ND*nano* Undergraduate Research Fellowship (NURF)
2011 Project Summary

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Project title: *Terahertz Probing of Carbon Nanofiber Composite Coating for Electromagnetic Shielding and Attenuation*

Cost-effective terahertz quasi-optical components such as shielding and attenuation devices, grid polarizers and mesh filters have been highly demanded due to their promising applications in terahertz technology. Carbon nanofiber (CNF) composite coatings have been shown to have low droplet roll off angle and high static contact angle which prevent contamination and corrosion, giving it an advantage over metals. The EMI shielding applications of CNF coatings have been studied at relatively low frequencies from 15 MHz to 75 GHz. This project aims at fully characterizing the EMI properties of novel large-area carbon nanofiber (CNF) composite coatings in the THz region, and on the basis of this, low-cost quasi-optical THz devices based on patterned CNF coatings using inkjet-printing process will be designed, fabricated and tested.

In this NURF project, the frequency domain terahertz spectroscopy and imaging system (Fig. 1) was optimized and applied for characterizing CNF composite coatings in the frequency range of 570-630 GHz. As shown in Fig. 2 (a), shielding effectiveness for different CNF loadings were measured, giving a highest value of ~32dB for the sample with the highest CNF content of ~14% by weight. The attenuation decreases with decreasing of the CNF loading. Linearly patterned CNF coating samples behave as polarizers, allowing maximum transmission for perpendicularly polarized E-field and showing strong absorption for parallel polarization. As shown in Fig. 2 (b), the THz absorption was seen to increase monotonically as the polarization angle decreased from 90 degrees to 0 degree. The polarizer samples showed a degree of polarization ~0.35, compared to 1 for an ideal polarizer. Measurements for THz band pass mesh filters were also performed (see Fig. 2(c)). These filters were designed to have a center frequency at 600GHz and can operate at any angle of polarization. The results were compared to simulations and analyzed. To reduce the complexity of inkjet-printing cross-slot filters, simulations were carried out for arrays of single slot filters. They gave nearly the same results but the filtering property was dependent on the polarization angle. Fractal designs for cross-slot filters, to operate as multiband filters were also simulated. These designs will soon be ink-jet printed for demonstration of cost-effective THz quasi-optical components.

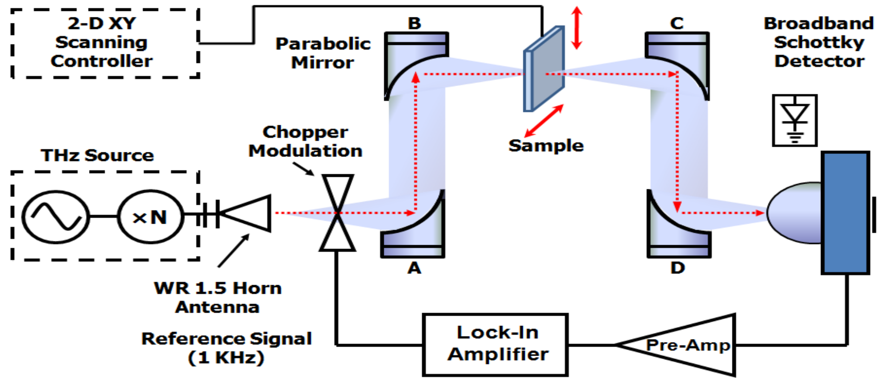

Fig 1. A frequency domain terahertz spectroscopy and imaging system based on broadband quasi-optical Schottky diode detectors. Mirrors A and B collimate and then focus the THz beam through the sample. Mirrors C and D collimate the transmitted signal again and focus it on to the detector. The sample under test, mounted on a computer-controlled XY positioning stage, is placed at the focal point of the THz beam between mirrors B and C. The system is designed to have a Gaussian beam waist (spatial resolution) of approximately 1 mm at the sample.

