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Tunable CNT Surfaces for THz Wave Applications

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The research and development in the frequency region of 0.1-1.0 THz is extremely significant for the wide range of applications, such as telecommunication and imaging systems, material spectroscopy, medical imaging and treatments, etc. Despite the problems in technology and high prices for basic components (phase shifters, directional couplers, etc.), the THz systems offer higher date rates for telecommunication, high spatial resolution in the visualization of objects, small size of antennas and other elements. The state-of-the-art of the THz devices reveals serious problems with radiation sources with continuous wave semiconductor-based source, electronically tunable phase shifters, etc.

Carbon nanotubes (CNT) offer unique properties due to their natural small dimensions and outstanding electrical properties. Their tunability properties makes them very attractive in application to the THz system. Integration of CNTs with the dielectric rod waveguide (DRW) technology transferred from cellulose membranes onto other substrates (sapphire DRW, optical glass, polished silicon) by direct dry transfer enables a novel technology platform for tunable THz systems.

Phase shifter can be developed by introducing the optically controlled varactor to the DRW. The phase change of 10-20 deg with almost negligible change in attenuation less than 0.1 dB can be achieved in the frequency range of 75-500 GHz. Besides, DRWs have no cut-off frequency enabling broad band operation.

The effect of the dielectric constant tuning of single-walled carbon nanotubes under light illumination is observed in the very wide frequency range of 0.1–1 THz. The optical absorption spectrum is not uniform and it consists of several absorption peaks related to electron transitions. Therefore, the change of capacity and resistance under different light wavelength illumination is different at different wavelengths.

The losses are attributed to the electromagnetic absorption by the CNT layers with differences stemming from variations in nanotube densities and total lengths of the transferred samples on the DRWs. The increased absorbance at lower frequencies has also been previously observed for CNTs.

Carbon based nanomaterials are perspective materials for very wide applications in millimeter wave and THz frequency range. Phase shifter based on DRW loaded with CNT layer is a perspective candidate for ultra-wide band device application. The ultra-wide band optically controlled CNT-based phase shifter can enable THz beam steering.

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