Measurements of temperature-dependent optical constants with spectroscopic ellipsometry and comparison with theory

Stefan Zollner
Department of Physics, New Mexico State University, Las Cruces, NM
Thursday, August 28th, 4pm, Room GN 230

Spectroscopic ellipsometry is an optical reflection technique, which allows measurements of optical constants (refractive index, absorption coefficient, dielectric function) from the change of the polarization of the light beam as it is reflected by a flat sample. Although I built two rotating-analyzer ellipsometers long ago out of necessity, for the past 25 years I have only used commercial ellipsometers or user facilities for data acquisition and relied on commercial software for data analysis. Instead, my main focus has been on industrial applications of spectroscopic ellipsometry, especially in the semiconductor industry, and the interpretation of the dielectric tensor to learn about materials. For many years, the temperature dependence of the dielectric tensor has been one of my specialties.

In the mid-infrared spectral region, the dielectric function of insulators is dominated by lattice absorption of a single photon by an infrared-active long-wavelength phonon. Analysis of infrared ellipsometry spectra therefore starts with crystallography (unit cell, Wyckoff positions) and the determination of phonon symmetries from group theory. For a simple rocksalt crystal like LiF with O_h symmetry, there are two threefold degenerate modes belonging to the T_{1u} representation, which correspond to acoustic and optical phonons. The latter is split into a transverse (TO) and longitudinal optical (LO) phonon by the Fröhlich interaction. This leads to a region of high reflectivity (reststrahlen band) which extends from the TO to just above the LO energy. The TO phonon peak is often asymmetric because of the frequency-dependence of the scattering rate. For more complex crystal structures, several phonon peaks can appear in the spectra. With increasing temperature, the optical phonons soften and their energies decrease, while their broadenings increase.

References:

[1] S. Zollner, in *Ellipsometry at the Nanoscale*, edited by M. Losurdo and K. Hingerl (Springer, Heidelberg, 2013), p. 607.
[2] S. Zollner, F. Abadizaman, C. Emminger, and N. Samarasingha, Adv. Opt. Techn. **11**, 117 (2022).
[3] M. Rivero Arias, C. Armenta, C. Emminger, C. M. Zamarripa, N. S. Samarasingha, J. R. Love, S. Yadav, and S. Zollner, J. Vac. Sci. Technol. B **41**, 022203 (2023).