Thickness Mapping and Layer Number Identification of Exfoliated van der Waals Materials by Fourier Imaging Micro-Ellipsometry

Ralfy Kenaz[1], Saptarshi Ghosh[1], Pradheesh Ramachandran[1], Kenji Watanabe[2], Takashi Taniguchi[2], Hadar Steinberg[1], and Ronen Rapaport[1]
1 Racah Institute of Physics, The Hebrew University of Jerusalem, Israel
2 National Institute for Materials Science, Japan
ralfy.kenaz@mail.huji.ac.il

As performance of van der Waals heterostructure devices is governed by the nanoscale thicknesses and homogeneity of their constituent mono- to few-layer flakes, accurate mapping of these properties with high lateral resolution becomes imperative. Spectroscopic ellipsometry offers simple, noninvasive and highly accurate optical characterization for determining the optical properties and thicknesses of such atomically thin films. However, the effective use of standard ellipsometric methods on exfoliated micron-scale flakes is inhibited by their tens-of-microns lateral resolution or very slow data acquisition. In this work, we demonstrate a Fourier imaging Spectroscopic Micro-Ellipsometer (SME) with sub-5 microns lateral resolution and three orders-of-magnitude faster data acquisition than similar-resolution ellipsometers [1]. The SME is capable of recording spectrally resolved ellipsometric data simultaneously at multiple angles of incidence in a single measurement of a few seconds. This record-high data acquisition rate along with up to 2 microns lateral resolution allow performing angstrom-level accurate and consistent thickness mapping on exfoliated mono-, bi- and trilayers of graphene, hexagonal boron nitride (hBN) and transition metal dichalcogenide (MoS_2, WS_2, $MoSe_2$, WSe_2) flakes [2]. The SME can successfully identify highly transparent monolayer hBN, a challenging proposition for other characterization tools. In addition, the SME can accurately extract the optical properties of atomically thin structures, as showcased on an exfoliated monolayer flake. The optical microscope integrated ellipsometer (Fig. 1(a)) can also map minute thickness variations over micron-scale flakes, revealing their lateral inhomogeneity (Figs. 1(b)-1(d)). The prospect of adding standard optical elements to augment generic optical imaging and spectroscopy setups with accurate *in situ* ellipsometric mapping capability presents potential opportunities in investigation of exfoliated 2D materials and their heterostructures.

References

[1] Ralfy Kenaz and Ronen Rapaport, Review of Scientific Instruments (2023), 94, 023908.
[2] Ralfy Kenaz et al., ACS Nano (2023), 17 (10), 9188-9196.

Figures

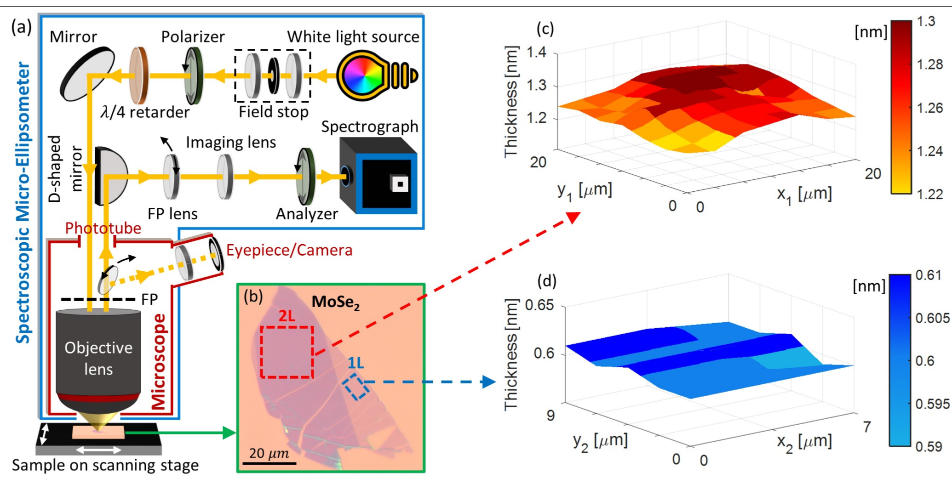

Figure 1: (a) Schematic of the Spectroscopic Micro-Ellipsometer (SME); FP: Fourier Plane. (b) Exfoliated $MoSe_2$ flake with marked areas for monolayer (1L) and bilayer (2L) thickness mapping by the SME. (c) Thickness map of $MoSe_2$ bilayer over an area of 20 × 20 μm². (d) Thickness map of $MoSe_2$ monolayer over an area of 7 × 9 μm². The SME spot size for these measurements is 5 μm.