Terahertz integrated sensors based on metal-insulator composite woven-wire meshes

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Sensing trace amounts of biochemical materials is an urgent demand in various applications, such as food safety, illicit substance inspection, environmental pollutant monitoring, and industrial leak detection. The spectroscopy technology with operating electromagnetic waves via free space and integrated-solid-state configurations is fast and label free, but exact light sources from X-ray to microwave should be selected to achieve noninvasive and non-destructive molecular sensing. Terahertz (THz) radiation, which lies between visible lights and microwaves, possesses low photon energy at a millivolt level, and most non-metallic barriers can pass THz radiation with imaging transparency. Many kinds of biochemical molecules have unique fingerprints in the THz spectral range that arise from intermolecular or intramolecular roto-vibrational transitions. As a result of those finger-prints, THz radiation is capable of label-free, noninvasive, and non-destructive molecular sensing. However, THz spectral sensing is a far-field detection in the conventional scheme. For a tiny analyte, a small absorption cross section exists between THz field and target analytes, which consequently decreases the output signals of transmittance or reflectance. Therefore, a signal enhancer needs to be combined with THz spectroscopy for highly sensitive detection of a minute sample. In this presentation, a scheme of metal–insulator composite woven-wire mesh (MCWM) is experimentally developed based on plastic woven-wire mesh with one side of metallic coating as shown in Fig. 1(a). The plastic woven-wire mesh is formed by crossly interweaving polyethylene terephthalate (PET) polymeric wires, where the parameters of D, W and Λ are respectively 120 μm, 249 μm and 738 μm. For the application of THz integrated sensor, the polymer thin film made of polyacrylic acid (PAA) is integrated with an MCWM to absorb target analytes. The PAA absorber is prepared from the 1 wt% PAA aqueous solution to attach an MCWM via a drop-and-dry process. Figure 1(b) illustrates various densities of PAA thin films can approximately linear shift transmission spectra of MCWM spectral dip. The first order of MCWM spectral dip represents THz wave resonance to cover structural unit aperture as shown in Fig. 1(c) and it is applicable in the experiments for sensing lactose and PE sphere particles, which mimic biological cells.

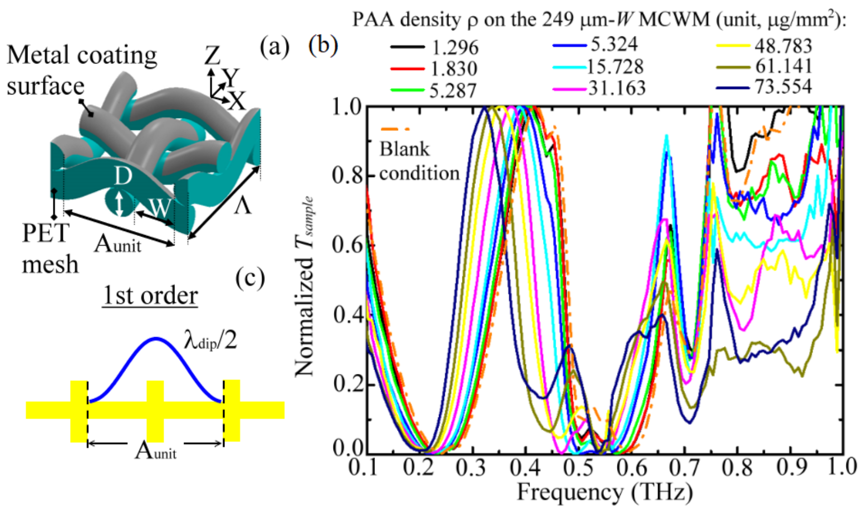

Fig. 1. (a) Unit structure of MCWM (a 3D-view drawing). (b) Normalized transmittance of a 249 μm W MCWM loaded with different weight densities of PAA membranes for a thickness detection experiment. (c) Schematic diagram of the characterized spectral dip wavelength at a lowest frequency relating to A_{unit} of MCWM.