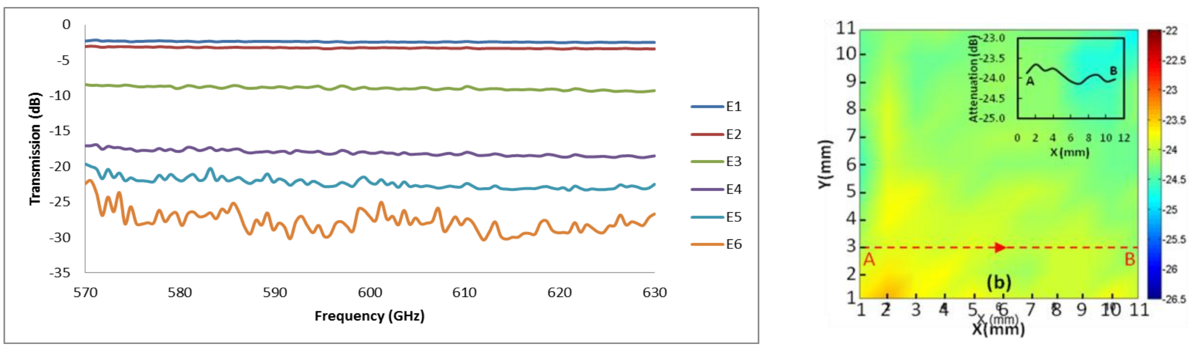

Fig 2a. Graph showing attenuation which increases with increasing loading from E1 to E6 samples.

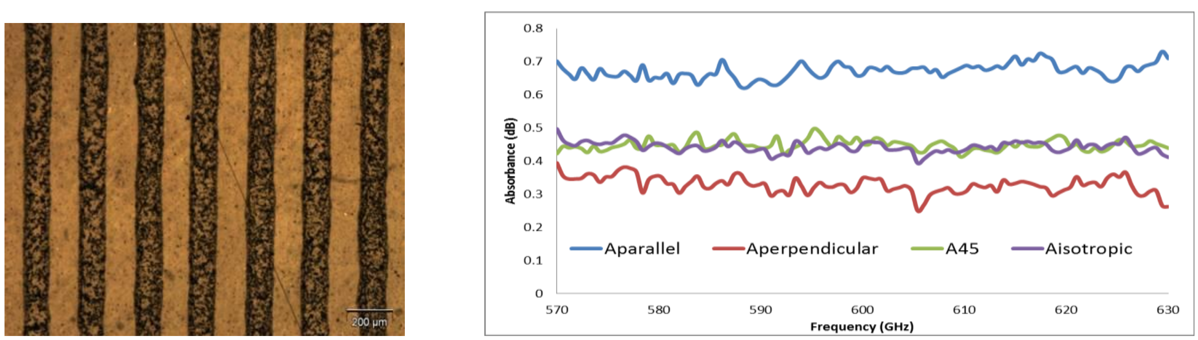

Fig 2b. Absorbance curves for polarizer at various angles of polarization

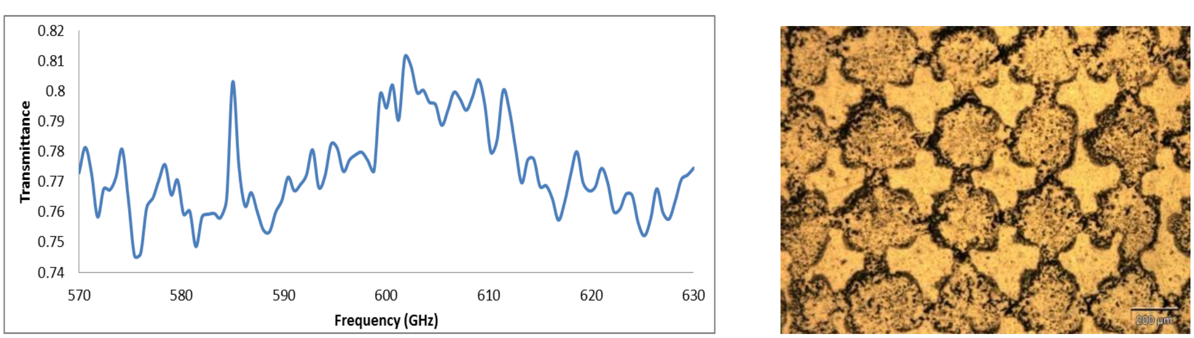

Fig 2c. Band pass filter measurements, being normalized with air