

## Magnetic particles functional characterization at the Bioinstrumentation Laboratory of the Centre for Biomedical Technology

J.J. Serrano<sup>1,2</sup>, N. Félix<sup>1,2</sup>, V. Ferro<sup>1,2</sup>, R.A. García<sup>1,2</sup>, A. Mina<sup>1,2</sup>, C. Sánchez<sup>1,2</sup>, P. Anaya<sup>1</sup>, L. Urbano<sup>1</sup>, A. Muñoz<sup>3</sup>, M. Manso<sup>3</sup>, D. Ruiz<sup>4</sup>, D. Losada<sup>4</sup>, F. Muñoz<sup>4</sup>, T. Fernández<sup>1,2,7</sup>, M. Ramos<sup>1,2,7</sup>, M. Maicas<sup>6</sup>, C. Aroca<sup>6</sup>, E. Alfayate<sup>5</sup>, J.A. Hernández-Tamames<sup>1,5</sup>, F. del Pozo<sup>1,2</sup>

<sup>1</sup> Biomedical Engineering and Telemedicine Centre (GBT), Centre for Biomedical Technology (CTB), Technical University of Madrid (UPM), Campus de Montegancedo, Autopista M40, km 38. Pozuelo de Alarcón, 28223 Madrid, Spain.

<sup>2</sup> Biomedical Research Networking Center in Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Campus Río Ebro - Edificio I+D, Bloque 5, 1ª planta, 50018 Zaragoza, Spain.

<sup>3</sup> Departamento de Física Aplicada, Departamento de Biología Molecular, Universidad Autónoma de Madrid, Spain.

<sup>4</sup> Foundation for Biomedical Research, University Hospital Ramón y Cajal, Madrid, Spain.

<sup>5</sup> CIEN Foundation - Queen Sofia Foundation, Madrid, Spain.

<sup>6</sup> Institute for System based on Optoelectronics and Microtechnology (ISOM - GDM), Technical University of Madrid (UPM), Spain.

<sup>7</sup> Center for Molecular Biology "Severo Ochoa", Universidad Autónoma de Madrid, Spain.

[ajserran@etsit.upm.es](mailto:ajserran@etsit.upm.es)

Nanoscience and nanotechnology are in the spotlight nowadays because researchers from these fields are now able to explain and control the phenomena observed at the nano and microscales. They are trying to create new medical applications like treatment and diagnosis using magnetic micro and nanoparticles by breaking down the frontiers between biology, chemistry and physics.

Researchers need to overcome several problems with these substances, such as toxicity issues or the understanding of the human body complexity, if magnetic micro and nanoparticles (MNPs) are wanted to be used in medical applications. Besides, there's a huge gap between in vivo and in vitro experimentation with MNPs that researchers are trying to remove. Following this idea, the Bioinstrumentation Laboratory is working on setting up a characterization platform of MNPs where researchers or fabricants send their samples and receive several data, such as the magnetic and mechanical response, relaxation time when are used as contrast agents in MRI, and movement behavior of the particles.

The magnetic and mechanical response is measured using the Alternating Gradient Field Magnetometer (AGFM) *MicroMag Model 2900 AGM System*<sup>®</sup>. Due to its high sensitivity, low noise floor and its capability to accommodate a large range of samples of very different properties, such as solid samples, ultra thin films, powders, liquids and even slurries, the AGFM can be used for characterizing the magnetic and mechanical properties of MNPs in biological samples. Some examples of actual research lines with the AGFM are the discrimination of the behavior of MNPs acquired by cells or situated on the extracellular matrix and the use of the AGFM as biosensor. The final goal is to use the AGFM combined with other techniques for the detection and identification of engineered MNPs as contaminant in ex-vivo samples (see Figure1) [1-4].

The *SMARTracer* Relaxometer, in conjunction with a 2T Electromagnet, allows the acquisition of the T1 and T2 relaxation rates of water and biological solutions containing MNPs when are employed as Contrast Agents in MRI. The relation between relaxation rates and the morphological and physical properties of the particles can be obtained by adapting the information contained in the Nuclear Magnetic Relaxation Dispersion (NMRD) profiles (dependence of the relaxivity on magnetic field strength, Figure 2(a)) into a Theoretical Model. The main goal of this research line is to obtain the concentration of MNPs on the tissue directly from a MRI using the information of the NMRD profiles and the data from the Theoretical Model (see Figure 2 (a,b)) [5-7].

