Metrology for graphene, and graphene for metrology

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Abstract The measurement infrastructure for graphene and related two-dimensional (2D) materials must be improved and focused in order for the technological promise of these materials to come to fruition. The comparison of the results of a suite of analytical measurements with the results of electrical test structure and device measurements to directly determine the relationship between the underlying atomic and chemical structure of the materials and interfaces and the end electrical device behavior is a powerful method to research and development. Such data on the structure-function relationship can be used to guide the optimization of device structures and fabrication processes. For example, by combining the results of a sophisticated suite of measurements (Raman spectroscopy, photoemission spectroscopy, scanning electron microscopy, and atomic force microscopy) with the electrical device parameters obtained from well-designed test structures, processes for metal contacts to 2D materials such as graphene [1] and molybdenum-disulfide (MoS_2), [2] are improved leading to higher performance electronic devices. The fundamental optical properties of 2D materials (e.g. archival data) must be carefully measured to enable optical methods such as Raman spectroscopy and spectroscopic ellipsometry to be used for determining material quality and process monitoring.

The unique physical and electrical properties of graphene also can be harnessed to improve measurements of other materials and systems. For example, by using an optically transparent graphene contact in internal photoemission (IPE) measurements, the offsets of both the valance band and the conduction band at the buried heterojunction interface of a InAs/GaSb tunnel field-effect transistor can be experimentally extracted. [3] This information is critical to optimize the electronic performance of these emerging nanoelectronic devices. In addition, graphene-based devices can be directly used to provide fundamental metrology for traceable standards. Due to its energetics, graphene allows observation of the quantum Hall effect at higher temperatures and lower magnetic fields then in traditional GaAs-based devices. With controlled device engineering of graphene p/n junctions a wide and tunable range of quantized resistance values can be observed at a fixed magnetic field. [4]

References

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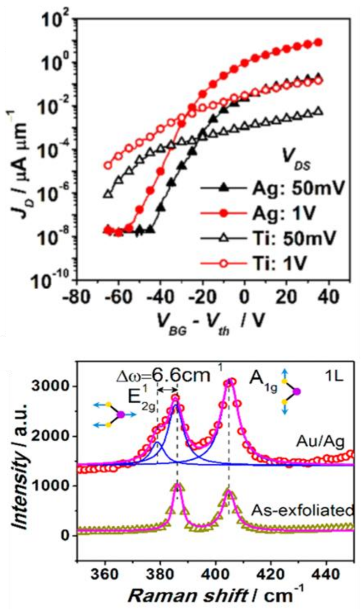

Figure 1: Correlation of the results of electrical device parameterization with Raman spectra to improve metal/MoS_2 contacts.

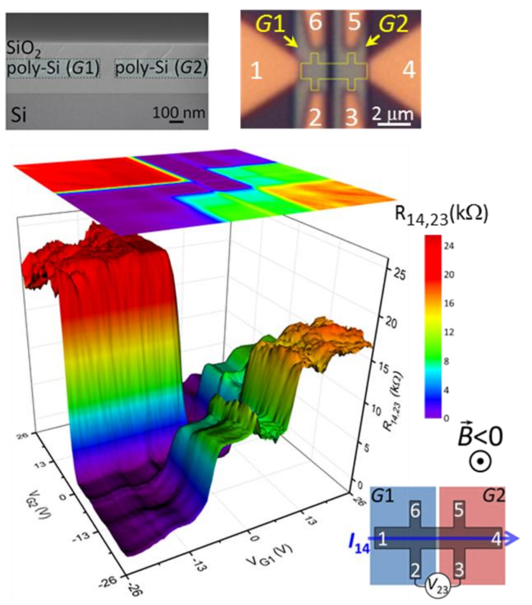

Figure 2: Multiple quantize resistance values observed in a graphene p/n junction Hall bar device.