QUANTITATIVE NANOSCALE ABSORPTION MAPPING OF TWO DIMENSIONAL MATERIALS

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We develop a novel technique for mapping the absorption properties of 2D MoS2 and MoSe2 monolayers with nanoscale resolution by taking advantage of the underlying substrate cathodoluminescence emission.
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1. Introduction

Atomically thin semiconductors hold the promise of complementing graphene in many different applications, where the lack of a band gap hampers its use. Single-layer transition metal dichalcogenides (TMDs) are the most studied class of 2D semiconductors to date (1). The direct gap of single-layer TMDs, in the visible and near-infrared ranges of the electromagnetic spectrum, has triggered the interest in its optical properties with the perspective of a new generation of optoelectronic devices (2).
If isolated atomic planes are assembled into heterostructures, often referred to as “van der Waals” (vdW) heterostructures, layer by layer precisely chosen sequences are obtained without the constraints imposed by epitaxy such as crystal-lattice match or chemistry compatibility (3). The interlayer interaction in TMD-based vdW heterostructures has resulted in a manifold of novel optical phenomena. For instance the possible formation of the interlayer exciton is promoted by the staggered band alignment of the TMD semiconducting single layer (4). Further, the interlayer coupling of excitons in MoS2 bilayers strongly depends on the twist angles between the two MLs (5).

2. Results

In this work we use a novel nondestructive contactless quantitative nanoscale absorption technique (QNAM) for mapping the absorption of 2D materials (6). That is achieved by using the Cathodoluminescence (CL) emission of the underlying substrate (Figure 1). Different substrates have CL emission in different spectral ranges, allowing quantitative absorption evaluation in such ranges. For instance, sapphire provides information in the deep UV range due to emission of the oxygen vacancy at 323 nm (4.3 eV); meanwhile, SiO2/Si substrate gives information on the whole visible range due to defect-related CL emissions (1.5–2.7 eV). The use of QNAM to analyze MoS2 and MoSe2 monolayers deposited on sapphire substrate is first shown, elucidating the interlayer interaction in van der Waals heterostructures. QNAM demonstrates that the UV absorption is enhanced in MoSe2/MoS2 vdW heterostructures. Further, an heightening at tilted grain boundaries with high misorientation angles with respect to mirror twin boundaries is in particular reported. When QNAM is carried out employing SiO2/Si as a substrate, it gives insights about the TMD optical properties in the visible range, such as the absorption of MoS2 at different wavelengths. In this case, QNAM demonstrate the higher absorption yield of the 0° twisted MoS2 homostructures with respect to the ones with 60° twisting angle.

3. Figure

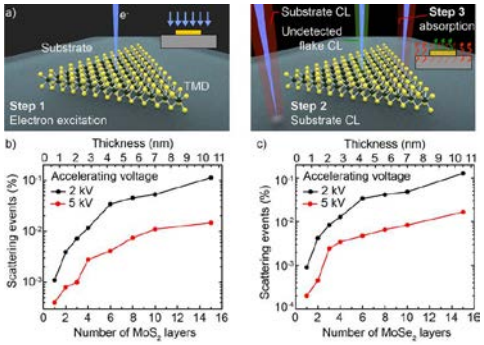

Figure 1 a) Working principle of the technique: 1- a focused e-beam rasters the sample surface; 2- the e-beam excites CL emission of both substrate and flake; the limited interaction volume prevents the emission from the flake to be detected; 3- the flake absorbs part of the substrate CL emission, which results in the QNAM contrast between bare and ML covered substrate regions. b-c) scattering events in MoS_2 and $MoSe_2$ vs layer thickness for accelerating voltages of 2 and 5kV.

4. References

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