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Multifunctional Fe-Au nanostructures for biomedical applications

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Cancer is the leading cause of death in Europe after cardiovascular disease, accounting for about 20% of deaths in the European Union [1]. One of the main strategies followed in oncology has been hyperthermia, which consists on raising the temperature of cancer cells to 40-45ºC to reach apoptosis i.e., programmed cell death [2]. One way to reach local and controlled hyperthermia is via functionalizable nanostructures that are activated by external stimuli such as magnetic fields or electromagnetic radiation. Gold nanostructures (Au-NS) have been the subject of much attention in the academic and clinical environment due to its biocompatibility and high absorption of electromagnetic radiation in the near-infrared (NIR) range caused by its surface plasmon resonance [3]. In parallel, magnetic nanostructures based on Iron (Fe-NS) have also been the subject of studies since they can combine the diagnostic properties (as contrast agents for magnetic resonance imaging) and therapy (magnetic hyperthermia) [4]. Although the Fe-oxide NS are the most reported in the literature, Fe-NS are a promising alternative. The high magnetic moment of Fe-NS that can increase the heat dissipation phenomena produced by the magnetic hysteresis, due to the irreversible magnetization/demagnetization processes induced by an applied alternating magnetic field [5].
The main goal of this work is to combine the "best of both worlds"producing multifunctional Iron-Gold nanostructures (Fe-Au-NS) with high heating performance when stimulated with radiation (500-1000nm) and with alternating magnetic fields for applications in controlled and localized hyperthermia.
Fe-Au-NS were produced by two methods: 1) through the ablation of Iron and Gold targets with a femtosecond pulsed laser in liquids (such as ethanol) and 2) by electrodeposition in self-organized alumina matrices. The first technique is particularly interesting for the development of NS-Fe-Au with complex structures such as the core-shell structure [4]. In turn, the second technique allows a controlled growth of nanowires, nanotubes, and more complex morphologies such as segmented Fe-Au-Fe nanowires [6].
The Fe-Au-NS have been fully characterized with scanning electron microscopy (SEM), X-ray diffraction (XRD) and superconducting quantum interference device (SQUID) techniques. The morphological analysis showed a narrow distribution in diameter and length of the obtained structures with improved robustness and high yield, making these techniques versatile approaches strongly compatible with large scale production. Finally, we show the possibility to tune accurately the size of the nanostructures and consequently provide an easy control over the magnetic properties of these nanostructures ultimately enabling reaching the superparamagnetic regime.

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