Backside Absorbing Layer Microscopy: a New Tool to Study the Optical, Chemical and Electrochemical Properties of 2D Materials

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Optical microscopy based on anti-reflective coatings is a simple yet powerful characterization tool which notably allowed the first observation of graphene in 2004 and of other single-layered materials in the following years. Since then, the field of two-dimensional materials has developed rapidly both at the fundamental and applied levels. Yet, these ultrathin materials present inhomogeneities (edges, grain boundaries, defects, multilayers...) which strongly impact their intrinsic (physical, chemical) properties and the performances of the electronic, optoelectronic and energy-conversion devices. The use of local characterization techniques (spectroscopy mapping, scanning probe techniques...) is thus essential. Recently, D. Ausserré et al. introduced a new enhanced-contrast optical microscopy technique, named BALM (Backside Absorbing Layer Microscopy), based on ultrathin (2-5 nm) and strongly light-absorbing (metallic) anti-reflective layers. This talk aims at presenting the remarkable assets of this technique for the study of 2D materials. BALM notably allows observing mono-layered materials with very strong contrast even in the case of transparent ones such as graphene oxide [1]. The inverted microscope geometry allows imaging in solvents so that it is possible to investigate molecular adsorption dynamics on 2D materials in real-time and with extreme sensitivity.[1-2] With its wavelength sensitivity, it can also be used as a precise technique to determine the refractive index and extinction coefficient of TMDCs (MoS_2, WS_2). But one of the main benefits of BALM comes from its combination to other techniques. We particularly considered the coupling between optical measurements and electrochemistry for which the anti-reflective substrate serves as working electrode. We investigated optically the dynamic of the electrochemical reduction of Graphene Oxide (GO), the electro-grafting of organic layers by diazonium salts reduction on GO and its reduced form (rGO),[3] as well as the intercalation of metallic ions within stacked GO sheets. By combining versatility and high-contrast, BALM is established as a promising tool for the study of 2D materials, especially for the local and in situ characterization of their optical, chemical and electrochemical properties.

[1] S. Campidelli, R. Abou Khachfe, K. Jaouen, J. Monteiller, C. Amra, M. Zerrad, R. Cornut, V. Derycke, D. Ausserré, Backside absorbing layer microscopy: Watching graphene chemistry, *Science Advances* **3**, e1601724 (2017).
[2] K. Jaouen, R. Cornut, D. Ausserré, S. Campidelli, V. Derycke, Ideal optical contrast for 2D materials observation using bi-layer antireflection absorbing substrates, *Nanoscale* **11**, 6129 (2019).
[3] K. Jaouen, F. Lebon, B. Jousselme, S. Campidelli, R. Cornut, V. Derycke, Optical monitoring of diazonium electrografting on gold and graphene oxide using Backside Absorbing Layer Microscopy, submitted.