Large-area electrical characterisation of graphene

Peter Bøggild, Jonas Due Buron, Dirch Hjorth Petersen, David M. A. Mackenzie, Tim Booth, Peter Uhd Jepsen

DTU Nanotech, Ørsteds Plads, Technical University of Denmark, Kgs. Lyngby, Denmark
peter.boggild@nanotech.dtu.dk

Abstract.

The gap between the rapidly upscaling of large-area graphene production compared to available electrical characterisation methods could become a major roadblock for emerging graphene applications. As an alternative to the often slow, cumbersome and destructive characterisation techniques based on electrical field effect or Hall measurements, THz time-domain spectroscopy (THz-TDS) [1] not only maps the conductance quickly and non-destructively, but also accurately. This is confirmed by direct comparison with micro four-point probe (M4PP) measurements, another low-invasive, well-established method already used by major semiconductor manufacturers for inline quality control. In addition to spatial maps of the sheet conductance, THz-TDS and M4PP offer unique information on otherwise hidden defects and inhomogeneities, as well as detailed scattering dynamics in the graphene film on nm to mm length scales [2-4]. We also show that THz-TDS can be used to map the carrier density and mobility, either by transferring graphene to a substrate equipped with a THz-transparent back gate [5], or by analyzing the frequency response in detail to extract the scattering time at a constant carrier density [6], which allows the mobility to be mapped even on insulating substrates. In contrast with conventional field effect and Hall measurements, THz-TDS measures the actual, *intrinsic* carrier mobility, i.e. not derived from a conductance (extrinsic) measurement. As field effect measurements are expected to remain useful for benchmarking, we have developed a fast (1 hour turn-around time) and clean (no solvents or water) method for converting a graphene wafer into 49 FET devices with electrical contacts, using a combination of a physical shadow mask and laser ablation [6,7]. Finally, the challenges of realizing in-line monitoring of the electrical properties in a graphene production scenario, and the prospects for establishing THz-TDS mapping as a measurement standard for large-area graphene films will be discussed.

References

[1] J. Buron, D. H. Petersen, P. Bøggild, D. G. Cooke, M. Hilke, J. Sun, W. Whiteway, P. F. Nielsen, O. Hansen, A. Yurgens, P. Uhd-Jepsen, Nano Letters, 12 (2012), 5074.
[2] J. D. Buron, F. Pizzocchero, B. Jessen, T. J. Booth, P. F. Nielsen, O. Hansen, M. Hilke, E. Whiteway, P. U. Jepsen, P. Bøggild, D. H. Petersen, Nano Letters, 14 (2014), 6348.
[3] M. R. Lotz, M. Boll, O. Hansen, D. Kjær, P. Bøggild, D. H. Petersen, Appl. Phys. Lett., 105 (2014), 053115.
[4] M. Boll, M. R. Lotz, O. Hansen, F. Wang, D. Kjær, P. Bøggild, and D. H. Petersen, Phys. Rev. B, 90 (2014), 245432.
[5] J. D. Buron, D. M. A. Mackenzie, D. H. Petersen, A. Pesquera, A. Centeno, P. Bøggild, A. Zurutuza, P. U. Jepsen, Optics Express, 24 (2015), 250745.
[6] J. D. Buron, F. Pizzocchero, P. U. Jepsen, D. H. Petersen, J. M. Caridad, B. S. Jessen, T. J. Booth, P. Bøggild, Scientific Reports 5 (2015), 12305.
[7] D. Mackenzie, J. Buron, B. S. Jessen, A. Silajdzic, A. Pesquera, A. Centeno, A. Zurutuza, P. Bøggild and D. H. Petersen, 2D Materials, 4 (2015), 045003.