Lock-in thermography: A new method for magnetic nanoparticles and the quantification of heat

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Magnetic nanoparticles (MNPs) and their ability to convert magnetic energy into heat are of explicit interest for several applications in biomedicine, in particular magnetic hyperthermia. The heating power of MNPs depends on their physico-chemical properties (e.g. size, colloidal stability and crystallinity) and external parameters such as magnetic field strength and frequency. However, precise evaluation of their heating power is non-trivial with conventional methods (e.g. fiberoptic cables, thermocouples and IR cameras) thus rendering comparative studies challenging. We propose a new method based on lock-in thermography to quantify the heating power of MNPs in a precise and reliable way. Nanoparticle suspensions are exposed to a modulated alternating magnetic field and their thermal signature is recorded with a synchronized IR camera. The signal is then processed and can be transformed into the heating slope.

Lock-in based analysis of the heating properties of MNPs has been particularly useful to:

1. Quantify their heating power in suspension, semi-solid and aggregate states. In particular to screen the thermal properties of nanoparticles with different sizes, crystallinities, coatings and stability.
2. Investigate sources of variability and errors related to the alternating magnetic field (e.g. field strength inhomogeneity and its effects on the heating power).

Overall, lock-in thermography is a new approach to precisely screen and analyze the heating power of different MNPs samples, facilitating comparative studies and the translation of these materials to the clinic.

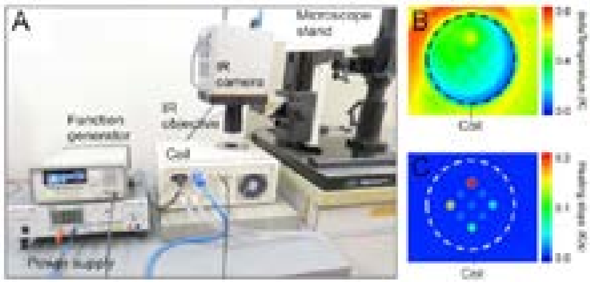

Figure 1: Lock-in thermography system for the quantification of heat generated by magnetic nanoparticles (A). Comparison between the sensitivity of a normal IR camera (B) and lock-in thermography (C): The temperature variations of MNP suspensions that are recorded by a normal IR camera (B) have a low resolution. The thermal signature of the same samples analyzed by lock-in thermography (C) allows an immediate and clear quantification of the MNPs heating properties.

Biography

Federica Crippa studied Biomedical Engineering at Politecnico of Milan (2008-2013). She graduated in Biomechanics and Biomaterials with a thesis titled 'Study of the AGEs effect on the mechanical properties of collagen fibrils through molecular models and experimental validation' developed between Politecnico of Milan and ETH Zurich. Afterwards Federica worked as Assistant Researcher in the lab of Prof. Jess G. Snedeker at Uniklinik Balgrist in Zurich, focusing on proteins micromanipulations and surface modification analysis. From June 2014, she joined the Bio-Nanomaterials group at the Adolphe Merkle Institute as a PhD student under the supervision of Prof. Alke Fink and Prof. Barbara Rothen-Rutishauser. Her main field of research involves synthesis and characterization of magnetic nanoparticles for hyperthermia and mechanobiology.

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