**Our Message**

- The complex anisotropic THz optical response of Cobalt columnar sculptured thin films (STFs) can be determined precisely using spectroscopic ellipsometry (SE).
- An anisotropic Bruggeman effective medium approach allows accurate analysis of the THz-SE data.
- The use of THz transparent substrates enhances STFs' show distinct surface functionalization allows the changes in the host (ambient) medium permittivity can be accurately monitored – metal STFs can serve as a building block for future THz biochemical sensor applications.

**Effective Medium Approach**

**Anisotropic Bruggeman EMA**

\[
\varepsilon_{ij} = \varepsilon_{m} + \left( \varepsilon_{a} - \varepsilon_{m} \right) \frac{c_{ij}}{c_{ij} + \varepsilon_{m} \delta} \]

- \( \varepsilon_{ij} \): anisotropic Bruggeman EMA dielectric function tensor components along the major axes / \( a, b, c \)
- \( \varepsilon_{m} \): host medium permittivity
- \( \varepsilon_{a} \): permittivity of the nanocolumnar inclusions
- \( c_{ij} \): volume faction of the nanocolumnar inclusions
- \( \delta \): depolarization factors with \( L_{ab}L_{bc}L_{ca} = 1 \)

**Optical Response of Metal STFs**

- STF's show distinct optical anisotropy in VIS spectral range.
- Dramatic changes have been observed upon ambient changes in the VIS spectral range.

**STF THz Optical Sensors**

- Detection of Liquids:
- Detection of Bio-molecules:
  - Minute amounts of liquids are detectable due to the changes in the STF optical response.
  - Surface functionalization allows selective detection of biomolecules and their THz optical properties.
  - Nanohybrid functional materials for the THz frequency domain.

**THz Dielectric Anisotropy of Co STFs**

- Measured in air and water ambient.
- The probe beam illuminates the backside of the sample as shown in the inset.

**Cobalt Sculptured Thin Films in Aqueous Environment**

- Calculated Mueller matrix (\( M_{ij} \)) difference spectra obtained by calculating the difference between \( M_{ij} \) obtained for the STF in water ambient and \( M_{ij} \) obtained for the STF in a test ambient.
- The test ambient is identical to water described by the commonly used (Debye relaxation) except for a constant offset in the permittivity \( \varepsilon_{\infty} \).

**THz Optical Sensor Response**

- Mueller matrix spectra obtained for the Co STF sample in air and water ambient.
- The in-plane rotation angle was \( \phi = 225^\circ \).

**Experimental Setup and Sample Preparation**

- Generalized THz Ellipsometry
  - Rotating analyzer ellipsometry configuration.
  - Achromatic (THz-MIR) polarization rotator (PR) to manipulate the input polarization state.
  - Backward wave oscillator (BWO) source.
  - Golay cell detector (GC).

- Co STF Sample Preparation
  - Custom electron-beam glancing angle deposition of Cobalt sculptured thin films.
  - 85° incident particle flux with respect to the substrate normal.
  - Low doped, double-side polished Si substrate.
  - No substrate rotation during deposition.
  - Nominal film thickness is 450 nm with a 65° slanting angle.

**THz Sensor Concept**

### THz Sensor Concept

- **Detection of Liquids:**
  - Minute amounts of liquids are detectable due to the changes in the THz optical response.
- **Detection of Bio-molecules:**
  - Surface functionalization allows selective detection of biomolecules and their THz optical properties.
  - Nanohybrid functional materials for the THz frequency domain.

**Experimental (green lines) and best-model calculated (red lines) off-diagonal Mueller matrix spectra for the Co STF sample for an in-plane rotation angle \( \phi = 135^\circ \).

Left: Mueller matrix spectra for a Co STF sample for three different in-plane rotation angles \( \phi = 90^\circ, 135^\circ, \) and \( 180^\circ \). The spectra for the silicon substrate before Co STF deposition are shown for comparison.

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Metal Sculptured Thin Film
THz Optical Sensors

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