Terahertz Time Domain Spectroscopy for Characterizing Nanomaterials for Commercial Applications

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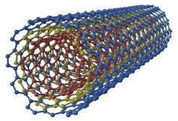
MIRALON® Yarn[1]



- Aligned filaments of structured carbon (carbon nanotubes, CNTs)
- Transfer load by van der Waals forces
- Laterally flexible, fatigue, and impact resistant
- Thermally and *electrically conductive in the axial direction*

- **Objective:** characterize alignment of CNTs in a yarn

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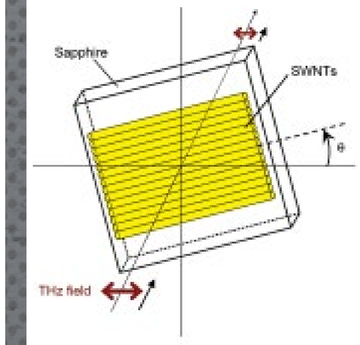
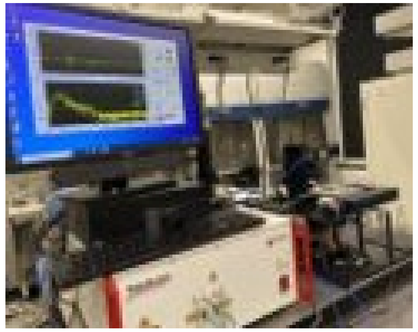
THz TDS for characterization of CNT alignment

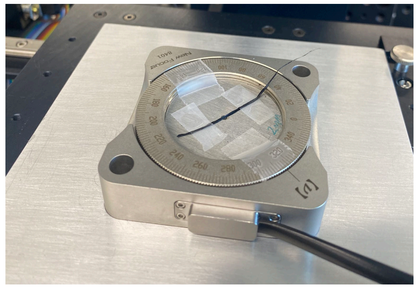


- THz radiation polarized along the CNT axis is strongly absorbed and reflected, while THz radiation polarized normal to CNT axis is transmitted [2,3]
- The absorbance: $\boldsymbol{A = -\log T}$
- The transmittance: $\boldsymbol{T = |\frac{E_S}{E_R}|^2}$ ($\boldsymbol{E_S}$ and $\boldsymbol{E_R}$ are the THz electric field amplitudes in the frequency domain for THz waveform transmitted through the sample and without the sample)
- Finite alignment of CNT induces a finite linear polarization:

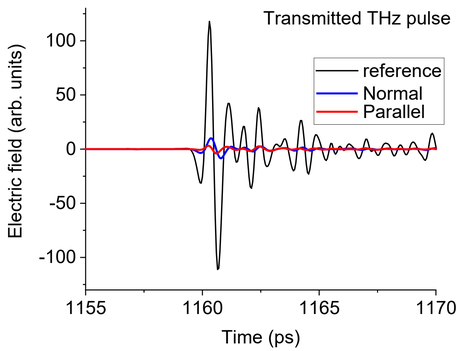
$$\boldsymbol{P = \frac{A_{||} - A_{\perp}}{A_{||} + A_{\perp}}}$$

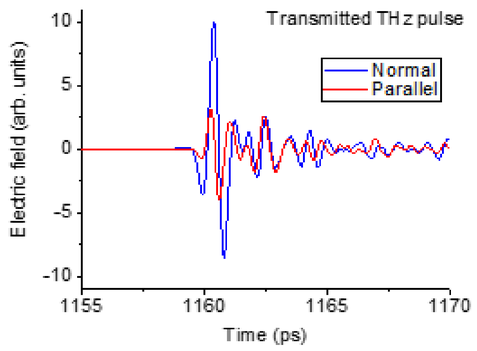
- 2 mm aperture in the center of a computer-controlled rotation stage
- Collect THz waveforms as a function of rotation stage angle



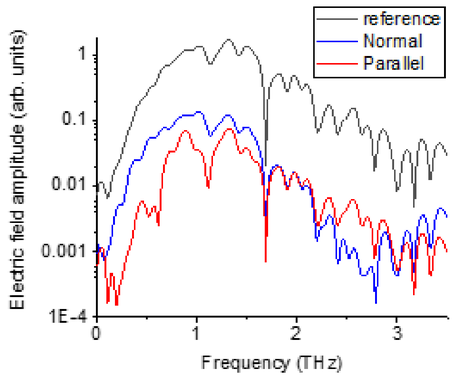


Results

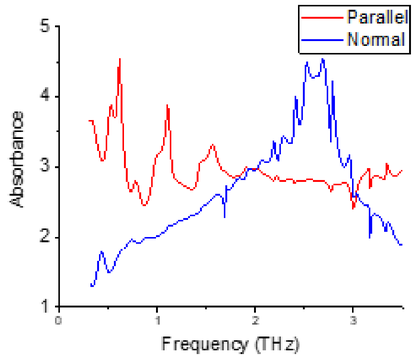




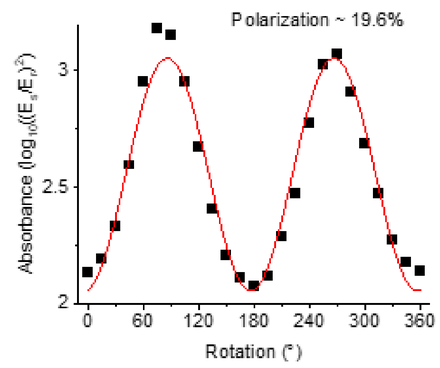
- THz attenuated in both normal and parallel orientation due to the presence of iron catalyst particles and amorphous carbon



- Attenuation stronger for THz polarized along the yarn



- Absorption by a CNT radial breathing mode at 2.7 THz



- Polarization is a measure of alignment that can be used in comparing yarns

References:
1. https://www.huntsman.com/products/detail/344/miralon; 2. L. Ren et al., *Nano Lett.*, 2009, 9, 7, 2610; 3. L. Ren et al., *Nano Lett*. 2012, 12, 2, 787.

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