Spectroscopic Ellipsometry Focus Topic
Room A215 - Session EL-ThA

Spectroscopic Ellipsometry Late News Session

Moderator: Tino Hofmann, University of North Carolina at Charlotte

5:00pm **EL-ThA9 Far-infrared Dielectric Functions of $Hg_{1-x}Cd_xSe$ Thin Films Determined via Ellipsometry and Reflectivity**, ***Frank Peiris,*** *J. Lyons,* Kenyon College*; G. Brill,* U.S. Army Research Laboratory

The dielectric functions of molecular beam epitaxy-grown $Hg_{1-x}Cd_xSe$ thin films were determined using a combination of ellipsometry and reflectivity. While we have reported the dielectric functions for this alloy system above 400 cm^{-1}, in the present study, by incorporating reflectivity measurements, we are able to recover the dielectric functions in a much wider spectral region (i.e., 85 cm^{-1} and 50,000 cm^{-1}). Initially, spectroscopic ellipsometry, performed between 400 cm^{-1} and 8000 cm^{-1}, determined the dielectric function and the thickness of $Hg_{1-x}Cd_xSe$ films. Ellipsometry results were then used to model the reflectivity data, which allowed us to obtain the absolute reflectance values and to map the dielectric function from the reflectivity spectra, obtained between 85 cm^{-1} and 8,000 cm^{-1}. By representing the dielectric function as a collection of classical oscillators, we were able to recover the details of absorption due to free electrons, phonons, and band electrons in the $Hg_{1-x}Cd_xSe$ alloy system. Specifically, our models find two transverse phonon modes for $Hg_{1-x}Cd_xSe$, where the HgSe-like mode blue-shifts and the CdTe-like mode red-shifts with increasing Cd concentration.

5:20pm **EL-ThA10 Tunable Giant Circular Dichroism in Spatially-coherent Si-Au/Ag Nano-plasmonic Chiral Heterostructures**, ***Ufuk Kilic,*** *M. Hilfiker,* University of Nebraska-Lincoln*; R. Feder,* The Fraunhofer Institute for Microstructure of Materials and Systems (IMWS), Germany*; R. Korlacki, E. Schubert, C. Argyropoulos, M. Schubert,* University of Nebraska-Lincoln

The differential absorption of left-and right-handed circularly polarized light so-called circular dichroism (CD) has recently gained enormous interest in optics, chemistry, pharmacology and biotechnology fields. [1] Particularly, the subwavelength scale periodic arrangement of nano-plasmonic structures is predicted to be a facile enhancement method of CD response and offers a great potential for chiral opto-electronics. [2,3]

In this study, by using the ultra-high vacuum, electron beam evaporated glancing angle deposition system, we successfully fabricated optically active, spatially coherent, and highly porous chiral hetero-structures (CHS).

Subsequent and repeated depositions of silicon (Si) and gold (Au)/silver (Ag) lead to nanometer-dimension sub-chiral segments which enables to tailor the circular dichroism induced by size, shape and material choice.

The incorporation of transmission mode Mueller matrix spectroscopic ellipsometry technique with finite element modeling(FEM) provides an excellent framework for optical characterization of this new type plasmonic metamaterials within the spectral range from 0.6 eV to 4.5 eV. We systematically studied the influence of geometrical parameters (such as handedness of the structure (left or right), pitch size, minor and major radius of fabricated CHS, and also number of turns) on CD phenomenon.

Interestingly, Au/Ag sub-chiral segments in CHS result in the emergence of multiple plasmonic modes which can be tunable depending on the Au/Ag-Si ratio in a single turn. In addition, the effects of both azimuthal rotation and angle of incidence on CD are also investigated as a part of this study. According to the FEM calculations, as compared with Si chiral structures, we observed a significant enhancement in the circular dichroism of Si-Au/Ag CHS which can be attributed to plasmonic resonance effect [2]. We also calculated Kuhn's dis-symmetry (g) factor ($g \approx (A_+ - A_-)/(A_+ + A_-)$, where A_-, A_+ are the absorbance coefficients for left and right circularly polarized light, respectively), which is useful for quantitative comparisons of chiro-optical properties of different structures. Unlike the other studies [4,5] which employs periodic nanostructures made up of single type material, we observed a very pronounced g-factor in our fabricated CHSs around 3-4 eV range.

References:

[1] de Dios, Carolina, et al. Optics Express 27.15, 21142-21152, (2019).

[2] Kneer, Luisa M., et al., ACS nano 12.9 :9110-9115(2018).

[3] Hentschel, Mario, et al., Science advances3.5, e1602735, (2017).

[4] Schulz, Matthias, et al., Nature communications 9.1, 2413, (2018).

[5] Lee, Hye-Eun, et al., Nature 556.7701, 360, (2018).

5:40pm **EL-ThA11 Numerical Ellipsometry: Methods for Selecting Measurements and Techniques for Advanced Analysis Applied to β - Gallium Oxide**, ***Frank Urban,*** Florida International University*; D. Barton,* retired*; M. Schubert,* University of Nebraska-Lincoln

Ellipsometry is an optical technique through which properties of materials may be determined from measurements of light reflecting from or transmitting through a sample. Usually the measurements require data processing and a key issue is determining which measurements to make. Previously two of us (Urban and Barton)[1] have addressed this for orthorhombic, anisotropic films on substrates and here we treat the case of reflection from a single anisotropic, monoclinic β-Ga_2O_3 crystal which is non-depolarizing and has a smooth, flat surface. Prior work on Ga_2O_3 by one author (Schubert)[2] used a very large dataset containing measurements at each wavenumber for three angles of incidence and 5 azimuth angles for each of 2 crystal orientations. Step 1 in that process was to determine the best-fit permittivity tensor, ε, using Levenberg-Marquardt least squares regression. Here we present methods to determine practically the same ε using a substantially reduced subset of the same data. We exclude measurements which are less useful due to large instrument-reported estimated experimental errors (σ), noise (low intensity), and mathematical insensitivity to the desired solutions. From 10 to 30 numerical solutions to the model equations are found at each wavenumber using the reduced data set as these allow an analysis of measurement accuracy. Solutions are found using each crystal independently. The number of measurements is reduced by a factor of 25 or so depending on the options selected with further reductions expected in future works. Examples using two β-Ga_2O_3 crystals, (010) and (-201) are presented.

1. F.K. Urban III and D. Barton, Thin Solid Films, 663, pp 116-1251, (2018)

2. M. Schubert, R. Korlacki, S. Knight, T. Hofmann, S. Schöche, V. Darakchieva, E. Janzén, B. Monemar, D. Gogova, Q.-T. Thieu et al., Phys.Rev.B 93, 125209 (2016).

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