Lower-frequency plasmons

Plasmons are more familiar to us in the high-frequency, visible part of the electromagnetic spectrum and notably in 3D metallic nanostructures. One well known example of where they can be seen is in stained glass windows. Here, the colours come about from oscillating collections of electrons on the surfaces of nanoparticles of gold, copper and other metals contained in the glass. However, graphene is only one atom thick and its electrons move in just two dimensions, explains Wang, so plasmons in this material occur at much lower frequencies.

What is more, terahertz radiation lies in the wavelength range of between about 1 to 0.03 mm but the width of the graphene ribbons is just 1 4 m. "A material that consists of structures with dimensions much smaller than the relevant wavelength, and which exhibits optical properties distinctly different from the bulk material, is called a metamaterial," said Wang in a LBNL press release. "So we have not only made the first studies of light and plasmon coupling in graphene, we've also created a prototype for future graphene-based metamaterials in the terahertz range."

Resonant excitations

So, how can varying the width of the graphene nanoribbons make them absorb different frequencies of light? As mentioned, a plasmon describes the collective oscillations of many electrons but its frequency depends on how rapidly these oscillations travel between the edges of a ribbon. When light of the same frequency as the oscillations is applied, a "resonant excitation" results, something that produces an increase in the strength of the oscillations and the amount of light absorbed at that frequency. Because the frequency of the oscillations depends on the width of the ribbon, varying its width thus allows it to absorb different frequencies of light.

The number of charge carriers in the ribbon can also affect the strength of the coupling between light and plasmons. One advantage of graphene is that the concentration of charge carries can easily be increased or decreased in the material by applying a strong electric field. Such a technique is called electrostatic doping. Finally, the researchers have also found that light shone perpendicularly onto the ribbons is much better absorbed at the plasmon resonant frequency than light shone at other angles.

Room-temperature measurements

Wang and co-workers obtained their results by shining terahertz light (from the beamline at Berkeley Lab's Advanced Light Source) onto the graphene ribbon arrays. They then measured the light transmitted using the beamline's infrared spectrometer. The result shows that coupling between light and plasmons in graphene is an order of magnitude stronger than in other 2D systems, like semiconductors. The light absorption in graphene can also be measured at room temperature unlike in these other materials, which need to be near absolute zero in experiments.

"Wang's team reports an interesting study of plasmons in graphene ribbons and show how to tune their properties, and the work represents a further step in understanding light-electrons interactions in this material," commented Andrea Ferrari of Cambridge University, who was not involved in the work. "The THz range covered by these experiments could eventually enable products such as portable terahertz sensors for remote detection of dangerous agents, environmental monitoring or high-speed wireless communications. However, to achieve these goals will require much more effort on the part of the graphene and plasmonics communities."

Wang told *nanotechweb.org* that his team, for its part, is now looking into designing different metamaterial structures from graphene and examining their properties.

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About the author

Belle Dumé is contributing editor at *nanotechweb.org*