Terahertz response of microfluidic-jetted fabricated 3D multilayer Metamaterials

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The metamaterials (MTMs) are defined as artificial materials which will achieved extraordinary electromagnetic properties that are not available in natural material. Due to their embryonic nature, MTMs evolve in rapid speed in this few years. The science of MTMs, particularly left-handed metamaterials (LH MTMs), has been well established theoretically, numerically, and experimentally in the literature.

The dimension of the element has to be tuned to meet the condition so that it acts as an effective medium to ensure that refractive phenomena will dominate over scattering or diffraction phenomenon when a wave propagates inside the MTMs medium. The ideal lattice size, p, of the MTMs is at least 6 to 10 times less then the incident wavelength. Most of the existed terahertz responses MTMs are a single layer 2D structure fabricated using conventional or advanced clean-room MEMS technology. Here, a new fabrication technique, namely Microfludic-jetted technique, for 3-D alternating SRR/ rod layers of LH MTMs in terahertz region was demonstrated. Material-jetted technique eliminates of the used of die or photomask technique thus reduce the fabrication cost and minimizes the fabrication time. In addition, Microfludic-jetted fabrication is a non-contact technique, thus minimizing contamination during the fabrication. The materiel used for the fabrication is toluene based functionalized-nanogold purchased from Sigma-Aldrich. Polyimide film with thickness of 54μm was used as the substrate for the deposition. During the fabrication, the jetting performance of the nozzle is controlled by the voltage and force duration applied to the printed head silicon piezo diaphragm. The precise deposition is determined by various factors which are the quality of the nozzle, jetting straightness, print height and angle deviation. Two components that determine drop placement accuracy are the jet straightness and print height. Fabricated results of individual SRR and rod structures were shown in Fig. 1(a). Also shown (Fig. 1(b)) was the illustration of 3D LH MTMs with structural size of p=200μm deposited on 54μm thick polyimide substrate and ~43μm thick adhesive clear polymer as the stacking layers.

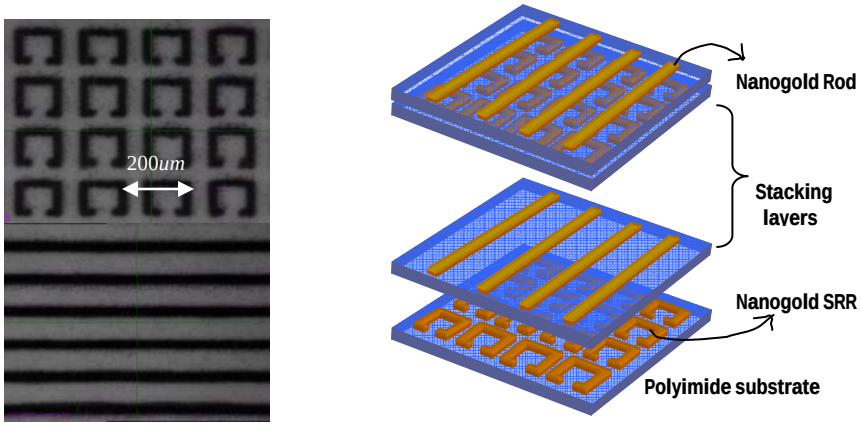

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Figure 1: (a) fabricated result of SRR (up) and rod (down) and (b) illustration of 3D LH MTMs with structural size of p=200μm deposited on 54μm thick polyimide substrate and ~43μm thick adhesive clear polymer as the stacking layers.

The fabricated LH MTMs were characterized utilizing THz-TDS with 0.1 to 2 THz in transmission mode (Fig. 2 (a)). The sample was placed in between the terahertz transmitter and detector in two orientations (Fig. 2(b)) which are: case 1, the wire strip is perpendicular to the E-field and case 2, wire strip is parallel to the E-field. The THz time domain waveforms are acquired by recording the THz transmitted pulse at each sample orientation. Spectral information as a function of frequency, both phase and amplitude is acquired through a Fourier transform of the time-domain data. The absorbance of the sample is shown in Fig. 3.

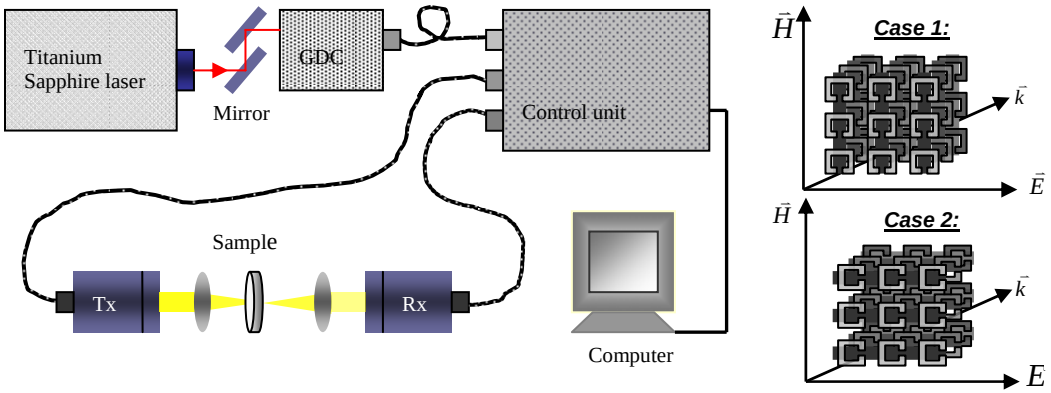

Figure 2: (a) THz-TDS setup and (b) sample orientation.

In case 1, the magnetic field has a component that is perpendicular to the structure, and was therefore expected to excite the SRR in the LH MTMs, whereas in the case 2, the magnetic field is purely parallel to the plane of structure, and was therefore expected not to excite the SRR structure. Absorbance peak for case 2 significantly observe at 0.15 THz demonstrated the magnetic response of the structure. For case 1, since the structure is symmetry to H-field, it showed no electromagnetic response.

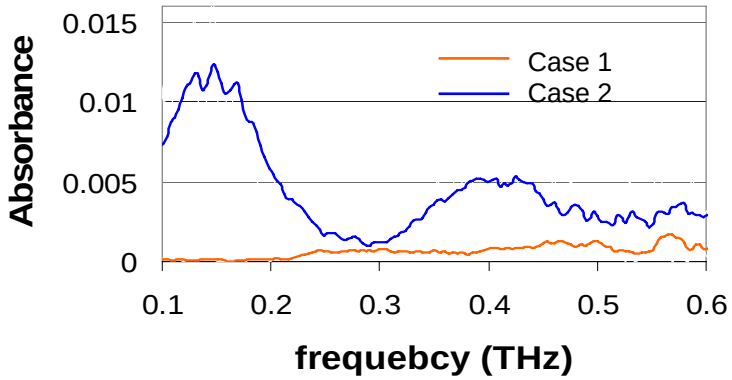

Figure 3: absorbance of the sample orient in two cases where the orange line indicates case 1 and blue line indicates case 2.

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