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Thin Film Characterization Using Spectroscopic Ellipsometry

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INTRODUCTION

Thin films are widely used in the semiconductor industry. Dielectric, metallic and epitaxially grown semiconducting films, are the building blocks of modern electronics. The versatile, non destructive optical method of ellipsometry is particularly suited for characterization of these thin films. In this paper we will discuss the application of the multiple angle and wavelength (MAW) technique to measure the dielectric function of the film. This technique evaluates unabiguously the complex dielectric function $\epsilon(E)$ of the film without any pre assumtions. For other techniques, a priori knowledge of one or more of the following is required to find $\epsilon(E)$: film components, thickness, functional form of the dielectric function and/or use of the Kramers-Kronig relation. In some cases the effective medium approximation (EMA) was used to determine the volume fraction of the film components. Application of the MAW technique to several semiconducting films was published previously (1). In the following different applications and examples will be given, including metal and insulator films.

EXPERIMENTAL

A rotating analyzer ellipsometer with variable angle of incidence capability was used as described in reference (2). The system is controlled by a 286 type PC computer which also performed the analysis for each sample. The spectral range of 3500-7300Å at 5 angles of incidence was used.In most cases, data was taken in 100Å intervals. The ellipsometric parameters psi and delta were obtained using a Fourier transform. The inversion process is based on the MAW analysis least squares technique (3-5). In most cases, the substrate optical properties were known, and a simple substrate-film-ambient model was used. The inversion process gave the complex dielectric constant at every wavelength measured, and the films thickness.

In many applications, the EMA technique, with its small number of parameters, was a better choice. However, the EMA cannot be used for a film with unknown components, or for a material with no published $\epsilon(E)$ data.

RESULTS

Several type of samples were tested, to cover a variety of cases, including metal film on metal substrate, insulator film on metal, semiconductor on semiconductor and insulator on semiconductor.

A sputtered aluminum film was analyzed in terms of Al_2O_3 on Al. The optical properties of these and all subsequent materials were taken from reference (6). The EMA analysis show that the sputtered Al is really only 70% pure Al with the remainder being voids or Al_2O_3. The top Al_2O_3 layer thickness is of order 20Å. A thin (<20Å) Mo film on stainless steel was measured and analyzed using MAW. Results for the thickness (15Å) are reliable, but the dielectric function does not produce the published Mo results. Two films produced in an attempt to deposit a Ga_2S_3 layer on GaAs during a chemical vapor deposition growth were measured and analyzed. The thickness of the layers were of order 100Å. The dielectric function of the unknown top layer on GaAs was calculated using MAW. The shape of the function was found to be similar to that of GaAs, but included a change in amplitude. We tried EMA, using GaAs and an insulator as components. The final result shown that 89% of the volume is GaAs.

Other examples, including BN films on semiconducting substrates, epitaxial semiconducting films of SiC on Si and III-V on III-V will be given.

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