Nanoconcavities-Patterned Aluminum Platforms for Advanced SERS Detection

Elisabet Xifre-Perez, Gohar I. Dar, Lluis F. Marsal
Departament d'Enginyeria Electrònica, Elèctrica i Automàtica, Universitat Rovira i Virgili, Avda. Països Catalans 26,, Tarragona, Spain
Lluis.masal@urv.cat

The detection of ultra-low concentrations of target analytes is a critical requirement in diverse fields such as food safety, medical diagnostics, and environmental monitoring [1,2]. In this work, we present robust, reproducible, rapid, and cost-effective methods for the fabrication of Surface-Enhanced Raman Scattering (SERS) active platform, based on the homogeneous nanopatterning of aluminum surfaces [3,4].
The nanopatterned aluminum substrates obtained by self-ordered nanoporous anodic alumina [5-7], enable the uniform and repeatable distribution of metallic nanoparticles, resulting in extremely high SERS enhancement factors for the detection of various analytes, including small molecules and pharmaceutical compounds [8–11]. As shown in Figure 1a, the nanopatterns consist of highly ordered nanoconcavities with well-controlled shape and size. These concavities are uniformly decorated with self-organized metallic nanoparticles formed by sputter deposition followed by thermal annealing, as illustrated in Figure 1b.
A comprehensive study is presented on the influence of deposition and annealing parameters on the morphology of the nanoparticles, including their size, shape, and spatial distribution. These parameters are key to tuning the plasmonic properties of the substrates and, consequently, their sensing performance.
The resulting nanostructured platforms have demonstrated outstanding SERS sensitivity and reproducibility, making them highly promising for the detection and quantification of a wide range of analytes in real-world applications.

Acknowledgments
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 945413, the Universitat Rovira i Virgili (URV), the Spanish Ministerio de Ciencia e Innovación (MICINN/FEDER) PDI2021-128342OB-I00, the Agency for Management of University and Research Grants (AGAUR) ref. 2021-SGR-00739, COST Action 20126-NETPORE and the Catalan Institution for Research and Advanced Studies (ICREA Academia).

References

[1] Z. Ling, L. Yang, W. Zhang, T. Yao, H. Xu, Food Safety and Health, 2 (2024) 72.
[2] C.D. Flynn, D. Chang, A. Mahmud, et al., Nature reviews bioengineering, 1 (2023) 560.
[3] J. Domagalski, E. Xifre-Perez, L.F. Marsal, *Nanomaterials*, 11 (2021) 430.
[4] E. Xifre-Perez, J. Ferre-Borrull, L.F. Marsal, Advanced Materials Technologies, 7 (2022) 2101591.
[5] A. Santos, J. Ferré-Borrull, J. Pallarès and L. F. Marsal, Physica Status Solidi (a), 208 (2011) 668-674.
[6] A. Santos, L. Vojkuvka, M. Alba, V. S. Balderrama, J. Ferré-Borrull, J. Pallarès and L. F. Marsal, Physica Status Solidi (a), 209 (2012), 2045-2048.
[7] G Macias, J Ferré-Borrull, J Pallarès, LF Marsal, Nanoscale Research Letters, 9 (2014) 315.
[8] G.I. Dar, E. Xifre-Perez, L.F. Marsal, J. Materials Chemistry C, 12 (2024) 17305.
[9] G.I Dar, E. Xifre-Perez, L.F. Marsal, Advanced Materials Interfaces, 10 (2023) 2300560.
[10] G.I Dar, E. Xifre-Perez, L.F. Marsal, Nanophotonics (in press) (2025) DOI: 10.1515/nanoph-2025-0108
[11] G.I Dar, E. Xifre-Perez, A. Santos, L.F. Marsal, View, 6 (2025) 20240077.

Figures

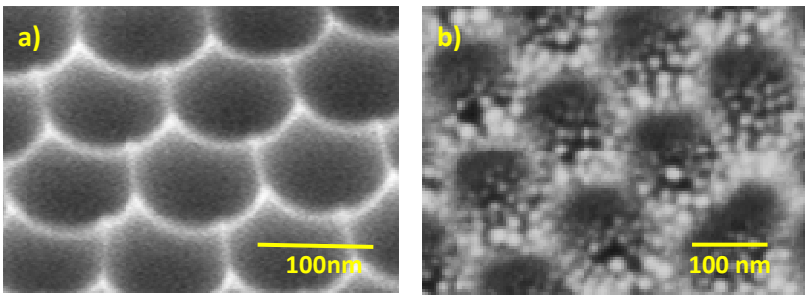

Figure 1: FESEM images of the nanoconcavities-patterned aluminium substrates without (a) and with Au nanoparticles decoration (b).