

MoO₃-based metasurfaces for enhanced sensing in the mid-infrared

R. Macaluso¹, M. Mercurio², V. Mocella³, K. Caicedo³, V. Aglieri⁴, A. Toma⁴, D. Persano Adorno⁵ and M. C. Larciprete²

1. Department of Engineering, University of Palermo, Viale delle Scienze (Bldg. 9), 90128 Palermo, Italy

2. Department of Basic and Applied Sciences, Sapienza University of Roma, Via A. Scarpa 16, 00161 Roma, Italy

3. Institute of Applied Sciences and Intelligent Systems, National Research Council, Naples, Italy

4. Clean Room Facility, Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy

5. Department of Physics and Chemistry 'E. Segré', University of Palermo (Bldg. 17) Palermo, Italy

Metasurfaces consist of subwavelength structures designed to efficiently manipulate light-matter interaction and achieve specific functionalities. When designed for the mid-infrared spectral region (2 – 25 μm), they can significantly enhance sensing capabilities due to the strong molecular vibration signatures present in this spectral window [1]. One of the most promising materials to build up metasurfaces for the mid-infrared is molybdenum trioxide (MoO₃). This is a polar material which supports surface phonon polaritons (SPhPs) in three different Reststrahlen bands (RBs) in the three orthogonal directions [2]. The strong radiation-matter coupling involved with the excitation of SPhPs can be used for sensing applications. The sensing wavelength window is however restricted to the MoO₃ RBs, which correspond to the wavelength range where the real part of the dielectric constant is negative. A way to extend this sensing wavelength window capability outside the RB is to exploit bound states in the continuum (BICs) by periodically patterning the MoO₃ film. In this case, also the transparency or low absorption region of the material, characterized by positive real dielectric constant, will be used [3].

In this work, to extend the operational wavelength range and functionality on the same polar material, we present a MoO₃-based metasurface consisting of regular patterns of microscale holes realized by focused ion beam (FIB) machining. The starting MoO₃ film, grown by pulsed laser deposition onto quartz substrate, was selected with high quality polaritonic response and its dielectric constant, retrieved by FTIR measurements, was used to design the BIC. Results show an enhanced sensing capability of the fabricated metasurface with respect to the corresponding planar MoO₃ film, highlighting its potential within the context of polymers and microplastic detection.

Acknowledgments

This work was financed by the European Union - Next Generation EU - PNRR M4 - C2 -investimento 1.1: PRIN 2022 PNRR (Directorial Decree n. 1409 - 14 September 2022, “Mid infrared metasurfaces and metamaterials for microplastic sensing applications”, Project code: P2022X4W28, CUP: B53D23028680001).

References

- [1] A. Tittl, A. Leitis, M. Liu, F. Yesilkoy, D.-Y. Choi, D. N. Neshev, Y. S. Kivshar, H. Altug, “Imaging-based molecular barcoding with pixelated dielectric metasurfaces”, *Science* **360**, 1105–1109 (2018).
- [2] M. C. Larciprete, D. Ceneda, C. Yang, S. A. Dereshgi, F. V. Lupo, M. P. Casaletto, R. Macaluso, M. Antezza, Z. M. Zhang, M. Centini, and K. Aydin, “Large-area polycrystalline α -MoO₃ thin films for IR photonics”, *J. Phys. D: Appl. Phys.* **57**, 135107 (2024).
- [3] S. Romano, G. Zito, S. Torino, G. Calafiore, E. Penzo, G. Coppola, S. Cabrini, I. Rendina, and V. Mocella, “Label-free sensing of ultralow-weight molecules with all-dielectric metasurfaces supporting bound states in the continuum”, *Photon. Res.* **6**, 726-733 (2018).