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Inverted optical reflection microscopy is a powerful tool to study nanomaterials undergoing *in situ* processes. Its configuration is highly compatible to work with solvents, and the use of metallic anti-reflection coatings can enhance sensitivity to changes in optical path length (OPL), in addition to serving as an electrode. We recently demonstrated some of its assets for the high-contrast observation of graphene oxide and its chemical modifications [1] as well as for the *in situ* study of ultrathin molecular film growth [1,2]. The present work is focused on the study of CVD-synthesized MoS_2 monolayers, with two main objectives. The first is to enhance its visibility and OPL sensitivity to bilayers, grain boundaries and other topographic features, by use of suitable metallic and dielectric interference coatings combined with optimal incident wavelengths and illumination conditions. An example is shown in Figure 1a.

The second purpose is for real-time local charge imaging during electrolyte gating. The method is based on exploiting the high sensitivity of optical parameters (n,κ) in 1L MoS_2 to its charge density, at certain wavelengths [3,4]. We show that optical images in charge accumulation and depletion states differ appreciably in optimized conditions, and allow for the direct extraction of charge profiles as shown in Figure 1b. A variation of this method, requiring additional FFT post-processing, was demonstrated in 2019 by Zhu et al. [5]. Additionally, we show that by using tailored multi-layer interference coatings, the optical sensitivity to gating is further enhanced. This work opens the door to measuring high-throughput *in operando* device physics parameters of nanomaterial electronic systems, using readily accessible optical equipment.

References

[1] S. Campidelli et al., *Sci. Adv.*, **3** (2017) e1601724
[2] K. Jaouen et al., *Nanoscale*, **11** (2019) 6129−6135
[3] Y. Yu et al., *Nano Lett.*, **17** (2017) 3613−3618
[4] V. G. Kravets et al., *NPJ 2D Mater. Appl.*, **3** (2019) 36
[5] H. Zhu et al., *ACS Nano*, **13** (2019) 2298−2306

Figures

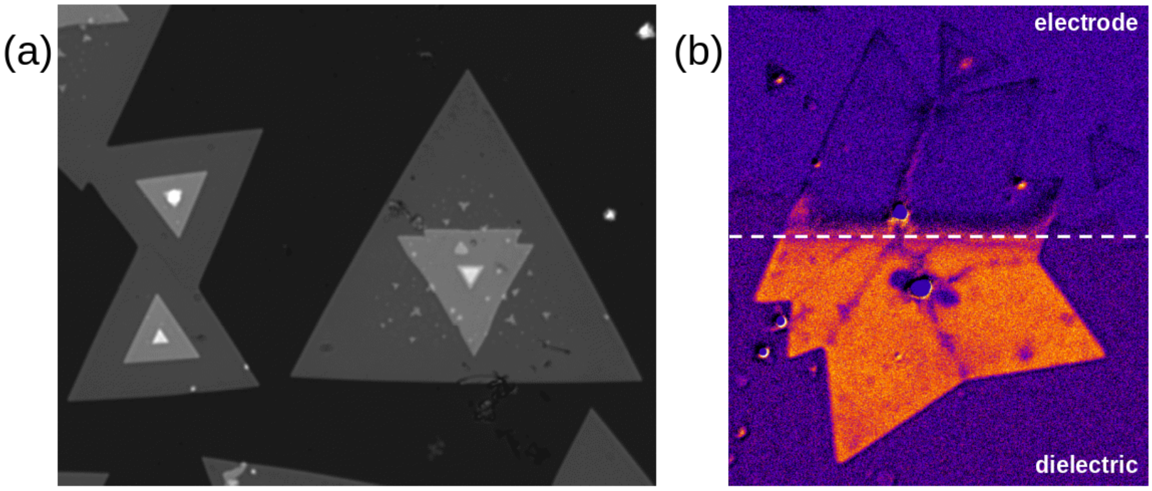

Figure 1: (a) Optical image of MoS_2 on a tailored multi-layer anti-reflection substrate, and (b) charge profile colorplot acquired by subtraction of accumulation and depletion images in electrolyte-gating configuration.