MoS_2 structures modified by laser irradiation for semiconductor-SERS sensing

Luisa D'Urso [1,*], Antonio Brancato[1], Marcello Condorelli[1], Vittorio Scardaci[1], Enza Fazio[2], Carmelo Corsaro[2], Giuseppe Compagnini[1]

[1] Department of Chemical Sciences, University of Catania, V.le A. Doria 6, I-95125 Catania, Italy
[2] Department of Mathematical and Computational Sciences, Physics Science and Earth Science, University of Messina, Viale F. Stagno D'Alcontres 31, I-98166 Messina, Italy

*Corresponding author email: ldurso@unict.it

Molybdenum disulfide (MoS_2) is a typical 2D-material attracting in the last years great interest for photocatalysis, optoelectronic and sensing applications. In the field of the chemical sensing, semiconductor surface-enhanced Raman scattering (SERS) has attracted more and more attention due to the possibility to overcome some deficiencies of noble metal nanostructures. A key goal in the employ of semiconductors like 2D-MoS_2 for SERS, is the improvement of the chemical mechanism (CM) of enhancement, mainly based on charge transfer phenomena. Recent progresses in the sensitivity were reported for defective MoS_2 nanosheets and for complex architectures, like MoS_2-nanoflowers [1, 2]. However, MoS_2 layers can easily suffer from aggregation phenomena that negatively influence the CM of enhancement. In this respect, hierarchical MoS_2-based nanostructures provide a hopeful approach to overcome the problem of the self- aggregation, as they are characterized by more stable structures with high chemical sensitivity. Here, MoS_2 nanosheets were proper modified by laser beam irradiation in aqueous dispersion. This is an easy, green and contaminant-free approach able to induce significant structural modifications. Highly defective MoS_2 layers and hierarchical architectures, like flower, tube and assembled lamellar structures, were obtained by a Nd:YAG nanosecond pulsed laser and were chemically characterised by XPS, UV and PL spectroscopies. The morphology of samples was assessed by scanning transmission electron and atomic force microscopy. SERS properties were studied using the 4-mercaptobenzoic acid (4-MBA) as a standard molecule. By using a Micro-Raman spectrometer, it was possible to find quickly isolated hierarchical structures and study the signal enhancement of the surface adsorbed analyte. Different chemical sensitivities were found as a function of the shape and composition and were attributed to different contributions: (a) the formation of a 1T MoS_2 phase, (b) the high surface area of the produced structures and (c) the presence of laser-induced defects. The as-developed strategy may therefore open up interesting perspectives for designing semiconductor materials in the field of SERS sensing.

Acknowledgements:
The authors L.D. and V.S. acknowledge funding and support from by European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022). The authors L. C., L. D., G. C., gratefully acknowledge to PRIN 2022 PNRR ELATED. PON Innovazione e Green DM 1062 is acknowledged by M.C. This work was supported by PON project Bionanotech Research and Innovation Tower (BRIT) financed by the Italian Ministry for Education.

References: [1] Ying Yin et al. Adv. Funct. Mater. 2017, 27, 1606694; [2] Jaspal Singh et al. Journal of Alloys and Compounds 849 (2020) 156502.