Magnetic Micro-Nano- Particles for Mechanobiology, towards future Biomedical Applications

Helene Joisten[1], Andrea Visonà[1,2], Patricia Obeïd[3], Robert Morel[1], Yanxia Hou[4], Marie Carrière[4], François Berger[5], Alice Nicolas[2], Bernard Dieny[1]

[1]Univ. Grenoble Alpes, CEA, CNRS, IRIG, SPINTEC, Grenoble F-38000, France
[2]Univ. Grenoble Alpes, CNRS, CEA/LETI-Minatec, Grenoble INP, LTM, Grenoble F-38000, France
[3]Univ. Grenoble Alpes, CEA, INSERM, IRIG, Biomics, Grenoble F-38000, France
[4]Univ. Grenoble Alpes, CEA,CNRS, IRIG, SyMMES, Grenoble F-38000, France
[5]Univ. Grenoble Alpes, INSERM, CHU Grenoble, BrainTech Lab, Grenoble F-38000, France

helene.joisten@cea.fr

Mechanobiology has made tremendous progress over the past decade, revealing in particular the importance of the mechanical properties of the surrounding environment and mechanical stresses on cell viability, fate, and cellular functions.

The studies presented here make a particular contribution to this recent field of research, by using the purely mechanical effects of magnetic particles on or in biological cells (without heat production, unlike magnetic hyperthermia), benefiting from the remote magnetic actuation, in various cell environments [1,2]. The magnetomechanical actuation of particles by an applied magnetic field - either rotating or alternating at low frequency, generated for example by linear or cylindrical Halbach arrays, or by electromagnets – can locally induce particle vibration or motion, with magnetism offering the advantage of remote and contactless control.

Anisotropic particles, such as permalloy ($Ni_{80}Fe_{20}$) microdisks (Fig. 1) [3], are particularly effective for this type of actuation due to their strong magnetic anisotropy and large magnetization. These magnetic microdisks have already been employed in various biological experiments, notably for the destruction of cancer cells (including renal and glioblastoma cells) through their vibration, with or without surface functionalization, firstly in 2D Petri-dish cultures [4,5]. More recently, our work has extended to 3D cell models, specifically pancreatic spheroids, which better mimic tissue organization and physiological functions than 2D systems. The first results are highly promising, demonstrating selective cancer-cell destruction in tumoroids while sparing healthy pancreatic organoids. However, further investigation is needed. Furthermore, magnetic microdisks actuation has also been shown to stimulate insulin production in pancreatic cells [6].

These remarkable effects still require in-depth studies and better understanding from biological and physical viewpoints. They open up fascinating avenues for further multidisciplinary research, investigation and interpretation.

References

[1] B. Dieny, R. Morel, H. Joisten, C. Naud, A. Nicolas, A. Visonà, P. Obeïd, S. Belin and F. Berger, Phys. Rev. Appl., 2025, 23, 13pp.
[2] A. Visonà, S. Cavalaglio, S. Labau, S. Soulan, H. Joisten, F. Berger, B. Dieny, R. Morel and A. Nicolas, Nanoscale Adv., 2025, 7, 219–230.
[3] S. Leulmi, H. Joisten, T. Dietsch, C. Iss, M. Morcrette, S. Auffret, P. Sabon and B. Dieny, Appl. Phys. Lett., 2013, 103, 5pp
[4] S. Leulmi, X. Chauchet, M. Morcrette, G. Ortiz, H. Joisten, P. Sabon, T. Livache, Y. Hou, M. Carrière, S. Lequien and B. Dieny, Nanoscale, 2015, 7, 15904–15914.
[5] C. Naud, C. Thébault, M. Carrière, Y. Hou, R. Morel, F. Berger, B. Diény and H. Joisten, Nanoscale Adv., 2020, 2, 3632–3655.
[6] S. Ponomareva, H. Joisten, T. Francois, C. Naud, R. Morel, Y. Hou, T. O. Myers, I. Joumard, B. Dieny and M. Carrière, Nanoscale, 2022, 14, 13274–13283.

Figures

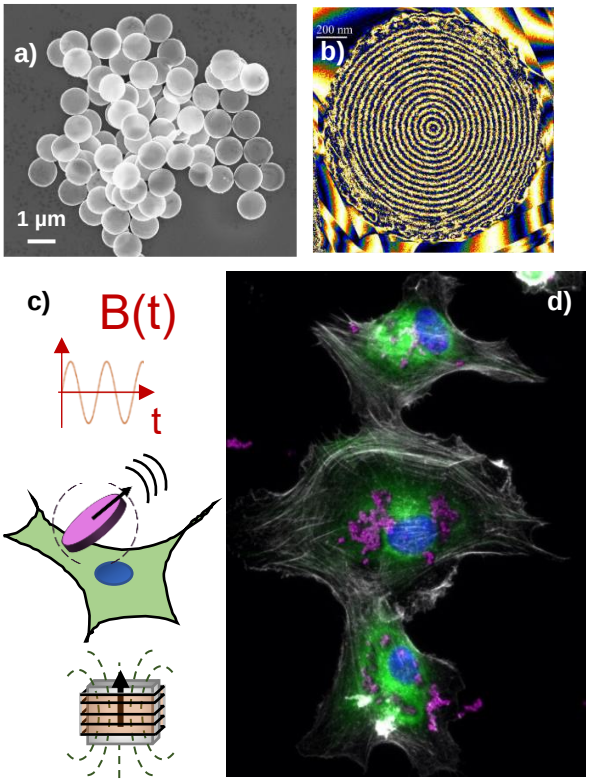

Figure 1. a) Magnetic particles - permalloy micro-disks of 1 µm in diameter, ~100 nm thick [3] - imaged by scanning electron microscopy (SEM). b) magnetic vortex state in a permalloy disk (Ø 1 µm), shown by electron holography (credit A. Masseboeuf [1]). c) sketch of the vibration of magnetic particle on a cell, induced by an alternating magnetic field at low frequency (2-20 Hz). d) Fluorescence microscopy image, highlighting the magnetic particles in or on U87-MG cells, after 24h of incubation, showing the actin filaments in white color, vimentin filaments stained in green color, nuclei in blue, magnetic particles in pink color.