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Quasi two-dimensional thin WS2 films prepared by rapid thermal crystallization of reactively sputtered WS3+x layers

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Tungsten disulfide (WS2), as a layered compound semiconductor, belongs to the family of transition-metal dichalcogenides (TMDC). The intra-layer bonding of the sulphur-tungsten-sulphur sandwich layers is covalent, while the inter-layer bonding within two stacks of these layers is of the van der Waals type [1]. With decreasing thickness down to one monolayer (1 ML), TMDCs change their properties compared to the bulk material. For instance, 1 ML of WS2 is a direct semiconductor, whereas in thicker films (>5 MLs) the indirect band gap dominates.
In this study, we have prepared few monolayer thin WS2 films by rapid thermal crystallization of thin amorphous WS3+x films on various substrates. The thin amorphous WS3+x films were reactively sputtered from a tungsten target in an argon/hydrogen sulfide gas mixture onto unheated substrates and thermally annealed subsequently. The crystallization of the amorphous films was promoted by ultra-thin layers of nickel or palladium, with the result that the layered structure was oriented parallel to the substrate surface [2]. We used a sub-millisecond flash lamp annealing in a 500 mbar argon atmosphere as well as thermal annealing at 800 °C for 20 min in H2S atmosphere to crystallize the WS3+x films.
The crystallization processes were performed with various thicknesses of the promotor layers and amorphous films (2 nm to 20 nm) as well as in dependence on the substrate materials. Time-resolved microwave conductivity measurements showed the photoactivity of these films. Spectroscopic ellipsometry revealed the positions of the A, B, and C exciton peaks. Raman spectroscopy and X-ray diffraction of few monolayers thin WS2 films (< 5 MLs) showed polycrystalline films with (001)-orientated crystallites.
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