

Fine tuning of the emission properties of nano-emitters in multilayered structures by deterministic control of their local photonic environment

Alberto Jiménez-Solano, Juan F. Galisteo-López and Hernán Míguez

Multifunctional Optical Materials Group. Instituto de Ciencia de Materiales de Sevilla. Consejo Superior de Investigaciones Científicas-Universidad de Sevilla. C/ Américo Vespucio 49, 41092 Sevilla, Spain

alberto.jimenez@csic.es

Abstract

Porous nanostructured photonic materials in the shape of periodic multilayers have demonstrated their potential in different fields ranging from photovoltaics^[1] to sensing^[2]. On the one hand their porosity makes it feasible to infiltrate them with an electrolyte or a polymeric matrix (which allows their use in dye sensitized solar cells or as flexible films^[3]). On the other, the possibility of controlling their refractive index profile via their porosity or the choice of materials, strongly affects the way light is transported or generated within them.

When applications dealing with light absorption or emission are considered, knowledge on how the local density of states (LDOS) is distributed within them is mandatory^[4] in order to realize a judicious design which maximizes light matter interaction. In order to do so, access to a photonic probe which senses the LDOS at different spatial positions is desired. Such probe must have reduced dimensions (in order to achieve a high spatial resolution in the mapping of the LDOS) and should lend itself to be incorporated in the fabrication procedure in such a manner that its spatial position within the sample can be controlled.

In this work we report a detailed study of how dye doped polystyrene nanospheres constitute an effective LDOS probe to study its distribution within nanostructured photonic media. Nanospheres with a diameter of 25 nm are incorporated in the fabrication procedure of nanostructured photonic multilayers (through a combination of spin and dip-coating with suspensions of oxide nanoparticles) in such a way that the high optical quality of the fabricated structure is maintained. Introducing the polymeric spheres at different stages of the fabrication process allows placing them at several positions of the structured sample. A combined use of photoluminescence spectroscopy and time resolved measurements are used to optically characterize the samples. While the former shows how depending on the probe position its PL intensity can be enhanced or suppressed, the latter allows to probe the LDOS changes within the sample, monitored via changes in its lifetime. We demonstrate how information on the local photonic environment can be retrieved with a spatial resolution of 25 nm (provided by the probe size) and relative changes in the decay rates as small as ca. 1%, evidencing the possibility of exerting a fine deterministic control on the photonic surroundings of an emitter.

References

- [1] C. López-López, S. Colodrero, M. E. Calvo and H. Míguez, *Energy Environ. Sci.*, **23** (2013), 2805.
- [2] A. Jiménez-Solano, C. López-López, O. Sánchez-Sobrado, J. M. Luque, M. E. Calvo, C. Fernández-López, A. Sánchez-Iglesias, L. M. Liz-Marzán and H. Míguez. *Langmuir*, **28** (2012), 9161.
- [3] J. R. Castro-Smirnov, M. E. Calvo and H. Míguez, *Adv. Funct.Mater*, **23**, (2013), 2805.
- [4] N. Danz, R. Waldhäusl, A. Bräuer and R. Kowarschik, *J. Opt. Soc. Am. B*, **19** (2010), 412.

Figures

