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Determining Optical Properties of Graphene using Terahertz Time-Domain Spectroscopy for Plasmonic Applications

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As wireless networking technologies continue to advance, our devices and systems are becoming more interconnected. At the same time, advances in materials science and nanotechnology are making possible increasingly smaller components with advanced functionality. Integrating these nanoscale components with an ever-evolving network is expected to lead to an Internet of *Nano*-Things [1], which has potential to revolutionize how we live and work. Taking this next evolutionary step in wireless networking is not without challenges to be overcome [2]. Many are looking to nanotechnology and new nanoscale materials to provide the desired functionality and the requisite material properties to make this possible.

Graphene boasts a long list of impressive physical properties [3]. Among these is the ability to support collective charge oscillations, known as *surface plasmons*, at a graphene–dielectric interface [4]. These surface plasmons can couple to THz-frequency electromagnetic (EM) waves, forming *surface plasmon polaritons*, or SPPs. The much smaller SPP wavelength strongly confines the free-space EM wave at the interface.

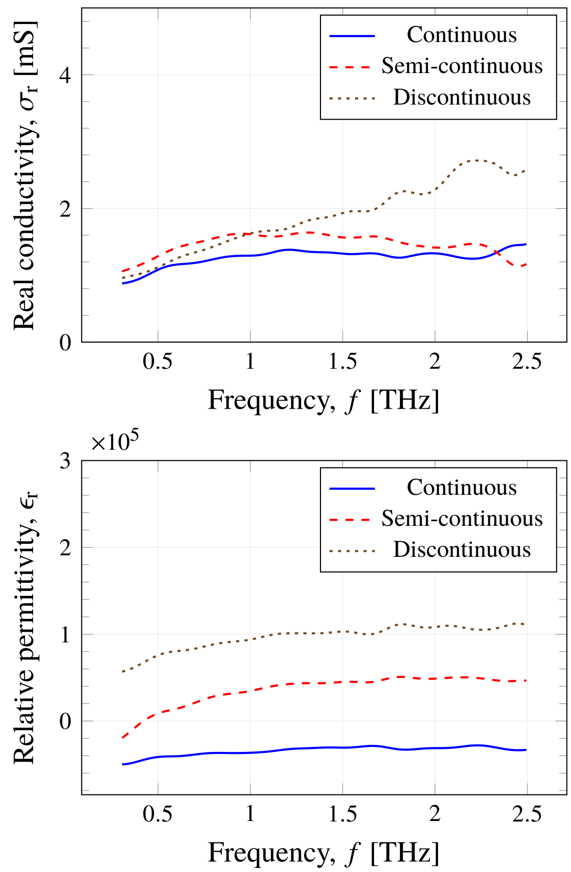

Fig. 1. Real conductivity and relative permittivity of continuous, semi-continuous, and discontinuous CVD-grown graphene.

In this work, we use terahertz time-domain spectroscopy (THz-TDS) to extract the complex optical properties of CVD-grown graphene transferred onto an undoped silicon substrate (Fig. 1). We determine the complex dielectric function of graphene based on the complex conductivity extracted from the Fresnel reflection coefficient at the substrate–graphene interface. We find that the relative permittivity is negative only in case of large-area continuous graphene. This is a characteristic seen in bulk metals. If the graphene is discontinuous, the relative permittivity will be positive, which is similar to the dielectric behavior of thin metal films. Extracting the optical properties of transferred graphene helps us determine if the graphene is capable of supporting plasmons, and therefore suitable for fabricating plasmonic nanostructures. We can then determine appropriate graphene dimensions to define a resonant cavity would act as an antenna in the THz range.

References

[1] I. F. Akyildiz and J. M. Jornet, "The internet of nano-things," *IEEE Wireless Communications Magazine*, vol. 17, pp. 58–63, Dec. 2010.
[2] I. F. Akyildiz, J. M. Jornet, and C. Han, "Terahertz band: Next frontier for wireless communications," *Physical Communication (Elsevier) Journal*, vol. 12, pp. 16 – 32, Sept. 2014.
[3] A. K. Geim and K. S. Novoselov, "The rise of graphene," *Nature Materials*, vol. 6, pp. 183–191, Mar. 2007.
[4] E. H. Hwang and S. Das Sarma, "Dielectric function, screening, and plasmons in two-dimensional graphene," *Physical Review B*, vol. 75, p. 205418, May 2007.