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Vacuum Variable-Angle Far-Infrared Ellipsometer

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Keywords

Far Infrared Ellipsometry, Phonons.

Abstract

We present the design and performance of a vacuum far-infrared (50-680 cm^{-1}) ellipsometer with a rotating analyser. The system is based on a Fourier transform spectrometer, an in-house ellipsometer chamber and a closed-cycle bolometer. The ellipsometer chamber is equipped with a computer controlled θ–2θ goniometer for automated measurements at various angles of incidence. We compare our measurements on $SrTiO_3$ crystal with the results acquired above 300 cm^{-1} with a commercially available ellipsometer system. After the calibration of the angle of incidence and after taking into account the finite reflectivity of mirrors in the detector part we obtain a very good agreement between the data from the two instruments. The system can be supplemented with a closed-cycle He cryostat for measurements between 5–400 K.

1 Introduction

Spectroscopic ellipsometry is a well established technique for precise measurements of the optical response of solids and liquids [1]. It is particularly well known for its sensitivity to very thin films, due to its ability to measure the change in relative phase between p and s polarized wave components. Historically, spectroscopic ellipsometry developed first in the near infrared to ultraviolet frequency range where brilliant sources and sensitive detectors are easily available [2]. More recently, ellipsometer systems based on Fourier transform infrared (FTIR) spectrometers were developed for the mid-infrared spectral spectral range ($\sim 400 - 6000$ cm^{-1}) [3] and instruments with rotating compensator design are available commercially.

However, in the far-infrared (FIR) spectral range ($\sim 50 - 600$ cm^{-1}), commercial instruments are still unavailable, despite the obvious richness of the physical phenomena occurring in this range, e.g., low-frequency phonons, free charge carrier absorptions and superconducting gaps. This lack might be partly due to the technical complications relevant to the FIR range, i.e., the necessity to use liquid He cooled detectors (bolometers) and the strong absorption of water vapor that has to be reduced either by evacuation or by an intensive purging with nitrogen or dry air.

Several in-house FIR ellipsometers [4, 5] were developed that are based either on evacuated chambers [6, 7], or on purged chambers [8]. Some ellipsometers used a synchrotron source, benefiting from its large brilliance advantageous in measuring small samples [6, 7, 9, 10]. An instrument designed at the Max-Planck institute in Stuttgart [6] incorporated a fixed compensator. Another instrument installed at the National Synchrotron Light Source in Brookhaven,