High time resolution thermometry on a magnetic nanoheater. A new tool for hyperthermia

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Abstract
Magnetic induction heating of nanoparticles has already been approved for hyperthermia therapy of cancer and other diseases. Nowadays the clinical treatment involves a direct injection of nanoparticles into the tumor and the application of a magnetic field until the temperature at 2 cm from the tumor is reaching 43 ^{o}C. The amount of nanoparticles to be injected for this purpose is very high and that means a long process until the nanoparticles are cleared from the body. Thus, the development of local intracellular hyperthermia involving a smaller number of particles would be very desirable. In order to make this strategy effective an adequate monitoring of the nanoheaters local temperature will be required. Here we present a single magnetic nanoparticle [1] that incorporates a luminescent molecular thermometer [2]. The temperature readout is optical and the thermometric probes are Eu^{3+}/Tb^{3+} lanthanide complexes encapsulated in the copolymer coating, around the iron oxide magnetic core. The thermometer shows an outstanding performance in terms of: sensitivity (5.8%·K^{-1} at 296 K), uncertainty (0.5 K), readout reproducibility (>99.5%), and fast time response (0.250 s). Experiments of time-resolved thermometry under an AC magnetic field reveal the existence of an unexpected temperature gradient between nanoheaters and surrounding media. A proof of concept of temperature mapping has been realized on cells that were incubated with the nanoparticles [3], (Fig 1). The heater/thermometer reported here shows great potential for the design of hyperthermia therapies based on localized manipulation of heat flows and short application times. In this way, local energy supply which is not immediately dissipated at the surrounding media could be enough to induce irreversible intracellular damage in tumor cells within a short time period, while maintaining the neighboring tissue temperature unchanged [4]

References

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Figures

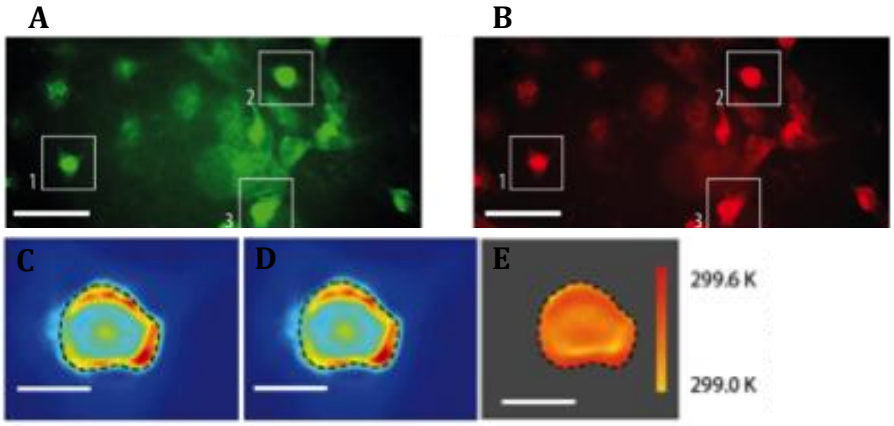

Figure 1. Imaging of Tb^{3+} (A) and Eu^{3+} (B) emissions from cell-internalized nanoparticles. Scale bars are 40 µm. Pseudocolour maps of spot 1 in Fig A&B illustrating the co-localization of the Tb^{3+} (C) and Eu^{3+} (D) emissions, temperature map (E) computed from this emissions at every pixel, and (D) histogram of the temperature distribution near the cell nucleus. Scale bars correspond to 10 µm.