Polaritonic properties of MoO_3 thin films deposited on different substrates for mid-IR photonics

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Alpha-phase molybdenum trioxide (α-MoO_3) is a polar material capable of supporting surface phonon polaritons (SPhPs) in the mid-infrared spectral range. This makes it a promising candidate for the next generation of nanophotonic devices usable for sensing, light manipulation at subwavelength scales, and thermal management. MoO_3's best polaritonic properties are achieved by using exfoliated flakes. They result, however, difficult to handle for practical applications, and other fabrication techniques, including pulsed laser deposition (PLD) are used to obtain large area MoO_3 films. PLD is a versatile and low-cost deposition technique which has already been employed for the deposition of α-MoO_3 films at relatively low temperatures (400 -500 °C), compared with other techniques [1,2]. Normally, one of the most used substates for MoO_3 deposition is quartz, probably because of its low cost and abundance in nature. Quartz has, however, a limited transmittance window in the infrared spectrum (up to about 3 μm). This means that longer wavelengths, which are very interesting for the sensing of organic or biologic molecules, will be absorbed. It is interesting therefore to explore the possibility of employing other substrates, with a longer transmittance window in the mid-infrared. Two very interesting substrates to this end are calcium fluoride (CaF_2) and barium fluoride (BaF_2). The first one has a transmittance window up to about 8 μm, whilst the second one can reach even 10 μm wavelength keeping a transmittance higher than 90% [3].

In this work we present a comprehensive comparison between MoO_3 films deposited onto quartz, CaF_2 and BaF_2 substrates. All films were prepared under the same conditions (450 °C, 10^{-1} mbar) by PLD. After deposition, structural and morphological characterization was carried out to assess the crystalline phase of MoO_3 films and their grain size, respectively. Afterwards, FTIR characterization was performed to make a comparison between the polaritonic properties of the MoO_3 films deposited on the three different substrates. Results show that all MoO_3 films exhibit the alpha phase regardless of the substrate. Moreover, the same phonon resonances observed in the film deposited onto quartz can be found also on the other films, with a certain different intensity modulation against light polarization. This means that the use of CaF_2 and BaF_2 substrates does not entail any disadvantages compared to quartz but rather allows the exploitation of the high transmittance of these substrates, essential in transmission spectroscopy.

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References

[1] 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).

[2] A. Bile, D. Ceneda, M. Centini, F. V. Lupo, D. Persano Adorno, R. Macaluso, K. Aydin and M. C. Larciprete, "Thermo-optical properties of α-MoO3 thin films in the mid-infrared and phonon frequency shift", J. Phys. Photonics **7**, 025015 (2025).

[3] E. Mitri, A. Pozzato, G. Coceano, D. Cojoc, L. Vaccari, M. Tormen, G. Grenci, "Highly IR-transparent microfluidic chip with surface-modified BaF_2 optical windows for Infrared Microspectroscopy of living cells", Microelectronic Engineering **107**, 6-9 (2013).