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Luminescent and Raman thermometers for determining local temperatures at the nanoscale

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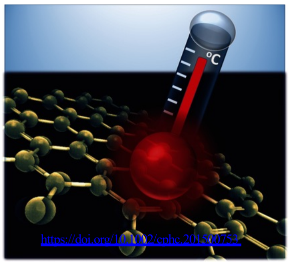
INTRODUCTION & AIM

The determination of **local temperature at the nanoscale** is a key point in obtaining control over physical, chemical, or biological processes, since temperature is an important parameter influencing their behavior. The field of nanothermometry has recently been growing very fast; many different strategies have already been tested and start to be applied in real situations, but the need of developing well-defined protocols for accurate temperature determination is still an open topic.

Realization of new materials:
- attainment of high sensitivity, related to the change in experimental observable as a function of the variation of the temperature T
- minimum temperature resolution, defined as the minimum variation of temperature that can be resolved.

For biomedical applications:
- biocompatible with the complex biological environment
- activated using non-invasive techniques, light in the near-infrared region, the biological window.

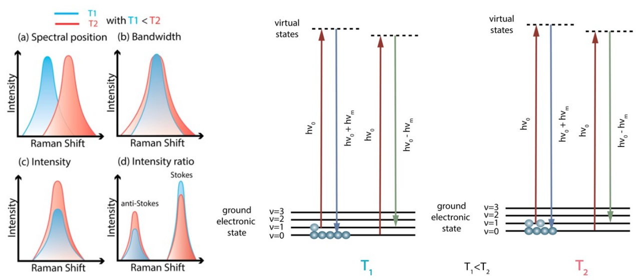


The goal of this work is the investigation of Raman active biocompatible materials, and new materials, which gather Raman spectroscopy and luminescence functionalities, for the contactless temperature sensing at the nanoscale.

METHOD

Raman Optical Nanothermometers

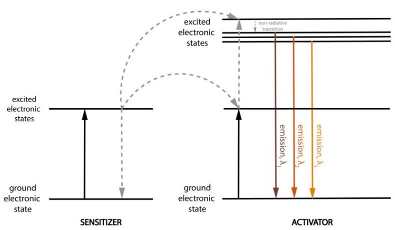
Variation of the Raman spectrum features caused by a temperature change.
Red lines correspond to the temperature T2, which is higher than T1, relative to the blue lines.

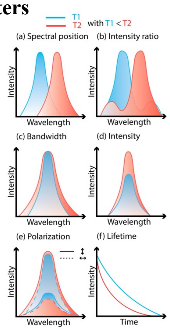


Schematic representation of anti-Stokes/Stokes methodology for temperature detection.
The result of the system interaction with the laser ($h\nu_0$) is the scattering of Stokes ($h\nu_S = h\nu_0 - h\nu_m$) and anti-Stokes ($h\nu_{aS} = h\nu_0 + h\nu_m$) photons.
When T=T_1, the lower temperature, the first vibrational state of the ground state (v = 1) is poorly populated (left panel), whereas when the temperature is raised to T2, the first vibrational state becomes more populated (right panel).

Fluorescence Optical Nanothermometers

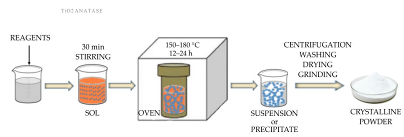
Level diagram of a system in which a ETU mechanism occurr, with an initial absorption of low-energy photons by the sensitizer, and the final upconversion emission of high- energy photons by the activator.

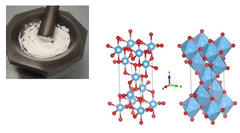


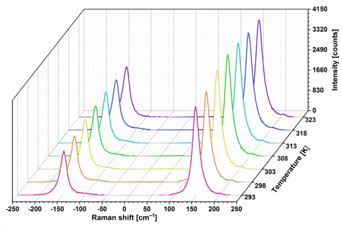


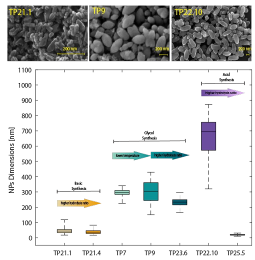
Schematic representation of the temperature effect on the features of a generic emission spectrum.
Red lines correspond to the temperature T2, which is higher than T1, relative to the blue lines.

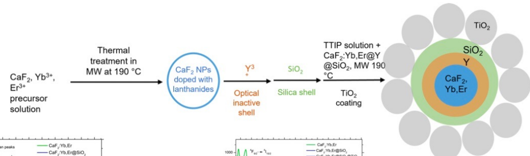
RESULTS & DISCUSSION

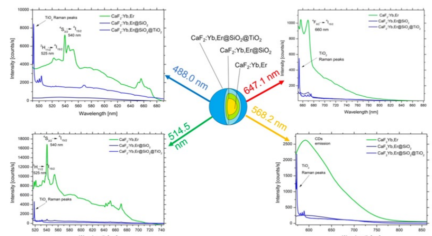






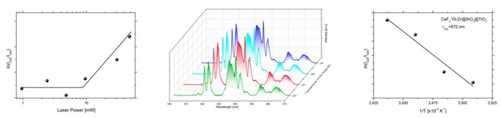


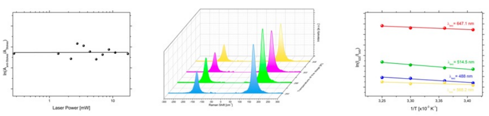




For the visible wavelengths investigated, all the principal anatase Raman peaks are identified in the nanocomposite sample.

Er^{3+} shows a strong up-conversion emission in the visible upon excitation at 972 nm





Anatase E_g Raman mode @ 150 cm^{-1} investigated by exciting in the visible, at 488, 514.5, 568.2 and 647.1 nm.

CONCLUSION

The outcomes constitute a significant step forward in the field of optical nanothermometry and introduce innovative ways to use multifunctional materials in nanoscale temperature sensing. Looking ahead, the future perspectives of this project will direct the efforts toward refining and enhancing the dual-mode nanothermometry system.

FUTURE WORK / REFERENCES

The versatile CaF_2 : Yb,Er@SiO_2 −TiO_2 nanocomposite has the potential to combine the most advantageous features of upconversion and Raman temperature probes, resulting in a highly sensitive and flexible approach to temperature measurement.

Future research could explore the possibility of achieving simultaneous upconversion and Raman nanothermometry using the same excitation wavelength.