Spectroscopic Ellipsometry Focus Topic
Room: East Exhibit Hall - Session EL-ThP

Spectroscopic Ellipsometry Poster Session

EL-ThP1 Microstructure and Dispersive Optical Parameters of Tungsten, Titanium and Tungsten-Titanium Films, ***V.V. Atuchin****, T.I. Grigorieva, A.S. Kozhukhov, V.N. Kruchinin, L.D. Pokrovsky,* Institute of Semiconductor Physics, Russian Federation*, R.S. Vemuri,* Pacific Northwest National Laboratory*, C.V. Ramana*, University of Texas at El Paso

Tungsten (W) and titanium (Ti) films are widely used in electrochemistry, microelectronics, energy conversion and nanotechnology. In integrated optics, the nanometric Ti films are used as a source for doping $LiNbO_3$ and $LiTaO_3$ substrate and optical waveguide fabrication by thermal diffusion. Because effective refractive indices of the waveguide modes are strongly dependent on the optical profiles in doped layer, precise control of Ti film thickness (h) is needed in the range h~10-50 nm. Ellipsometry can be successfully applied for nondestructive determination of the thickness of a dielectric and semi-transparent metal film when optical constants of the material are known. Regrettably, noticeable scattering was found for optical constants reported earlier in literature for W and Ti films and crystals. As it seems, this scattering appeared due to different film quality and surface state. The focus of the present work is centered on W, Ti and W-Ti film fabrication and evaluation of their optical parameters with spectroscopic ellipsometry. Tungsten and tungsten-titanium films were prepared by magnetron sputtering deposition in vacuum below 10-5 Torr. Titanium films were fabricated by thermal evaporation method in vacuum below 10-5 Torr. The substrate temperature was T=100 °C. For precise determination of optical parameters, thick metal films (h~100 nm by as determined from optical interferometry) were prepared on silica substrate. To increase the metal adhesion, the substrate was subjected to RCA chemical cleaning just before insertion into vacuum chamber. Structural parameters of metal films were studied with reflection high-energy electron diffraction (RHEED). Surface micromorphology was controlled with atomic force microscopy (AFM). Spectral dependencies of refractive index $n(\lambda)$ and extinction coefficient $k(\lambda)$ were determined with the help of spectroscopic ellipsometry in the spectral range, λ~250-1030 nm. A relation between optical constants of pure metal W and Ti and mixed metal W-Ti films is discussed.

EL-ThP2 Temperature Dependences of the Dielectric Response of InSb Measured by Spectroscopic Ellipsometry, ***J.J. Yoon****, T.J. Kim, S.Y. Hwang, M.S. Diware, Y.D. Kim,* Kyung Hee University, Republic of Korea*, Y.C. Chang*, Academia Sinica, Taiwan, Republic of China

InSb is a promising material for optical devices, particularly for high-frequency and nonlinear-optical applications. InSb has a high electron mobility and offer excellent design flexibility as a result of its large conduction-band offset in multilayer structures. Consequently, InSb offers significant potential for devices such as quantum-well lasers, laser diodes, and heterojunction bipolar transistors. A knowledge of the dielectric function at various temperatures is required for optimizing the properties for specific device applications. In-situ control of growth is also becoming an important technique. Therefore, the dielectric function at growth temperatures is also needed. On the other hand, critical point (CP) energies can be better identified from low-temperature data, where the decreased electron-phonon interaction allows separation of CP structures that are nearly degenerate at room temperature.

Although the optical properties of InSb have been well studied, there are only a few reports of their temperature dependence in the 1.2 to 5.6 eV spectral ranges [1]. Here, we report results of an investigation of the temperature dependence of the dielectric response of InSb from 22 K to 700 K and from 0.74 to 6.57 eV.

Spectroscopic ellipsometric (SE) data were obtained on a bulk semi-insulating InSb (100) substrate. The cryostat consisted of a stainless-steel chamber with high-quality stress-free fused-quartz windows. To avoid condensation at low temperatures, the sample was maintained in ultrahigh vacuum during measurement. SE data were obtained at an angle of incidence of 70.41° using a conventional rotating-compensator system with a diode-array detector. The influence of the oxide overlayer was removed mathematically by a multilayer calculation. In the E_2 energy region only four structures are clearly resolved at 300 K. However, at 22 K the E_2' and E_2 structures are seen to consist of five CPs. We identified the origin of these structures with band-structure calculations using the LASTO method. Separation of the E_0', $E_0'+\Delta_0'$, E_2, $E_2+\Delta_2$, E_2', E_1' and $E_1'+\Delta_1'$ CPs was clearly found in the region of the E_2 peak. Two saddle-point transitions, Δ_5^{cu}-Δ_5^{vu} and Δ_5^{cl}-Δ_5^{vu}, are clearly seen. We also determined the temperature dependences of the newly observed transitions near 5.9 eV. These results will be useful in a number of contexts, including the design of optoelectronic devices based on InSb, as data for improved band structure calculations, and for in-situ monitoring.

[1] S. Logothetidis, L. Vina and M. Cardona, Phys. Rev. B **31**, 947 (1985).

