Terahertz Characterization of Ultrathin Conductive Materials using Parallel Plate Waveguide Time Domain Spectroscopy

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New types of atomically thin materials including graphene exhibit an extraordinary electronic and optical properties and can lead to a major breakthrough in terahertz (THz) science and technology. However, their conductivities are sometimes extremely low, making it challenging to characterize their THz basic properties with conventional THz time domain spectroscopy (THz – TDS).

Here, we develop a new parallel plate waveguide (PPWG)-based THz-TDS technique which is suitable for ultrathin or 2D conductive materials. Additionally, we develop an approach which fulfill some criterions including high sensitivity, compatible with any standard THz-TDS system and nondestructive.

Using a series of extremely thin gold films, we firstly investigate on the sensitivity of our approach and we develop the formalism for extracting the basic parameters from our measurements. We compare the gold thin films response to a transverse magnetic (TM) waveguide mode excitation and to a transverse (TE) waveguide mode excitation. As result, we find that the transverse electric (TE) mode excitation provide higher sensitivity and then in good agreement with the expected THz response of this type of films as shown Fig 1a.

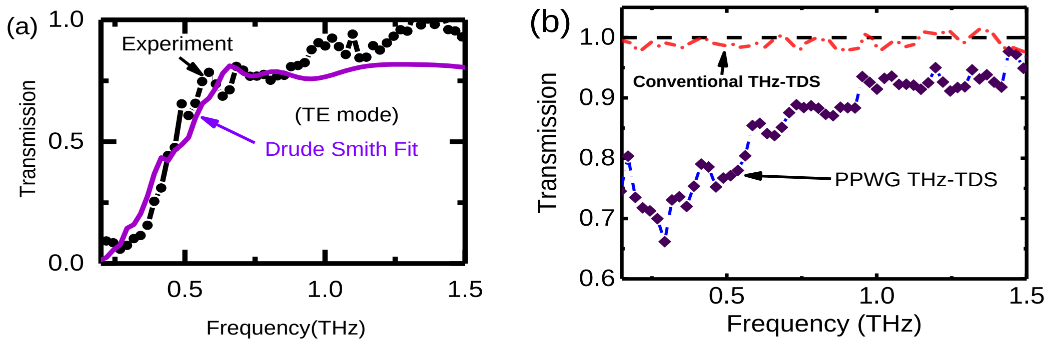

Fig. 1 a) Experimental transmission data and the Drude Smith model fitting for 4nm-thick gold in PPWG. b) Comparison of experimental transmission data taken with conventional THz-TDS and PPWG THz-TDS for graphene.

For the second set of experiment, we investigated on the sensitivity of our approach by comparing with conventional THz-TDS using graphene samples. Fig 1b demonstrates that a carrier density of ~ 2 x 10^{11} cm^{-2}, which induces less than 1% absorption in conventional THz transmission spectroscopy exhibits ~30% absorption in our waveguide geometry. Here, the sensitivity of the waveguide system can be increased by simply increasing the length of the waveguide along which the THz wave propagates, which enables us to detect low-conductive 2D materials.

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