Graphene for terahertz technologies

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The material graphene and the terahertz (THz) region of the electromagnetic spectrum appear to be a happy marriage. There are a number of reasons for this. First of all, graphene absorbs a significant fraction of incident THz light – easily 10% or more – which is significantly more than the absorption of visible light – a few %. This happens through *intraband* (Drude) absorption, rather than *interband* absorption. Furthermore, the absorbed energy from incident THz light is efficiently transduced to the electronic system of graphene, whose temperature increases [1]. This electronic temperature is substantial due to the small electronic heat capacity of graphene and its strong electron-electron interactions. The efficient THz-induced carrier heating has several interesting consequences, which will likely become technology relevant. One very recent example is the extremely efficient generation of THz harmonics [2], which is related to the modified THz conductivity of graphene carriers in the heated state [3].

Another very promising application of THz-induced heating of graphene carriers is THz photodetection: through the photo-thermoelectric (PTE) effect, the THz-induced electron heat is converted into an electronic response. Through an in-depth understanding and optimization of the PTE effect in graphene, and by integration with a narrow-gap (~100 nm) antenna, we have developed a graphene-based THz photodetector [4].

Our THz photodetector operates at room temperature and has a linear response over 3 orders of magnitude in power. Crucially, it outcompetes current room temperature THz detectors on the market, as it is simultaneously

i) highly sensitive, with a noise-equivalent power <100 pW/Hz$^{1/2}$;

ii) extremely fast, with a response time <30 ns (setup-limited) or 10 ps (RC-time-limited);

iii) broadband, with an antenna-limited spectral sensitivity in the range 2-4 THz.

Importantly, we clearly identify that the PTE effect is responsible for the photoresponse, and show that the experimental results are consistent with a simple analytical model of the PTE photoresponse, and a numerical model of the absorption enhancement due to the narrow-gap antenna structure. This understanding will lead to further performance improvements.

We expect that this graphene-enabled THz detection technology can have applications in fields such as industrial quality control.

References

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