To achieve dynamic characterization, which means in this case movement of magnetic particles, it was made a set up that involves: magnets, auxiliary geometries for focalization, viscometer, analysis and simulation software as well as random laboratory material. With all these things together plus theoretical phenomena, it is possible the understanding of this kind of magnetic particles characteristics. The principal research lines are oriented to cellular filters fabrication, focusing of magnetic particles using magnetostatic fields, mathematical model optimization of magnetic phenomena, and human and animal models for in vitro experimentation (phantoms). The final goal is the use of these techniques to separate cells and its implementation for treatment and diagnosis (see Figure 3) [8-12].

### References

[1] V. Ferro, J.J. Serrano, T. Fernández, M. Ramos, F. del Pozo. Caracterización del comportamiento magnético y mecánico de nanopartículas en biofluidos y células con un AGFM. Proceedings of the XXVIIth Annual Congress of the Spanish Society of Biomedical Engineering (CASEIB 2009), Cádiz, November, 2009, pp.285-288, ISBN: 978-84-608-0990-6.

- [2] V. Ferro, J.J. Serrano, T. Fernández, M. Ramos, C. Maestú, F. del Pozo. Alternating gradient field magnetometers as a tool for the investigation on the mechanical and magnetic behavior of magnetic nanoparticles in biological samples. *Clinical Applications of Nanotechnologies in the Field of Cancer*, Montpellier, France, January, 2010.
- [3] V. Ferro, J.J. Serrano, T. Fernández, M. Ramos, C. Maestú, F. del Pozo. Using alternating gradient field magnetometers for the characterization of the mechanical and magnetic behavior of magnetic nanoparticles in biological samples. *Proceedings of the Nanospain 2010 International Conference*, 2010.
- [4] V. Ferro, J.J. Serrano, C. Maestú, C. Sánchez, M.C. Maicas, C. Aroca, M.M. Sanz, F. del Pozo. El magnetómetro por gradiente alternante de campo: una nueva herramienta para la caracterización de nanopartículas magnéticas en biofluidos y tejidos biológicos. *Proceedings of the XXVIIth Annual Congress of the Spanish Society of Biomedical Engineering (CASEIB 2008)*, Valladolid, October, 2008, pp.348-351, ISBN: 978-84-691-3640-9.
- [5] N. Félix, J. J. Serrano, and F. del Pozo. Discrepancias encontradas al evaluar un modelo teórico con datos experimentales en la caracterización de nanopartículas como agente de contraste en imágenes de RM. *Proceedings of the XXVIIth Annual Congress of the Spanish Society of Biomedical Engineering (CASEIB 2009)*, Cádiz, November, 2009, ISBN: 978-84-608-0990-6.
- [6] N. Félix, J. J. Serrano, and F. del Pozo. Noticed discrepancies when evaluating experimental data against theoretical model on the characterization of superparamagnetic particles as contrast agents in mri. *In the 6th Conference Field Cycling Relaxometry 2009 proceedings*, 2009.
- [7] N. Félix, J.J. Serrano, C. Maestú, and F. del Pozo. Challenges on the characterization of superparamagnetic particles as contrast agents in mri. *Proceedings of the Nanospain 2010 International Conference*, 2010.
- [8] R. A. García, A. Macías, J.J. Serrano, and F. del Pozo. Primeras experiencias en guiado y focalización de micro y nanopartículas magnéticas con fines biomédicos. *Proceedings of the XXVIIth Annual Congress of the Spanish Society of Biomedical Engineering (CASEIB 2009)*, Cádiz, November, 2009, ISBN: 978-84-608-0990-6.
- [9] R. A. García, A. Macías, J.J. Serrano, and F. del Pozo. Fantoma de sangre humana, 2011. P200930776.
- [10] R. A. García, A. Mina, N. Félix, J.J. Serrano, and F. del Pozo. Caracterización de micro y nanopartículas magnéticas para aplicaciones biomédicas. *Revista Biotecnología y Bioingeniería*, 14(2):43–59, 2010.
- [11] R.A. García, J. J. Serrano, A. Mina, and F. del Pozo. Magnetic fields interactions phenomena in guidance and focusing of magnetic micro and nanoparticles. *Proceedings of the Nanospain 2010 International Conference*, 2010.
- [12] A. Macías, R.A. García, J.J. Serrano, and F. del Pozo. Procedimiento para caracterizar fluidos a base de agar para experimentación con nanopartículas magnéticas en aplicaciones de guiado y focalización *Proceedings of the XXVIIth Annual Congress of the Spanish Society of Biomedical Engineering (CASEIB 2009)*, Cádiz, November, 2009, ISBN: 978-84-608-0990-6.

## Figures

