Nanoscopy of van der Waals heterostructures fabricated by the wet transfer method

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Introduction

Two dimensional crystals have been in the focus of scientific research for almost two decades, since the discovery of their first representative, graphene [1]. Among other properties which make these materials interesting for various applications ranging from tribology to optoelectronics, the possibility to combine them at will into vertical stacks, called van der Waals heterostructures (VdWhs), has opened the door to a world of new, equally interesting, and unique materials whose electronic and optical properties can be tailored by changing the VdWh constituents [1].

In this work we investigate VdWhs fabricated from 2D transition metal dichalcogenides (WS_2 and MoS_2, in particular), which are considered to be strong candidates for various applications in the fields of optics and optoelectronics [2]. The fabrication of these heterostructures was done using a modified variant of the wet transfer method which has proven to be superior to the commonly used procedures in terms of its simplicity and quality of the produced VdWh [3]. The structural and optical properties of the VdWh fabricated by this method were thoroughly investigated by atomic force microscopy, Raman and photoluminescence spectroscopy.

Wet transfer

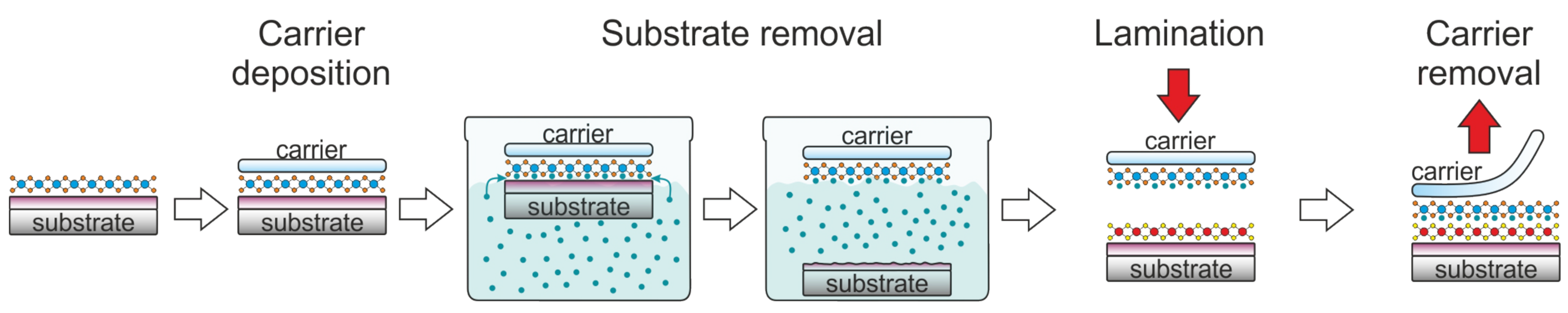
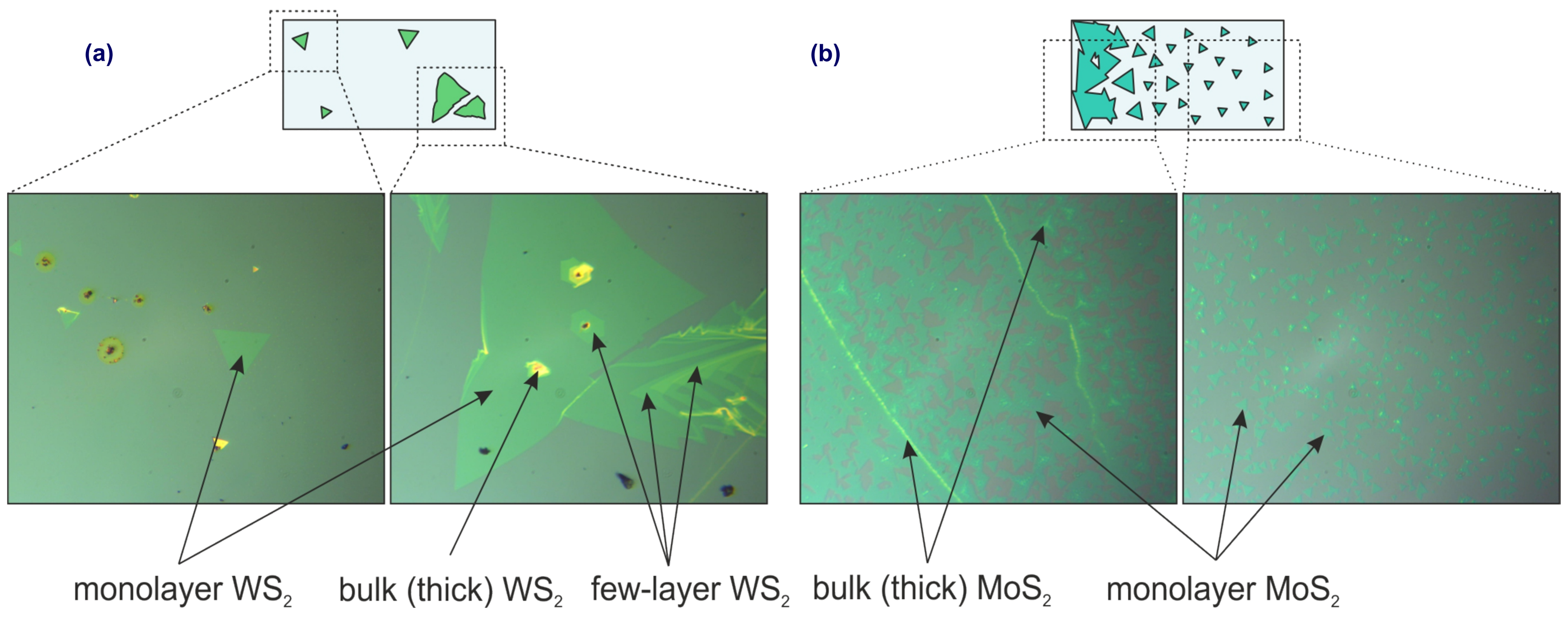
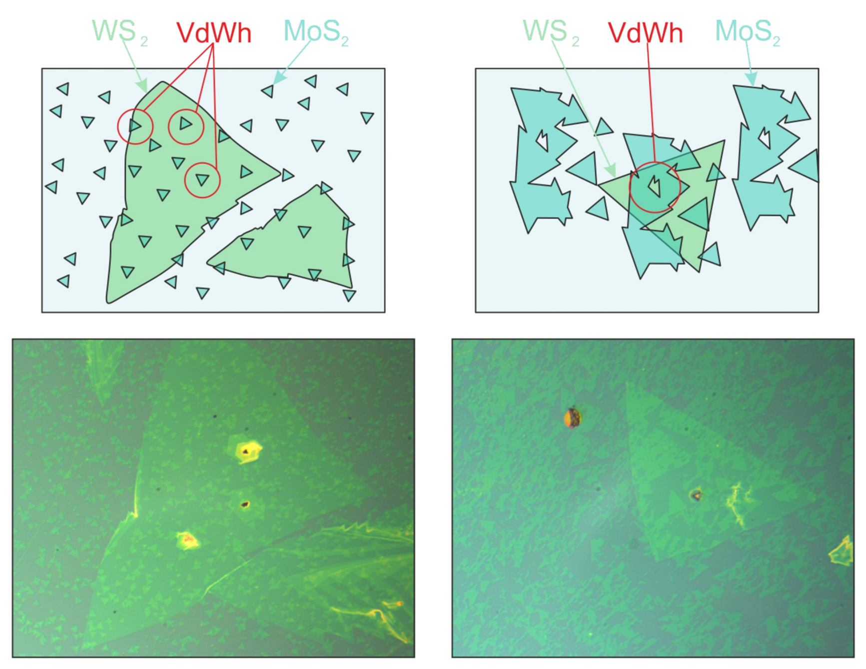


