MOCVD and Characterization of WSe_2/MoS_2 and MoS_2/WSe_2 Vertical Heterostructures

Songyao Tang[1]
Susu Zhang[1], Yibing Wang[1], Hleb Fiadziushkin[1], Yingfang Ding[1], Amir Ghiami[1], Zhaodong Wang[2], Susanne Hoffmann-Eifert[2], Michael Heuken[1,3], Andrei Vescan[1], Holger Kalisch[1]
1. Compound Semiconductor Technology, RWTH Aachen University, Sommerfeldstraße 18, 52074 Aachen, Germany
2. PGI-7&10 and JARA-FIT, Forschungszentrum Jülich GmbH, Wilhelm Johnen Straße, 52428 Jülich, Germany
3. AIXTRON SE, Dornkaulstraße 2, 52134 Herzogenrath, Germany
tang@cst.rwth-aachen.de

Abstract

Two-dimensional transition metal dichalcogenides (2D-TMDC) have been widely acknowledged as potential building blocks for future (opto-)electronic applications. Using metal-organic chemical vapor deposition (MOCVD), wafer-scale synthesis of high-quality 2D-TMDC can be realized with a controllable thickness from monolayer to multilayer. Due to their layered nature, 2D-TMDC can be easily transferred from the growth substrate onto a target substrate. This process furthermore enables layer-by-layer stacking of vertical heterostructures. In contrast to the rising number of publications focusing on mechanically stacked heterostructures of 2D-TMDC, few works report on the direct synthesis of vertical heterostructures in a continuous MOCVD process. In this work, employing a state-of-the-art AIXTRON CCS reactor, MOCVD processes for the synthesis of wafer-scale WSe_2/MoS_2 and MoS_2/WSe_2 vertical heterostructures are designed. The detailed mechanisms behind heterostructure growth are discussed. It is found that the growth of the second material is strongly influenced by the type and morphology of the first layer. Bilayer domains and defects of the first material layer serve as favorable growth sites for the second material. Furthermore, in contrast to the sapphire surface, chalcogen atoms on the monolayer surface appear to promote the adsorption/migration of metal adatoms to favorable growth sites and thus accelerate the growth in heterostructures. X-ray photoelectron spectroscopy was used to examine the chemical composition of heterostructures, indicating that a third compound might be formed at the interface of WSe_2/MoS_2 heterostructures. Furthermore, structural and optical properties of these grown heterostructures (GHS) were characterized and compared with those of individual monolayers (ML) and transferred heterostructures (THS), revealing the role of interlayer coupling and the influence of different processes on the interface of heterostructures.

Figures

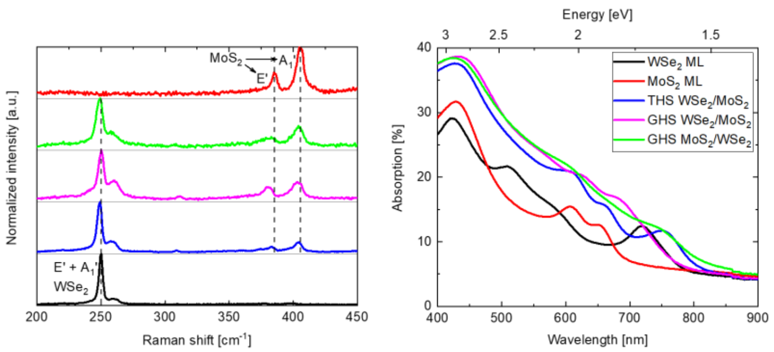

Figure 1: Comparison of Raman (left) and absorption (right) spectra acquired from MoS_2 monolayer (red), WSe_2 monolayer (black), transferred heterostructure (THS) of WSe_2/MoS_2 (blue), grown heterostructure (GHS) of WSe_2/MoS_2 (violet) and MoS_2/WSe_2 (green), respectively. In comparison with individual monolayers, a red-shift can be observed on heterostructures in both Raman peaks and absorption onset energy.