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Optical Properties of MgO Thin Films Deposited on GeO2 and SiO2 Substrates

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Abstract

In this study, optical properties of magnesium oxide (MgO) thin film deposited on germania (GeO2) and silica (SiO2) were studied as a function of wavelength in the range 0.3-1.1μm using matlab. Refractive indices, extinction coefficients, and absorption coefficients were investigated. The transmittance spectra of MgO thin films of different thicknesses deposited on the different substrates were also examined. The films were found to show high transmittance and low absorbance in the visible and near infrared region. However, the absorbance of the film was found to be high in the ultraviolet. The effects of interference on transmission spectra were also considered. The results give good reason for the applications of MgO thin films in optoelectronic devices.

Keywords: Matlab • MgO • Optical properties • Refractive indices • Substrate

Introduction

Metal oxides have earned a place in recent years as optical and optoelectronic devices in the visible, infrared and near ultraviolet region [1,2]. Among these oxides, MgO is one of the most important due to its wide band gap, good chemical and thermal stability, high economical availability, and eco-friendly nature [3]. Recently, much research has been focused on the synthesis of MgO thin films due to promising utilizations for optical and optoelectronic applications such as reflector, anti-reflection coating, beam splitters, attenuator, and photovoltaic cells [8-12]. The films are produced by depositing a very thin layer of material on the surface of another, the substrate. To perform the functions for which they are designed, the films must have the proper composition and thickness. And so, to predict their photoelectrical properties, it is imperative to know how the refractive index, reflectance, and transmittance vary as a function of wavelength. It is also necessary to know how the thickness of the film affects its optical properties. In this work, transmittance and reflectance of MgO thin film of different thicknesses have been studied and analyzed on GeO2 and SiO2 substrates to obtain the optimal configuration for the development of optoelectronic devices [4-7].

Theoretical Calculations

Equations of reflectance and transmittance for thin films have been derived, then simulated and visualized matlab shows the model of an optical thin film of thickness, and index of refraction, on a transparent substrate, of thickness several orders of magnitude larger and refractive index.

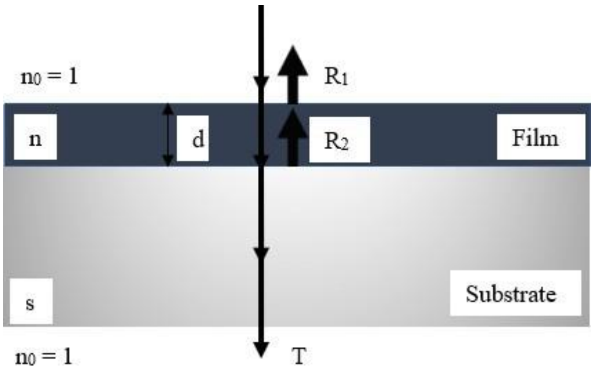

Figure 1. Model of a thin film on a transparent substrate

As seen in the figure, for normal incidence, the incident light beam gives rise to a reflected beam and a transmitted beam, both perpendiculars to the interface. R_1 is the intensity of the reflected light on the interface between air and film, and R_2 is the intensity of the reflected light on the interface between the film and substrate. Reflection at the interface between substrate and air is not considered. In this work, MgO is used as the thin film on SiO_2 and GeO_2 substrates. The Cauchy- Urbach dispersion model is used to study the refractive index of the thin film as function of the wavelength [14]. Where A, B, and C are fitting parameters, and the

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wavelength of light in micrometers. Fitting parameters calculated at different powers for different thicknesses of deposit varies significantly. We use the modeling parameters used for the MgO. The parameters of MgO are given in Table 1. From these fitting parameters, the index of refraction of MgO as function of wavelength has been studied using Matlab. Refractive indices of substrates are given by the Sellmeir dispersion model [15].

Discussion

Optical properties were investigated in the region between 0.3 and 1.1 µm. The refractive indices for MgO thin film, as well as the GeO_2 and SiO_2 substrates are shown respectively. It is observed that between 0.3 and 0.8 µm, the refractive index of SiO_2, GeO_2, and MgO decrease exponentially with the wavelength. After 0.8 µm, the evolution of the refractive index is linear. It describes the variation of the extinction coefficient as a function of wavelength. It is observed that it decreases exponentially between 0.3 and 0.7 µm, and after that, it is almost constant with a value very close to zero. This describes the variation of the absorption coefficient as a function of wavelength. It also decreases exponentially between 0.3 and 0.7 µm, and then becomes almost zero at higher wavelengths. It is explained by the very small absorption of MgO in the visible and near-infrared light.

It represents the optical transmission spectra without interference effect of the MgO thin films of different thicknesses deposited on GeO_2 and SiO_2 respectively, as a function of wavelength. Both figures show an increase of the transmittance at higher wavelength. Also, higher transmittance is observed for thinner films. It shows the transmittance with interference effect of MgO thin film of different thicknesses deposited on SiO_2 and GeO_2 as a function of wavelength. It was observed that there were interference peaks with maxima and minima. The interference fringes were produced due to multiple reflection of light between the top surface of the film in contact with air and the bottom surface of the film in contact with the substrate. From these figures it can also be seen that the number of peaks increase with the increase in thickness. So it can be said that the effect of interference increases with the increase in thickness. This shows the transmission spectra of MgO thin films of different thicknesses deposited on GeO_2 and SiO_2 substrates. It was observed that the films exhibit high transmittance between 70 and 80 % for wavelengths between 0.8 and 1.1 µm, for a thickness of 0.20 µm.

Conclusion

The optical properties of MgO thin films of thicknesses of 0.10, 0.20, 0.40, and 0.60 µm deposited on GeO_2 and SiO_2 substrates were investigated to obtain the optimal thin film-substrate configuration. A MgO film of thickness of 0.20 µm deposited on GeO_2 or SiO_2 substrates was found to exhibit the highest transmittance when the wavelength range was between 0.8 and 1.1 µm. This result might aid in the design of a proper MgO thin film for a potential application in optoelectronic devices.

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