Far infrared ellipsometry study of a $(Ce,Ca)MnO_3$ thin film

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We study the temperature dependent optical response of a 4% Ce doped (conducting) $CaMnO_3$ thin film grown on an orthorhombic $YAlO_3$ substrate by Pulsed Laser Deposition. We focus mostly on the far-infrared range in our analysis, but also performed measurements covering a broad range of photon energies up to the ultraviolet part of the spectrum. All experiments were done using spectroscopic ellipsometry.
Spectroscopic ellipsometry is an optical spectroscopy technique based on precise control and analysis of the polarization state incident on and reflected from planar surface of a sample under generally oblique angle of incidence. For each frequency (photon energy) of the spectrum, two parameters are obtained from the analysis of the polarization state: *ellipticity* and *tilt* of the ellipse polarization. These two parameters are in principle related to the real and imaginary parts of the complex refractive index of the material at a given frequency.
A perovskite describes a type of material with the generic formula ABO_3, where A and B are two atoms with different sizes, and O is the oxide part. Due to the ionic character of perovskite materials, their infrared response is dominated by strong resonances of lattice vibrations: phonons. Since the vibrational character is given by the crystal structure, the changes of the structure are reflected in changes and anomalies of the phonon spectrum. For undistorted cubic perovskite, the cubic symmetry allows only for 3 infrared-active phonons and isotropic response. When the symmetry is lowered, additional modes will appear and the response will depend on crystal orientation. At the same time, infrared spectroscopy is very sensitive to possible conductivity of the crystal.

In our study system - a thin film (100nm) of $(Ce,Ca)MnO_3$ on $YAlO_3$ - the situation is complicated by the anisotropy of the substrate – especially in the far-infrared range where the phonons are located – and a major part of the work done here is dedicated to understanding and quantitative analysis of the ellipsometric experiments on orthorhombic substrate and film.
Our orthorhombic substrate $YAlO_3$ was selected for its lattice parameter to support the growth of the $CaMnO_3$.We were primarily interested in the changes of the far-infrared response of the conducting electrons in $(Ce,Ca)MnO_3$ around and below the apparent magnetic transition at 105K.

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