Nonlinear conductivity response of thin graphene/PET film measured by reflection-mode air-plasma THz-TDS

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Due to its unique electronic band structure, graphene is among the most nonlinear optical materials known. Here we show that THz-frequency reflection measurements can characterize the nonlinearity in a quantitative manner. Standard THz-TDS measurements with thin film samples suffer from internally reflected echoes from the film, making the extraction of accurate graphene parameters difficult. Due to the extremely short pulse duration, air-plasma based THz-TDS can avoid such issues and lead to accurate extraction of graphene properties from standard THz transmission measurements [1]. The reflection-mode technique is especially useful for highly absorptive samples/substrates, but reports on reflection-mode TDS with air-plasma based THz sources have been very scarce [2]. We show that with a reflection-mode setting, the conductivity of graphene supported by a thin polymer film can be accurately measured, and we observe strong, instantaneous nonlinear conductivity depletion under high THz field excitation. Our two-color femtosecond air-plasma based THz-TDS setup is shown in Fig. 1(a). A high-resistivity silicon wafer is placed at 45° in the collimated THz beam path to pick up the reflection signal from the graphene/PET sample (230-μm thick). A 45° metallic reflector on a flip mount changes the setup from reflection-mode to transmission-mode. The reflection-mode results are shown in Fig. 1(b,c). At relatively low THz electrical field strength ("LF", ~60 kV/cm), the graphene caused a much stronger reflection signal compared to the bare substrate. With a much higher THz field ("HF", ~1.05 MV/cm), the transient conductivity response was greatly depleted and the fitted σ_{DC} decreases from 3.3 mS down to about 1 mS. Our demonstration paves the way for accurate characterization of the electrical properties of thin/flexible graphene materials in the technically important reflection mode measurements.

References

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Figures

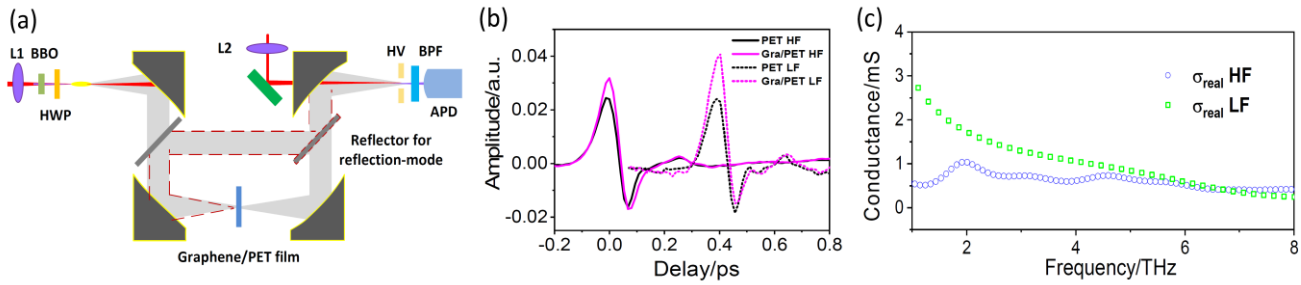

Figure 1: (a) The two-color air-plasma based THz-TDS setup, supporting both reflection- and transmission-mode. (b) Measured waveforms. (c) Extracted real sheet conductance from reflection signals, which shows strong nonlinear conductivity depletion.