Polycrystalline MoO_3 films fabricated by pulsed laser deposition for infrared polarization manipulation.

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Abstract. We performed infrared optical characterization of polycrystalline MoO_3 films deposited by pulsed laser deposition on fused silica substrates. Several samples have been fabricated using different parameters such as temperature and oxygen pressure. Our analysis shows that under appropriate fabrication conditions it is possible to obtain a dominant α-phase film, with a well-defined, normal to surface (z-axis) orientation. These results are confirmed by reflection spectra performed at 45° incidence angle revealing a strong modulation of the sharp z-phonon Reststrahlen band as a function of the incident field linear polarization.

1 Introduction

The development of a photonic platform in the mid infrared range is motivated by applications, such as detection of traces of biomolecules and harmful/explosive substances, passive radiative cooling as well as devices for thermal imaging and for medical diagnostics. Recent promising solutions are based on the exploitation of polar materials [1] including ultra-thin van der Waals (vdW) materials such as MoO_3, MoS_2, Ga_2O_3, hBN [2-3]. Several works reported on the great potential of polar materials for IR sensing applications up to terahertz (THz) regime [4-7] and for the realization of compact IR photonic devices [8-10]. Among vdW materials, Molybdenum trioxide (α-MoO_3) is attracting great attention [11] as it supports surface phonon polaritons (SPhPs) in three different wavelength bands for the three orthogonal directions (range 10-20 μm) being a biaxial natural hyperbolic material [12-14].

Despite this huge natural potential of the material, the development of a new highly versatile and compact MoO_3 based platform for IR photonics is hampered by the lack of availability of good quality scalable films and/or multilayer stacks. According to literature, MoO_3 for IR photonics and polaritonics is mostly used in the form of crystalline flakes, coming from bulk MoO_3 crystals through a complex mechanical exfoliation process followed by a transfer to an appropriate substrate. The realization of single alpha phase, oriented, large area MoO_3 film is still an open technological challenge.

2 Discussion

In this work we report on fabrication and characterization of polycrystalline MoO_3 films deposited by pulsed laser deposition (PLD) on quartz substrates. Our results show that PLD can be properly adapted to obtain α-phase MoO_3 films at reasonably low temperatures (e.g. 500 °C) with a considerable strong off plane anisotropy related to a well oriented z-axis. All the samples have been analysed by X-ray diffraction (XRD) and atomic force microscopy (AFM) to confirm the orthorhombic α-phase of MoO_3 films, the polycrystalline nature and assess films morphology.
Optical characterization in the IR has been carried out by Fourier-transform infrared spectroscopy (FT-IR) in reflection mode with an incidence angle of 45° and a rotating linear polarizer. As an example we report in Fig. 1 and Fig. 2 reflection spectra for two samples obtained with different fabrication conditions exhibiting very different optical properties in the IR range.

In Fig. 1 we show the reflection spectrum of a 500 nm-thick MoO_3 film deposited on fused silica substrate 500° C and 10^{-1} mbar oxygen pressure. It can be noticed a strong tunable peak around 1000 cm^{-1} related to phonon modes along the z-axis. High reflectivity is obtained for p-polarized input field corresponding to a strong z-component of the e.m. signal. The reflection peak

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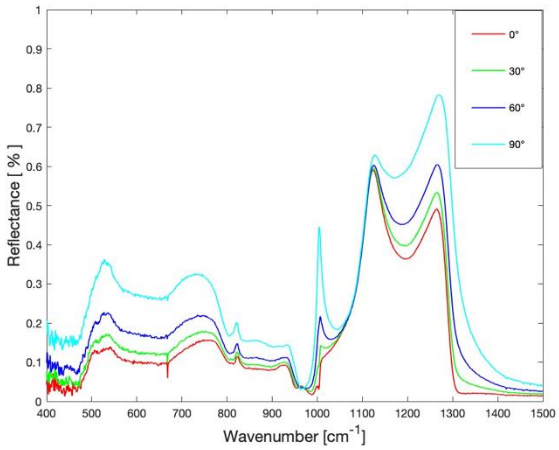

Fig. 1. FTIR reflection spectrum measured at an angle of incidence of 45° as a function of the different input polarization on MoO_3 film 500 nm-thick, grown by PLD on fused silica substrate, T=500°C, $P_{O2}=10^{-1}$ mbar.

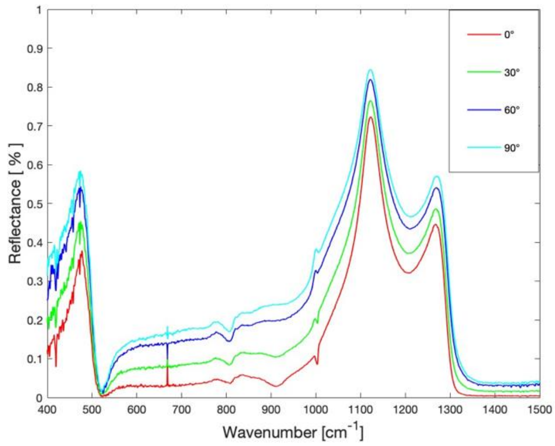

Fig. 2. FTIR reflection spectrum measured at an angle of incidence of 45° as a function of the different input polarization on MoO_3 film 500 nm-thick, grown by PLD on fused silica substrate, T=400°C, $P_{O2}=10^{-1}$ mbar.

is strongly suppressed for s-polarized incident field, corresponding to in-plane fields components. This is a signature of a well oriented z-axis of the sample. On the other hand, the spectrum depicted in Fig. 2 does not show modulation of the reflection peak as a function of the input polarization. In this case the 500 nm-thick MoO_3 film has been fabricated under the same oxygen pressure conditions as the previous sample but at lower temperature (400°C). XRD shows that both films are polycrystalline and exhibit only the orthorhombic α-phase. This means that, despite the presence of only the single alpha phase, the MoO_3 film grown at 400 °C does not present any peak modulation.

3 Conclusions

We have fabricated and characterized MoO_3 films deposited by PLD. Our analysis shows that under proper fabrication parameters a dominant α–phase is obtained, and a good alignment of the z-crystal axis is achieved. We also show that the samples fabricated with different deposition parameters do not display the same behaviour. Thus our results highlight a path to fabricate large scale and low cost MoO_3 films for infrared polarization management devices in the IR.

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