**Andreia Araújo[1]*,** Ana Pimentel[1], Maria João Oliveira[1,2], Manuel J. Mendes[1], Ricardo Franco[2], Elvira Fortunato[1], Hugo Águas[1] and Rodrigo Martins[1]**

[1]i3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, Universidade NOVA de Lisboa and CEMOP/UNINOVA, Campus de Caparica, 2829-516 Caparica, Portugal

[2] REQUIMTE, UCIBIO, Departamento de Química, Faculdade de Ciências e Tecnologia, Universidade NOVA de Lisboa, 2829-516 Caparica, Portugal

*andreiajoiaraujo@hotmail.com, **rm@uninova.pt

# Direct growth of plasmonic nanorod forests on paper substrate for low-cost flexible 3D SERS platforms

When metal nanoparticles (MNPs) are excited by electromagnetic radiation, their free electrons collectively oscillate, resulting in a localized surface plasmon resonance (LSPR). At the LSPR, the MNPs can produce a particularly intense localized scattered near-field and propagating far-field. MNP far-field scattering has recently been considered a promising light-trapping mechanism since it can improve the optical path length in photovoltaic devices [1,2]. Surface-enhanced Raman spectroscopy (SERS), on the other hand, takes advantage of near-field scattering, which is mainly associated to the enhanced local electric field intensity in the MNPs vicinity [3]. Paper substrates, coated with ZnO nanorods (NRs) decorated with Ag nanoparticles (NPs), allowed the production of inexpensive, highly-performing and extremely reproducible three-dimensional (3D) SERS platforms (Figure 1). The ZnO NRs were synthesized by a simple, fast and low-temperature hydrothermal method assisted by microwave radiation and made SERS-active by decorating them with a dense array of Ag NPs deposited via a single-step thermal evaporation technique. Using Rhodamine 6G (R6G) as probe molecule, with an amount down to $10^{-9}$ M, the SERS substrates allowed a Raman signal enhancement of $\approx 10^{7}$. The contribution of the inter-Ag-NPs gaps for 3D geometry, ZnO NRs orientation and the large sensing area allowed by the NRs scaffolds, were determinant factors for the significant Raman enhancement observed. The results demonstrate that plasmonic nanorod forests, covered with Ag NPs, are efficient SERS substrates with the advantages of being recyclable, flexible, lightweight, portable, biocompatible and extremely low-cost.

## References

[1] Araújo A, Mendes M J, Mateus T, Vicente A, Nunes D, Fortunato E, Águas H and Martins R 2016 Influence of the substrate on the morphology of self- assembled Ag nanoparticles by rapid thermal annealing J. Mater. Chem. C 1–22.

[2] Morawiec S, Mendes M J, Mirabella S, Simone F, Priolo F and Crupi I 2013 Self-assembled silver nanoparticles for plasmon-enhanced solar cell back reflectors: correlation between structural and optical properties. Nanotechnology 24 265601–12.

[3] Araújo A, Caro C, Mendes M J, Nunes D, Fortunato E, Franco R, Águas H and Martins R 2014 Highly efficient nanoplasmonic SERS on cardboard packaging substrates. Nanotechnology 25 415202.

## Figures

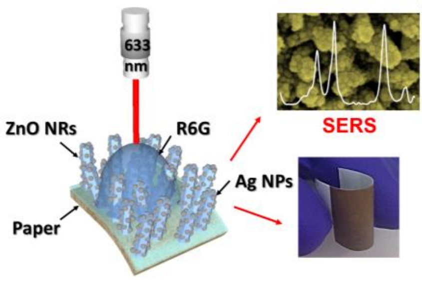


**Figure 1:** Scheme array of plasmonic nanorod forests on paper substrate for low-cost flexible 3D SERS .