Imaging charge modulation in operating 2D MoS_2 devices by excitonic reflection microscopy

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Field-effect transistors rely on modulation of the charge density profile (CDP) in a semiconducting channel upon application of source–drain and source–gate voltages. The capability to map directly the local variations of the charge density in operating devices is thus highly desirable. However, few techniques allow such *in operando* CDP mapping. Kelvin probe force microscopy is typically the method of choice as it can be used to image work function modulation in FETs and its changes as a function of V_{DS} and V_{GS} [1]. Yet, KPFM suffers from its extremely low throughput—typically several minutes per image at each (V_{DS},V_{GS}) polarization point.

In 2D TMDs, and in particular monolayer MoS_2, it is known that the optical parameters (n,κ) are highly sensitive to the charge density near exciton energies [2–4]. Based on this, we developed the use of an interference reflection microscope (IRM) at illumination wavelength near the exciton energy as a means to access the CDP in operating MoS_2 FETs [5]. As exemplified in Fig. 1(a), this technique, which we call excitonic reflection microscopy (XRM), can reveal with strong contrast the gradient in CDP from source to drain in biased devices. Videos acquired while varying V_{GS} and V_{DS} can furthermore give access to the CDP evolution with sub-second throughput, allowing direct observation of the gate vs. drain competition. Additionally, averaged regions-of-interest can be plotted and studied as a function of time, as exemplified in Fig. 1(b).

The FET in Fig. 1 uses an ionic liquid as gate electrolyte, which yields very high gate capacitance but limits operation speed. We will also show that XRM can be used adventageously in a special solid-state configuration based on backside absorbing layer microscopy [6], allowing for CDP imaging with enhanced contrast, among other advantages.

References

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Figures

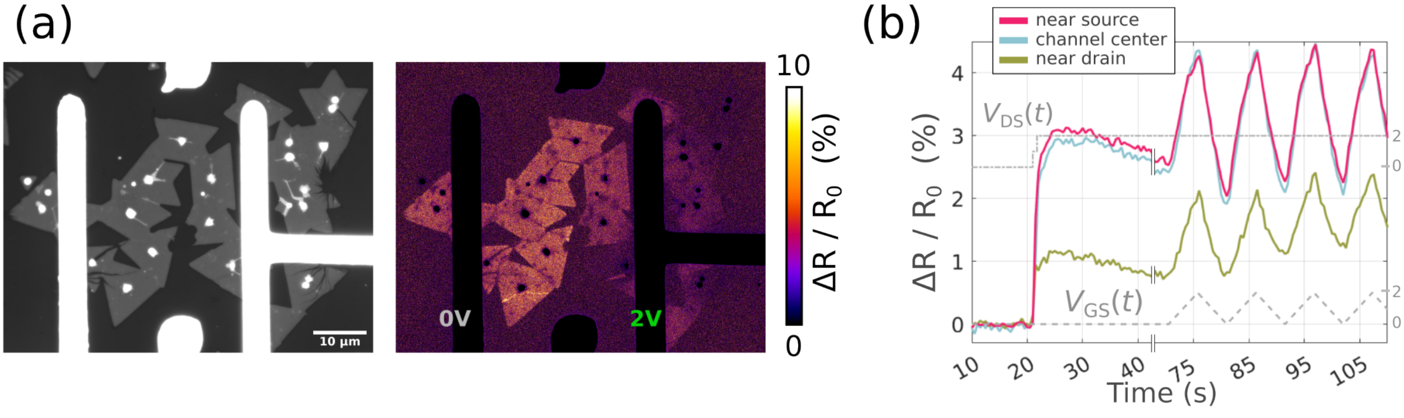

Figure 1: (a) Micrograph and effective CDP image of an MoS_2 field-effect transistor. (b) Three regions-of-interest plotted as a function of time, evolving upon application of (V_{DS} ,V_{GS}).