Jan Obrzut
Randolph E. Elmquist.
National Institute of Standards and Technology, Gaithersburg, MD 20899-8542, USA
jan.obrzut@nist.gov

Non-contact measurement of graphene conductivity using a microwave cavity; IEC standard 62607-6-4 and its benefit to the graphene industry

Abstract
Recent years have witnessed many breakthroughs in research as well as a significant investment to advance the mass production of graphene materials. Currently, there are several methods being used and developed to prepare graphene-like materials of various dimensions, shapes and number of layers. The most commonly reported quality parameter of graphene materials is the conductivity. In this context, the availability of a standard conductivity measurement technique and graphene reference material for which the 2D surface conductivity can be related to number of layers, mobility and fundamental physical constants, can be a breakthrough that may change the face of the industry. Here we describe a non-contact measurement technique to reliably determine surface conductivity of single-layer or multi-layer atomically thin nano-carbon graphene structures [1]. The measurements are made in an air filled standard R100 rectangular waveguide configuration at one of the resonant frequency modes, typically at TE_{103} mode in the range of 7.435 GHz. Surface conductivity measurement involves monitoring a change in the quality factor of the cavity as the specimen is progressively inserted into the cavity in quantitative correlation with the specimen surface area. The specimen consists of a nano-carbon-layer supported on a low loss dielectric substrate. The thickness of the conducting nano-carbon layer does not need to be explicitly known, but it is assumed that the lateral dimension is uniform over the specimen area. The non-contact surface conductivity measurements are illustrated for a typical graphene grown by chemical vapor deposition process (CVD), and for a high quality monolayer epitaxial graphene grown on silicon carbide wafers for which we performed non-gated quantum Hall resistance measurements [1, 2]. The non-contact cavity method for nano-carbon graphene layers has been standardized [3], and like other non-contact methods (i.e., ellipsometry and optical density) it allows characterization with high speed and efficiency, compared to transport measurements where sample contacts must be defined and applied in multiple processing steps. We believe that the described non-contact microwave cavity test method standard [3] can enable the industry to assess the quality and the corresponding electronic properties of their product, without ambiguity. The effort can also aid manufacturing of many other 2D crystals, which are structurally related to graphene.

References

[1] J. Obrzut, C. D. Emiroglu, O. Kirillov, Y. Yang, R. E. Elmquist; Measurement Journal 87 (2016) pp 146–151.
[2] Y. Yang, L.-I. Huang, Y. Fukuyama, F.-H. Liu, M.A. Real, P. Barbara, C.-T. Liang, D.B. Newell, R.E. Elmquist; Small 11 (2015) pp 90–95.
[3] IEC TS 62607-6-4:2016, Nanomanufacturing - Key control characteristics - Part 6-4: Graphene - Surface conductance measurement using resonant cavity.