Nanoparticles for two-photon intracellular thermal sensing.

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Thermal sensing at the micro and nano scales is one of the most challenging tasks that nanotechnology is nowadays facing. It is required to get a full understanding and characterization of photonic and electrical devices under real operation conditions where relevant local thermal loadings can take place as a consequence of either Joule dissipation or optical activation of non-radiative processes. In biological systems (such as tissues and individual cells) the exact knowledge of the local temperature is essential since it is known that temperature is one of the most important parameter determining the dynamics of the system. During the last years different approaches have been used to achieve thermal sensing with high spatial resolution while ensuring enough temperature sensitivity. Several techniques (such as thermal scanning and molecular fluorescence microscopies) have been already shown to satisfy both requisites simultaneously. Nevertheless, these techniques have limited applications in which, for example, three dimensional thermal imaging or in depth measurements is required.

Very recently a new approach to the thermal imaging at the nanoscale has come into sight. This is based on the incorporation of fluorescent nano-thermometers into the system to be thermally scanned. Fluorescent nano-thermometers are fluorescent nano-particles whose luminescence properties are strongly determined by the local temperature of the environment in which they are hosted. Any luminescent nano-particle whose luminescent properties (in terms of intensity, spectral position, spectral shape or decay time) are strongly dependent on temperature can be considered as a nano-thermometer. Nevertheless, the real application for thermal imaging and sensing in photonic, electrical and biological systems requires additional features such as possibility of multi-photon excitation (for high spatial resolution experiments), possibility of being dispersible in water (for easy incorporation into cells), good thermal stability and, finally, high fluorescence quantum efficiencies for high contrast imaging.

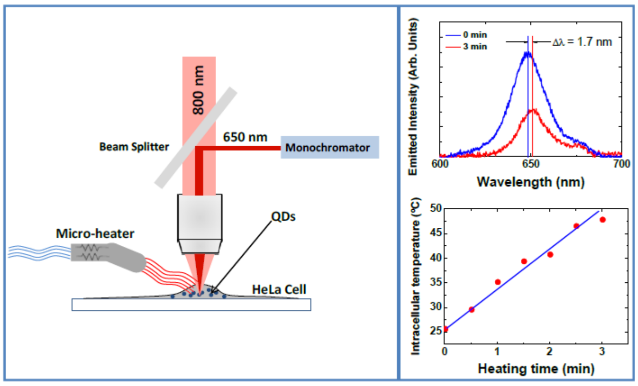

Figure 1.- Experimental set-up and experimental results on the intracellular thermal sensing using two-photon emitting QDs.

In this work the fluorescence properties of two-photon emitting nano-particles have been systematically investigated as a function of temperature in the 20-70 ºC range. We have focused our attention in two different types of two-photon emitting nano-particles: Semiconductor Quantum Dots and double doped Erbium and Ytterbium doped nano-crystals. From the obtained results the potential thermal sensitivity of these two types of nano-particles has been discussed and the mechanisms at the basis of this thermal sensitivity elucidated. We have concluded that in the case of rare earth doped nano-crystals, thermal sensitivity is based on temperature induced changes in the population of excited states. On the other hand, in the case of Semiconductor Quantum Dots, thermal sensitivity is caused by a complex competition between different mechanism including temperature induced changes in the energy gap of bulk material, thermal induced dilatation and changes in the confinement energy. Although complexes, all these process give the opportunity of improvement and tailoring of the potential thermal sensitivity.

We also include in this work experimental evidence of the potential application of these systems for real intracellular thermal sensing by optical methods. Figure 1 shows a simple experiment designed to test the ability of CdSe Quantum Dots for direct measuring in intracellular thermal loading induced in cancer cells by external air fluxes.