Fe3O4 Nanoparticles as Multifunctional Theranostic Agents

Alejandro G. Roca[1],
Aritz Lafuente[1],
José Francisco López-Barberá[1],
Javier Muro-Cruces[1],
Alberto López-Ortega[2],
Elvira Fantechi[3],
Miryana Hemadi[4],
Borja Sepúlveda[5],
Josep Nogués[1,6]

[1] Catalan Institute of Nanoscience and Nanotechnology (ICN2), Campus UAB, 08193 Bellaterra, Barcelona, Spain.
[2] Dept. Ciencias&Institute for Advanced Materials and Mathematics INAMAT2, Univ. Pública de Navarra, 31006 Pamplona, Spain.
[3] Dipartimento di Chimica and INSTM, Università degli studi di Firenze, Sesto Fiorentino (FI) I-50019, Italy.
[4] Université Paris Cité, CNRS-UMR 7086, Interfaces, Traitements, Organization et Dynamique des Systèmes (ITODYS), Paris, France
[5] Instituto de Microelectrónica de Barcelona (IMB-CNM, CSIC), Campus UAB, Bellaterra, 08193 Barcelona, Spain
[6] ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

alejandro.gomez@icn2.cat

Nanoparticles have attracted an enormous interest during the last decades due to their appealing properties which have led to countless applications in very widespread fields. Interestingly, the physicochemical properties of nanoparticles can be efficiently tuned by designing not only their size but also their shape. For biomedical applications, iron oxides, magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3), are becoming the preferred material due to their excellent biocompatibility. However, most of the research performed in maghemite/magnetite nanoparticles has been carried out on isotropic spherical particles. [1] Here we present a rationally designed synthesis pathway based on the thermal decomposition of to obtain high quality nanocubes [2] and on solvothermal strategies to reach magnetic iron oxide nanorods, both over a wide range of sizes. The nanocubes with an edge length below 17 nm show a great colloidal stability (Figure 1), even after transferring them to water. Moreover, the 17 nm nanocubes exhibit an excellent magnetic hyperthermia and NMR relaxivity performance (better than their spherical counterparts), making them excellent candidates for potential applications in nanotheranostics. In addition, the Fe_3O_4 nanocubes are outstanding heat mediators for photothermia in the near infrared biological windows (680-1350 nm), with heating efficiencies similar to, or better than, the best photothermal agents [3]. In addition, the magnetic and optic anisotropies of the nanocubes have been exploited for a relatively new approach for in situ local temperature sensing.

On the other hand, structural and magnetic properties of elongated IONPs between 25 and 400 nm (length) and aspect ratios between 4 and 8 are presented (figure 2). The magnetic nanorods were synthesized by the solvothermal method using iron organic precursors. Different strategies for their transfer to water have been addressed. We will correlate their magnetic properties with the performance in hyperthermia and MRI applications as a function of the structural and colloidal properties, compared to their spherical equivalents.

References

[1] A. G. Roca, H. Gavilan, M. E. F. Brollo, S. Veintemillas-Verdaguer, M. P. Morales, L. Gutiérrez, Adv. Drug Del. Rev 138 (2019) 68–104.
[2] J. Muro-Cruces, A. G. Roca, A. López-Ortega, E. Fantechi, D. Del-Pozo-Bueno, S. Estradé, F. Peiró, ACS Nano 13 7 (2019). 7716–28.
[3] A. G. Roca, J. F. Lopez-Barbera, A. Lafuente, F. Özel, E. Fantechi, J. Muro-Cruces, M. Hémadi, B. Sepulveda, J. Nogues, Physics Reports 2023 (accepted)

Figures

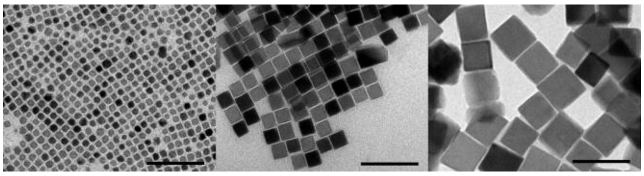

Figure 1. TEM images of magnetite nanocubes with different average sizes (left 10 nm, centre 17 nm and right 30 nm).

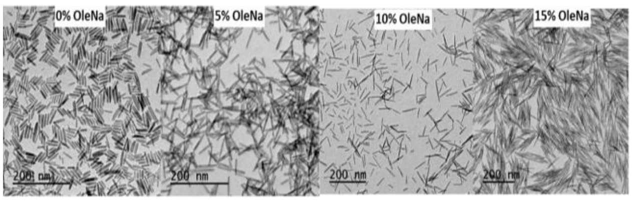

Figure 2. TEM images of magnetite nanorods with different aspect ratios as a function of the amount of sodium oleate.