

β -Ga₂O₃ Deposited via MOCVD for Mid-Infrared Polarization Control

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Abstract. We performed infrared optical characterization of polycrystalline β -Ga₂O₃ films, in the 10-18 μ m range, deposited by metal organic chemical vapor deposition on sapphire substrates. Our results show that it is possible to obtain a dominant β -phase film, with a well-defined, normal to surface z-axis orientation. These results are confirmed by reflection spectra performed at 45° incidence angle which reveals a z-phonon Reststrahlen band as a function of the incident field linear polarization.

1 Intro

Optical anisotropy is at the basis of the strong field localization that allows the excitation of surface waves, polaritons [1]. In the infrared range these waves are called Surface Phonon Polaritons and are excited by the coupling between electromagnetic fields and lattice vibrations, phonons [2]. Phonon polaritons allow a sub-wavelength confinement of light, making the properties of the surface extremely sensitive to the presence of impurities or substances that can then be detected. The use of low symmetry crystals gave the opportunity to create polarization control systems with applications in imaging and spectroscopy [3-4].

The growing demand for sensors in the infrared range in recent years has given impetus to research new materials and among these, although much studied in the visible, Gallium Trioxide (Ga₂O₃) is having relevance.

Ga₂O₃ is known as a polymorphic material that can crystallize in several forms. Among these, β -Ga₂O₃, with monoclinic structure, is the most thermodynamically stable phase at standard temperature and pressure. Lately shear polaritons have been demonstrated in this phase [5]. However, application development requires good-quality, monocrystalline films in order to achieve relative anisotropy, which is difficult to obtain.

2 Discussion

In this work we report on the infrared optical characterization of β -Ga₂O₃ samples, made with metal organic chemical vapor deposition (MOCVD) technique, on sapphire substrate.

Our results show that samples deposited by MOCVD have a good β -phase Ga₂O₃ with a considerably strong off-plane anisotropy related to a well-oriented z-axis.

Optical characterization in the IR has been carried out by Fourier-transform infrared spectroscopy (FT-IR) in reflection mode with an incidence angle of 15° and 45° and a rotating linear polarizer for the incoming light.

The theoretical study was carried out by a Matlab script [6] with β -Ga₂O₃ data for the dielectric constant, showing

that the low crystalline symmetry of the β phase leads to a strong polarization rotation of the reflected field that could be used to manipulate the polarization state of an incoming IR radiation.

As an example of the experimental results, we show in Fig. 1 and the reflection spectrum of the 450 nm-thick Ga₂O₃ film deposited on sapphire substrate for the 45° incident angle at different incoming polarization.

Whilst for the theoretical calculations we report the spectrum at 45° in Fig. 2 for the β -Ga₂O₃ on sapphire substrate in Fig.2.

Making a comparison between Fig. 1 and Fig. 2, we can see a good agreement between the experimental and theoretical results, which is a proof that a good β -phase Ga₂O₃ has been deposited.

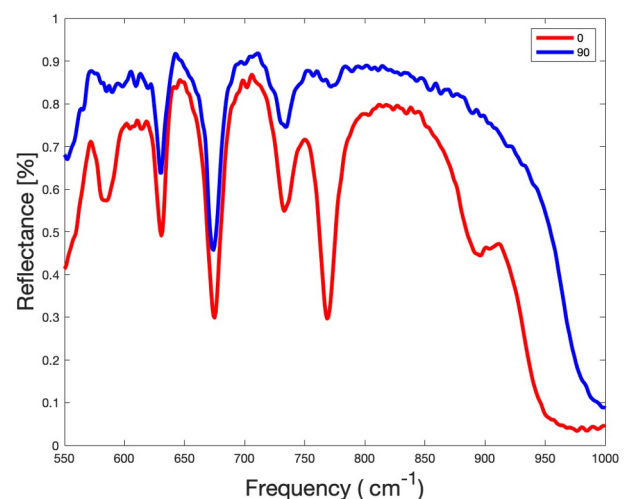


Fig. 1. FTIR reflection spectrum measured at an angle of incidence of 45° as a function of the different input polarization angles on β -Ga₂O₃ film 450 nm-thick, grown by MOCVD on sapphire substrate. (0° stands for p-polarization, 90° stands for s-polarization)

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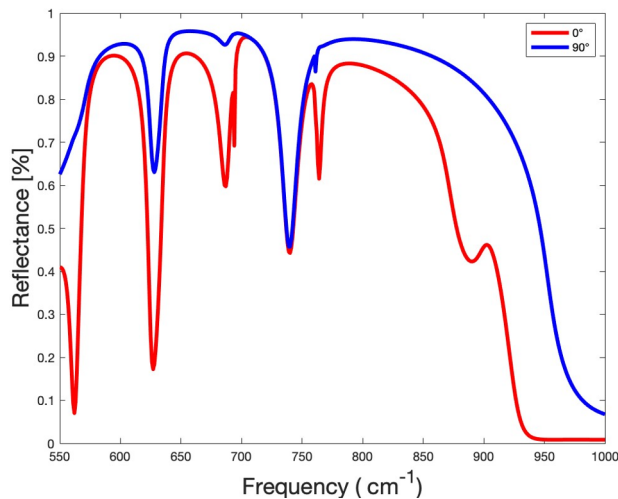


Fig. 2. Simulated reflection spectrum at an angle of incidence of 45° as a function of the different input polarizations on β - Ga_2O_3 film 450 nm-thick on sapphire substrate. (0° stands for p-polarization, 90° stands for s-polarization)

We note that only the peak at 770 cm^{-1} , related to excitation of the z-phonon, is strongly polarization sensitive. The other ones are weakly affected by the input polarization. The reason could be addressed with polycrystallinity, meaning that the x and y axes of the sample are randomly oriented.

Both measurements at 15° and 45° show a good orientation of the z-axis of the sample, as it can be read from the tunability of the z-phonon peak for the different input polarizations.

3 Conclusion

We have optically and theoretically analyzed β - Ga_2O_3 samples deposited via MOCVD.

Our analysis shows that under proper fabrication conditions a dominant β -phase is obtained, and a good alignment of the z-crystal axis is achieved.

Our results prove that these films fabricated with MOCVD can be used for infrared polarization control devices in the IR.

References

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