Simulation and experimental investigation of 2D materials with far and near-field THz spectroscopy

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We show a direct comparison of the near and far-field THz spectroscopy used for characterisation of 2D materials. We demonstrate that the spatial resolution is dependent on the field detected (i.e. far or near-field), the limitation that arises from the detection scheme and the behaviour of the 2D materials when a THz field is applied. The observed material behaviour is also supported via simulations with Computer Simulation Technology (CST) software.

Fig. 1 shows the experimental results of the CVD graphene characterized with the far and near-field THz detection. The black squared area in the Fig.1a measured with our far-field setup (Picometrix© T-ray™ 4000) system is shown with a higher resolution in Fig.1c measured with the near-field spectroscopy via a low temperature Gallium-Arsenide photoconductive field detector [1]. As it can be observed the near-field detection will increase the spatial resolution, thus offering a more detailed characterization of the graphene quality.

The simulated structure shown in Fig.2a is a square shaped 1 layer graphene with side lengths of 40µm and another layer (shown in red) on top with side length of 20µm. The probes shown in Fig.2b are placed every 5µm throughout the sample and 51 layers of them every 10µm until 501µm mimic the cantilever structure used for the detection in the near-field setup. The thickness of one layer graphene and the high resistivity silicon substrate are 0.35nm and 525µm respectively. The excitation signal is a plane wave shown in Fig.2a and the simulation was done with 50.294.400 mesh cells.
Fig.3 shows the real part of the conductivity for the simulated graphene, where (a) is the theoretical calculated value via the Kubo formalism [2,3] (b) shows the detected value only with a single probe 11µm away from the sample and (c) as an average of all the probes, thus mimicking the cantilever. As it can be observed the path that the signal has to travel will distort the value of the conductivity, affecting of course also the spatial resolution that can be achieved with this method.

References

[1] http://www.protemics.com/index.php/products/teraspike/td-800-x-seriesL

[2] Falkovsky, S. Pershoguba, Physical Review B 76, (2007) 1–4.

[3] G.W. Hanson, IEEE Transactions on Antennas Propagation 56, (2008) 747–757.

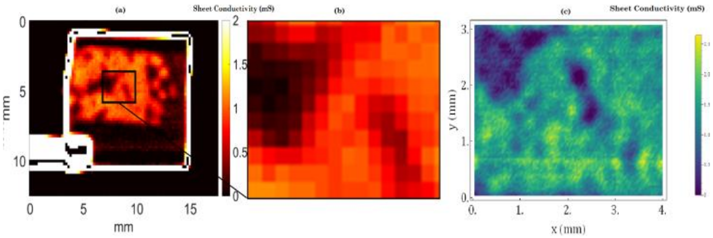

Figure 1: (a): Far-field sheet conductivity map of the CVD graphene, (b): Zoomed area of the indicated square in the first image, (c): Near-field sheet conductivity map of the area in (b)

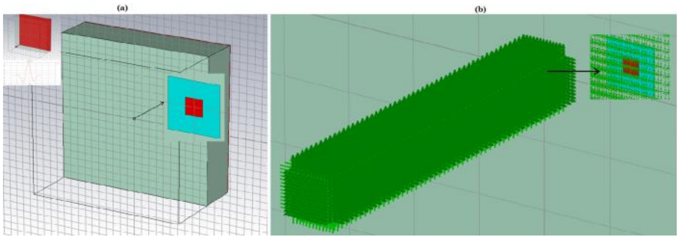

Figure 2: The simulated structure via CST

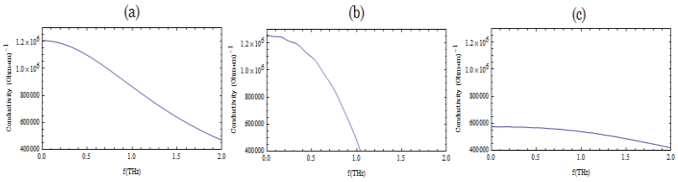

Figure 3: Real part of conductivity: (a) calculated with Kubo formalism, (b) from the probe 11µm away from the graphene sample, (c) average from all the 51 probes