EL-ThP3 Tailored Helical Nanostructures Investigated with Mueller Matrix Ellipsometry, ***R. Magnusson****, J. Birch, C.-L. Hsaio, P. Sandström, H. Arwin, K. Järrendahl*, Linköping University, Sweden

Metamaterials showing chiral features in the optical spectral range have been fabricated with the aim to obtain polarized reflection with high ellipticity.

A series of tailored anisotropic and transparent structures of helical Al1-xInxN nanorods were grown using UHV magnetron sputtering on sapphire substrates. Due to an internal in-plane composition gradient across the crystalline structure, the nanorods will tilt relative to the substrate normal. By rotating the substrate step-by-step around its normal during deposition 'staircase' helical structures are obtained. The layer thickness for each step is controlled to tailor the nanorods. Samples with different pitch and layer thickness and with right-handed as well as left-handed chirality were grown.

Ellipsometric measurements were performed using a dual rotating compensator ellipsometer providing the full Mueller matrix in the spectral range 245-1700 nm at multiple angles of incidence and 0-360º sample orientation. The relation between the optical characteristics of the samples, specifically the ellipticity, and structural parameters such as number of layers, layer thickness and nanorod pitch of the samples, was studied. For certain wavelengths, near circular polarization is observed both for right- as well as left-handed helical structures.

Based on the Mueller matrix data, descriptions of the polarization states and degree of polarization in reflection for different incoming states of polarization will be presented.

EL-ThP4 Study of the Thin Film Growth of Volatile Condensable Material via In Situ Ellipsometry and Quartz Crystal Microbalance Measurements, ***J. Pu****, F. Zhou, N.J. Ianno*, The University of Nebraska

DC-93-500, SCV-2590 and SCV-2590-2 silicone/siloxane based co-polymer serve as adhesive components in communications satellites and other spacecraft under adverse low-earth and geo-synchronous orbits. The outgassing and deposition of Volatile Condensable Materials (VCM's) from these adhesives onto optically-sensitive surfaces of satellites is of significant interest to spacecraft-contamination engineers. In our work, samples of these materials are heated to 100 C in a liquid nitrogen (LN2) cooled cryo-shroud lined high vacuum chamber. One MK-18 quartz crystal microbalance (QCM) sensor is placed above the effusion cell which is mounted on the bottom of the chamber. At various QCM temperatures from 120K to 180K, we observed the formation of a thin film of volatile contaminant material on the gold coated QCM crystal. Spectroscopic ellipsometric data is simultaneously acquired from the depositing film. Generally, quartz crystal microbalance measures an areal mass density which is related to the density and the geometric thickness of the film, while in-situ spectroscopic ellipsometric can determine either thickness or refractive index for very thin film. Therefore, a reasonable assumption for the density of the film must be made in order to determine the thickness. By using these two techniques in combination, we can find the actual mass condensed at different temperatures. Our findings for the optical constants of materials condensed from different bulk compounds as a function of temperature will be presented.

EL-ThP5 Combined Electrochemical Impedance Spectroscopy and In Situ Spectroscopic Ellipsometry of Anodically Grown SiO_2, *E.A. Montgomery,* University of Nebraska - Lincoln*, T.E. Tiwald,* J.A. Woollam Co., Inc.*, E. Schubert, M. Schubert,* University of Nebraska - Lincoln*, C. Beasley,* Gamry Instruments*, **C. Briley***, University of Nebraska - Lincoln

Electrochemical oxidation of silicon (n-type) at room temperature in a mixture of ethylene glycol, water and potassium nitrate has been performed by applying constant current densities to prepare thin SiO2 layers. In-situ Electrochemical Impedance Spectroscopy (EIS) and Spectroscopic Ellipsometry (SE) are employed during the SiO_2 film growth. Using EIS and SE techniques in-situ one is able to monitor the capacitive changes and also the film thickness change of the oxide. The thickness of the oxides is also measured ex-situ before and after growth using SE. Equivalent circuit models corresponding to the electrolyte-oxide-silicon interfaces and optical models are fit to EIS and SE data respectively, to gain insight into the quality of the anodically grown SiO_2.

EL-ThP7 In Situ Spectroscopic Ellipsometry of Nanoscale Germanium Films Deposited via High Power Impulse Magnetron Sputtering, ***N. Murphy,*** Air Force Research Laboratory, *L. Sun,* Air Force Research Laboratory and General Dynamics Information Technology, *A. Waite,* Air Force Research Laboratory and Universal Technology Corporation, *J. Jones, R. Jakubiak*, Air Force Research Laboratory

Germanium films were deposited on both glass and silicon substrates using high power impulse magnetron sputtering (HiPIMS). Throughout the deposition process, the optical constants and thicknesses were measured and recorded via *in-situ* spectroscopic ellipsometry. Preliminary analysis of the films' optical behavior has indicated that the refractive index is highly sensitive to changes in thickness. As film thickness increases from 100 to 500 Å, the refractive index displays the tendency to slowly decrease due to void porosity, lack of crystalline order and surface roughness. The preservation of the refractive index seen in the HiPIMS deposited Ge films is a direct result of their high density and low void fraction, following the relationship between density and refractive index as given by the Gladstone-Dale approximation.

Authors Index

Bold page numbers indicate the presenter