Rational Design of Hybrid Magnetic Nanoarchitectures: Tailoring magnetic properties for Biomedical Applications

S. Slimani[1,2*] and D.Peddis[1,2]

[1]Department of Chemistry and Industrial Chemistry & Genova, INSTM RU , nM2-Lab, University of Genova, 16146 Genova, [2]Institute of Structure of Matter, National Research Council, nM2-Lab, Via Salaria km 29.300, Monterotondo Scalo 00015, Roma, Italy

*sawssen.slimani@unige.it

Magnetic nanoparticles (MNPs) are unique complex objects whose physical properties are distinctively different from those of their bulk counterparts, due to finite-size and surface effects that become increasingly dominant at the nanoscale [1]–[3]. These features give rise to a variety of magnetic behaviors, making MNPs highly attractive for a broad range of applications, particularly in biomedicine (e.g., drug delivery, contrast-enhanced magnetic resonance imaging [MRI], magnetic hyperthermia therapy, and magnetic particle imaging [MPI]). On the other hand, designing Hybrid Magnetic nanoarchitecture (HMN) represents a powerful tool to further tune magnetic properties and obtain new multifunctional materials with tailored characteristics. HMNs typically consist of a precisely engineered magnetic core in intimate contact with various functional components (e.g., polymers, mesoporous structures such as silica, zirconia, or zeolites, or biological molecules like enzymes and antibodies, or organic ligands). This functionalization step is absolutely pivotal in biomedical applications since it serves multiple critical functions, such as ensuring long-term colloidal stability in complex physiological environments, providing versatile functional groups for specific biomolecular conjugation, and potentially influencing the overall magnetic behavior through interface effects that are not present in either component alone[4]. These hybrid effects open exciting possibilities for creating materials with precisely tuned magnetic responses for specific applications. Accordingly, this presentation will focus on the rational design of HMNs, discussing their synthesis and functionalization process, highlighting how the control the magnetic properties through core design (size, composition, crystallinity) and molecular coatings (Type, thickness, functionality) leads to significantly enhanced performance of the material. This talk will also report specific examples of optimized systems for medical use, including efficient magnetic hyperthermia [5]–[7].

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