Ellipsometry Measurement for Graphene

Ellipsometry has proven to be an effective characterization technique for graphene since Novoselov and Geim's Nobel Prize in 2010. A single layer of graphene, which is theoretically 3.35Å thick, absorbs about 2.3% of transmitted light across the VIS/IR spectrum and as much as 10% in the UV region. This thin layer, which has the equivalent thickness of three hydrogen atoms, is visible to the human eye under the right conditions. These properties translate into measurable changes in the polarization state of light and allow for ellipsometric characterization of the film thickness and refractive index.

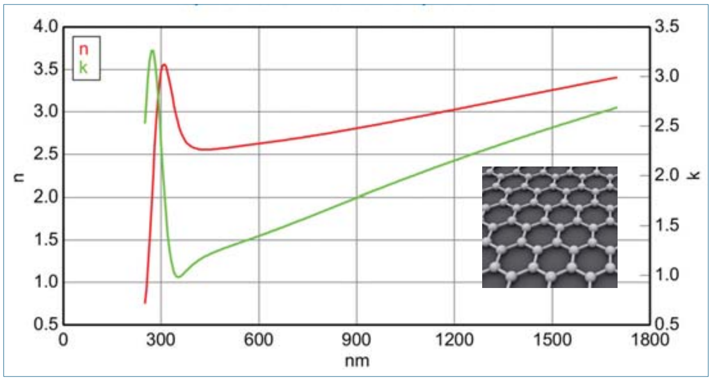

Figure 1. Optical properties of exfoliated graphene deposited on thermally oxidized silicon.

Graphene is a uniquely challenging ellipsometry problem because its electronic properties result in a material that is optically absorbing across the entire measurable spectrum while also being an ultra-thin film. This combination generally results in insufficient information to determine the optical properties of the film from a single measurement. However, this can be overcome by designing an experiment that will enhance information content, such as the interference enhancement technique, a Multi-Sample Analysis approach or a combination of both.

The interference enhancement technique requires the graphene to be deposited on a thick transparent film, with preferred thickness of at least 300nm. The thick, transparent film acts as an etalon, with the interference pattern dampened by the presence of the graphene. When measurements are taken at various angles of incidence, a sufficiently large change in path length occurs which provides additional independent data and allows for the characterization of the refractive index. Once the interference enhanced ellipsometric data is collected, standard analysis procedure for absorbing films applies.

The Multi-Sample Analysis technique is another approach that can provide additional information to assist in characterization of the graphene refractive index. As the name implies, the key to this technique is to measure multiple samples, varying the thickness of the graphene or the substrate in which it is deposited while ensuring that the varied conditions don't lead to variation in graphene properties. A mono-layer to bi-layer variation in thickness is typically sufficient to obtain enough independent information for characterization. Graphene doesn't begin to act as a bulk 3-dimensional material until it is more than a few mono-layers thick so the mono- to bi-layer variation should not result in a variation of the refractive index of the film. When varying the substrate, the most common method is to use thermal oxides of varying thicknesses. This will ensure that there isn't a sample-to-sample variation in the graphene-substrate interaction with the added benefit of providing interference enhancement. Some evidence suggests the substrate can affect the properties of the film, therefore, it is important to ensure that the substrate choice will not lead to variation in the graphene under analysis.

Finally, it is important when measuring graphene to ensure that your beam probes only the graphene and doesn't spill off onto the substrate. This error is common when measuring mechanically exfoliated graphene due to the small sample size produced by this technique.

For more detail, please contact an applications engineer to discuss your application: measurements@jawoollam.com.