporation of magnetic nanoparticles (MNPs) into these biocompatible mesoporous scaffold formulations [5,6] provides final materials with additional magnetic functionality and reinforced mechanical properties for bone tissue engineering applications. Magnetic functionality comprise different beneficial effects like magnetic stimulation on biological media (i.e., enhancement of cell adhesion/proliferation), guiding of growth factors loaded magnetic nanocarriers[7],or the *in vivo* localized heat release by magnetic hyperthermia with the help of an externally applied alternating magnetic field[8].

So the aim of this study was conducted by the synthesis, the structural and physicochemical characterization and the applications as scaffolds for bone tissue engineering and soft and hard hyperthermia devices for cancer treatment of magnetic-mesoporous silica nanocomposite materials.
In the present work we report the synthesis procedure of magnetic mesoporous SBA-15 ceramics with controlled morphology. Different procedures and synthetic parameters are varied in order to control the physico-chemical, textural and magnetic properties of these materials.

Our results show that magnetic mesoporous silica presents a flat two-dimensional hexagonal symmetry with the presence of mesoporous ordination cylindrical geometries, opened at both ends, with magnetite nanoparticles anchored on their surface and in the channels as shown by TEM and SEM micrographs (figure 1). Measured by BET, these materials show a surface area above 250 m^2/g, which assures a higher ability to be loaded with different molecules than conventional ceramics. The presence of crystalline magnetite is corroborated by the XRD spectra (figure 2) which reveals the typical iron oxide crystalline pattern peaks. In the figure two, spectra are presented corresponding to samples with low (bottom spectra) and high (top spectra) amounts of magnetite in the ceramic. Magnetic characterization was performed with a vibrating sample magnetometer (VSM), where field dependent magnetization cycles were performed at room temperature for two samples (with low and high magnetite content) and results are presented in figure 3. The magnetization cycles show no hysteresis or coercive forces, which is highly desirable for biomedical applications to avoid magnetic agglomeration of particles. In addition hyperthermia characterizations have been performed to assess the magneto-thermal abilities of two representative samples. The hyperthermia response can be tuned by varying the content of magnetite as evidenced in figure 4, where negligible temperature increase (low magnetite content) or a high increase of about 40º C in only one minute (high magnetite content) can be obtained depending on the physicochemical properties of the ceramic and the magnetite content. This tunable response can be an advantage for different tissue engineering purposes since it allows for magnetic enhancement of bone cell growth and differentiation (low thermal increase) or locally killing cancer cells (high thermal increase) with magnetic hyperthermia by selecting the proper magnetite doping. In addition the porous character of SBA-15 ceramics allows to functionalize the material with growth factors, specific antibiotics or therapeutic drugs to promote regeneration and healing in bone diseases.

In summary, magnetic mesoporous SBA-15 ceramics have been synthesized by different routes and varying chemical parameters to obtain tunable physicochemical, morphological and magnetic properties suitable for different biomedical applications.

References

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Figures

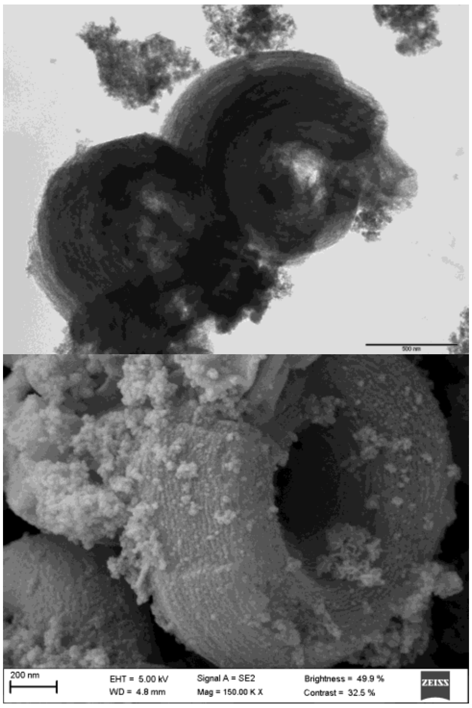

Figure 1. SEM and TEM micrographs of a representative sample of magnetic ceramic.

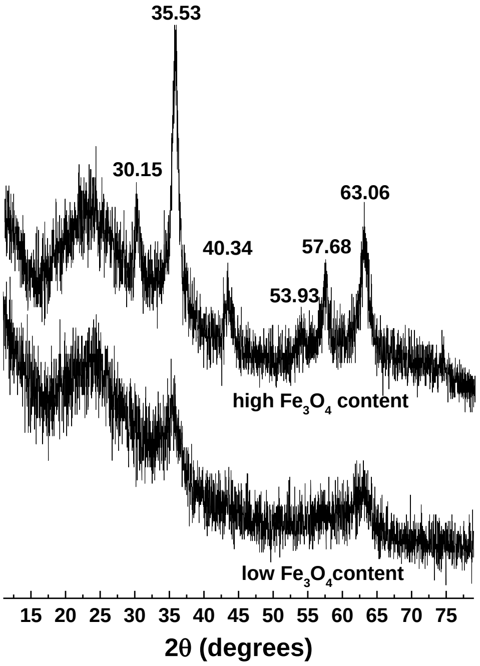

Figure 2. Comparation of XRD pattern of low and high magnetite content of two representative samples of magnetic ceramics.

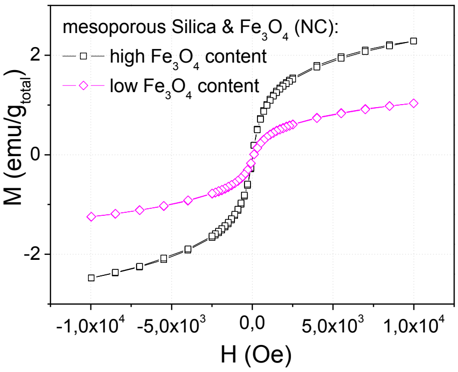

Figure 3: Field dependent magnetization performed at room temperature.

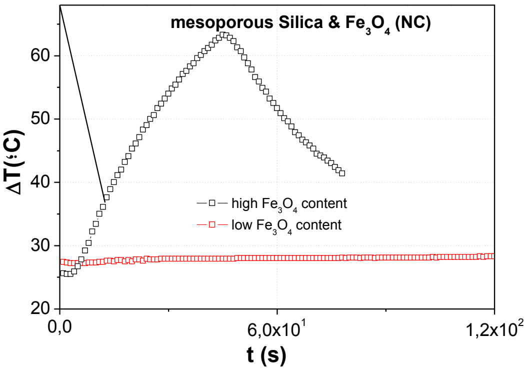

Figure 4. Magnetic hyperthermia measurement performed with an alternating magnetic field (f=293 kHz; B=30 mT) of two representative samples with low and high magnetite content.