Spectroscopic Ellipsometry Focus Topic
Room 304 - Session EL2+EM-TuA

Spectroscopic Ellipsometry: Novel Applications and Theoretical Approaches

Moderators: Alain Diebold, SUNY Polytechnic Institute, **Ruediger Schmidt-Grund**, Technical University Ilmenau, Germany

4:20pm **EL2+EM-TuA-7 A Study of Wire Grid Polarizers with Mueller Matrix Ellipsometry***, T. Gholian Avval, M. Linford,* Brigham Young University*; N. Keller,* ***G. Andrew Antonelli,*** Onto Innovation, Inc.

Wire grid polarizers are essential optical components used in a wide variety of optical systems, from AR/VR to medical imaging to optical measuring systems. Physical properties of the polarizer, such as groove height and width all impact the polarizer's efficiency. Here we show how a wire grid polarizer can be characterized non-destructively in the fabrication process with Mueller Matrix ellipsometry and RCWA-based analysis. Using this methodology, physical properties like grating profile, height, pitch, material thicknesses and even grating tilt can be measured non-destructively and inline to provide process control.

4:40pm **EL2+EM-TuA-8 Temperature Dependence of the Direct Band Gap of InSb from 80 to 700 K***,* ***Melissa Rivero Arias,*** *N. S. Samarasingha, C. Emminger, S. Zollner,* New Mexico State University

In this undergraduate student presentation, we describe measurements of the dielectric function of bulk InSb near the direct band gap using Fourier-transform infrared (FTIR) spectroscopic ellipsometry from 80 to 800 K in an ultra-high vacuum (UHV) cryostat with diamond windows. Indium antimonide (InSb) is the zinc blende compound semiconductor with the smallest direct band gap (ε_0= 0.18 eV at room temperature) due to its heavy elements and the large resulting spin-orbit splitting and Darwin shifts. It also has a low melting point of 800 K. Previously, the bandgap of InSb has mostly been measured optically up to room temperature and estimated from Hall effect measurements of the effective mass up to 470 K. Ellipsometry measurements of the direct gap of InSb have been described at 300 K. Calculations indicate that InSb should undergo a topological phase transition from semiconductor to semi-metal (and topological insulator) at 600 K. It is interesting to see in the data if this transition occurs below the melting point of InSb.

5:00pm **EL2+EM-TuA-9 Coherent Acoustic Phonon Oscillations in Ge Using Pump-Pulse Time-Resolved Spectroscopic Ellipsometry***,* ***Carlos Armenta,*** New Mexico State University*; M. Zahradnik,* ELI Beamlines, Czechia*; C. Emminger,* Humboldt University Berlin, Germany*; S. Espinoza, M. Rebarz, J. Andreasson,* ELI Beamlines, Czechia*; S. Zollner,* New Mexico State University

Photoexcitation of bulk materials can create hot charge carriers that relax by transferring energy to the lattice, hence exciting phonons in the process. By photoexciting the material through femtosecond laser pulses, coherent acoustic phonon (CAP) oscillations at picosecond time scales are generated via this method. These CAP oscillations are related to an increase in charge carrier density, as well as strain triggered by the laser pulse, however details of this relationship are scarce in the literature. CAP oscillations affect the pseudo-dielectric function (DF) of the material, which makes time-resolved spectroscopic ellipsometry ideal to understand the processes in hand.

The present work aims to describe the relationship between CAP oscillations and charge carrier density, as well as surface orientation dependence via femtosecond pump-probe ellipsometry of Ge. Photoexcitation is induced by 800 nm laser pump pulses at different intensities, generating a strain pulse that travels normal to the surface within the ~200 nm penetration depth in the semiconductor. Measurements in Ge at (100), (110), and (111) orientations and charge carrier concentrations ranging from ~7.5×10^{20} cm^{-3} to ~3.5×10^{21} cm^{-3} were performed. The behavior of these oscillations is characterized by analyzing the changes in the pseudo-DF of Ge as a function of the delay time between the pump and probe pulse. Analyzing the E1 and E1+Δ1 critical points (CP) and the variation of their parameters (energy, broadening, amplitude, and phase) with delay time, the behavior of phonon oscillations can be studied.

In order to determine these parameters, second derivatives of the pseudo-DF were calculated using a linear filter technique based on extended Gauss (EG) functions. The periods of these oscillations are deduced by tracking the energy of these CPs as a function of time

5:20pm **EL2+EM-TuA-10 Time-Resolved Spectroscopic Ellipsometry Helped by Imaging Spectroscopic Ellipsometry***,* ***Shirly Espinoza,*** ELI Beamlines, Czechia

Thanks to femtosecond pulsed lasers, at ELI Beamlines in the Czech Republic, we developed a time-resolved femtosecond ellipsometry technique, where a pump beam from any wavelength between 200 nm and 2000 nm excites a material; and a second pulse, the probe beam, with a continuous spectrum from 350 nm to 750 nm measures the dielectric function of that material. The pump and the probe beam can be separated in time from femtoseconds to nanoseconds generating a time-scan of the relaxation processes that happens in the material when it returns to its original unexcited state.

This time-resolved pump-probe ellipsometry technique is available to the scientific community through a yearly call for user proposals. We then get the opportunity to measure different type of materials from thin films to crystals of semiconductors and metals including 2D materials and organic samples deposited on metal layers. By imaging ellipsometry, the sample inhomogeneity, roughness and optical properties prior and after the pump-probe measurement are diagnosed. A discussion about newly imaging-analyzed samples that were and will be study by pump-probe ellipsometry will be presented.

Author Index

Bold page numbers indicate presenter

— A —
Andreasson, J.: EL2+EM-TuA-9, 1
Antonelli, G.: EL2+EM-TuA-7, **1**
Armenta, C.: EL2+EM-TuA-9, **1**
— E —
Emminger, C.: EL2+EM-TuA-8, 1; EL2+EM-TuA-9, 1
Espinoza, S.: EL2+EM-TuA-10, **1**; EL2+EM-TuA-9, 1
— G —
Gholian Avval, T.: EL2+EM-TuA-7, 1
— K —
Keller, N.: EL2+EM-TuA-7, 1
— L —
Linford, M.: EL2+EM-TuA-7, 1
— R —
Rebarz, M.: EL2+EM-TuA-9, 1
Rivero Arias, M.: EL2+EM-TuA-8, **1**
— S —
S. Samarasingha, N.: EL2+EM-TuA-8, 1
— Z —
Zahradnik, M.: EL2+EM-TuA-9, 1
Zollner, S.: EL2+EM-TuA-8, 1; EL2+EM-TuA-9, 1