# Comparative study of the optical properties of α- and β-phase $Ga_2O_3$

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Gallium oxide ($Ga_2O_3$) is a wide bandgap semiconductor with a bandgap of 4.5-5.3 eV. Due to being wide bandgap, the material has a large breakdown voltage [1], which is a crucial characteristic for its usage in optoelectronic applications. More specifically $Ga_2O_3$ is a promising candidate for high power electronics and solar blind UV photodetectors [2, 3]. $Ga_2O_3$ can crystallise in 5 different phases: corundum α, monolithic β, spinel γ, cubic δ, and orthorhombic ε. Most research has been conducted on β-$Ga_2O_3$ as it is the most thermodynamically stable phase. However, recent years there has been increasing effort into the corundum α phase as it has become more available due to more refined growth techniques [4]. An important avenue of discussion is the comparison of the optical properties of the different phases of $Ga_2O_3$ as greater insight of the optical character is a central parameter for optoelectronic device design; while also determining measurement methods that allow the optical constants to be found in a repeatable and reliable manner. Here we use UV-vis spectrophotometry and the Swanepoel method [5] to determine and compare the optical constants of films of α- and β-$Ga_2O_3$.

Films of α- and β-phase $Ga_2O_3$ were grown by halide vapour phase epitaxy (HVPE) and metalorganic vapour phase epitaxy (MOCVD), respectively. Both were deposited on c-plane $Al_2O_3$ with estimated thicknesses 350 nm (α-$Ga_2O_3$) and 750 nm (β-$Ga_2O_3$). The transmittance spectra of the samples were obtained using a UV-vis spectrophotometer equipped with an integrating sphere. The method of analysis used to determine the optical constants was the Swanepoel method [5]. This method is based on the analysis on interference fringes (shown in Figure 1(a,d)) in the transmittance data of a film with a thickness close to the wavelength of light. Data analysis was performed using a MATLAB code written by the author, and allowed the determination of the thickness of the films as well as their refractive index and absorption coefficient.

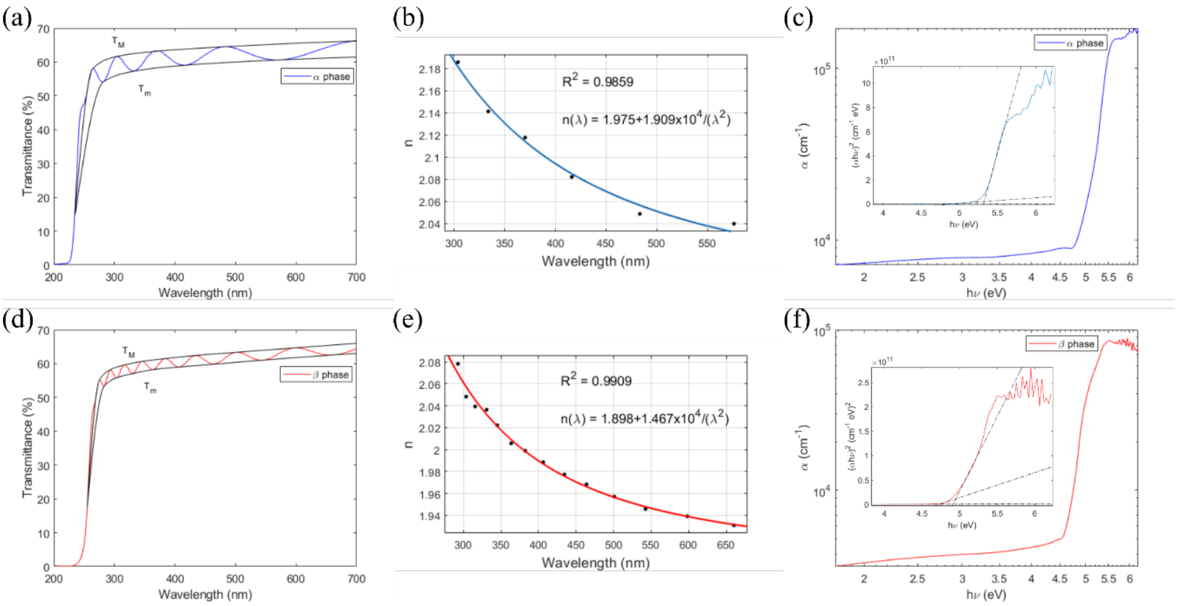


*Figure 1 – Transmittance (a, d), refractive index (b, e) and absorption coefficient (c, f) of the α- and β-phase $Ga_2O_3$ films.*

Figures 1(b, e) shows the refractive indices over a range of wavelengths calculated using the Swanepoel method. The data follows a parabolic curve that can be fitted with use of the Cauchy dispersion relation which shows the trend of the refractive indices over the range of wavelengths. The values are in good agreement with the literature [6, 7] and agree that the refractive index of α-$Ga_2O_3$ is slightly greater than that of β-$Ga_2O_3$.

The Swanepoel method also allows to determine the thicknesses of the films. The average thickness was determined to be 351±1 nm, and 769±1 nm for the α- and β-phase films, respectively, which coincide greatly with the thicknesses from the growth.

Finally, the absorption coefficient spectra for both samples were obtained against photon energy (Figures 1(c, f)). This was then used to determine the bandgap energy with using of the Tauc plot method (shown in inset) [8]. The direct bandgap for α and β phase was determined to be 5.3 eV, and 4.9 eV respectively; with both values lying within the range of bandgap energies that are comparable with literature [9, 10].

Determination of the optical constants for semiconductor materials is an important factor in understanding optical device design and basic material properties. The methods here presented show reliable and straightforward analysis techniques that allow for these properties to be found within a good figure of merit.

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