Illustration of wet transfer method. Si/SiO_2 is used as substrate, PDMS sheet as carrier and the aqueous solution of NH_4OH has been picked as the separator between the substrate and 2D crystal.

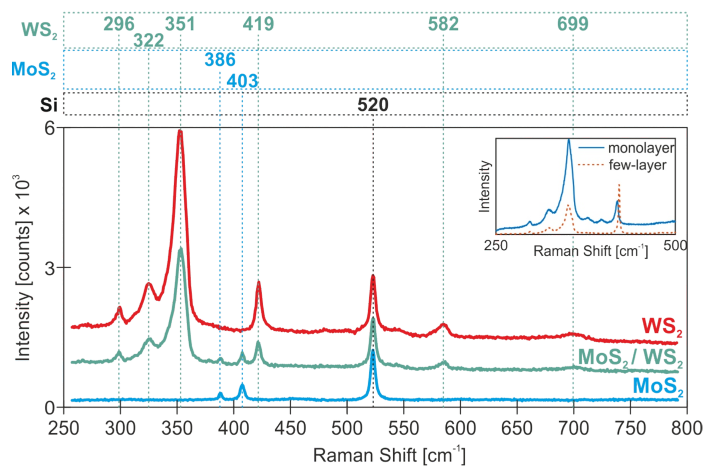
Samples made using WTM



Optical spectroscopy images of (a) WS_2 and (b) MoS_2 on the substrate



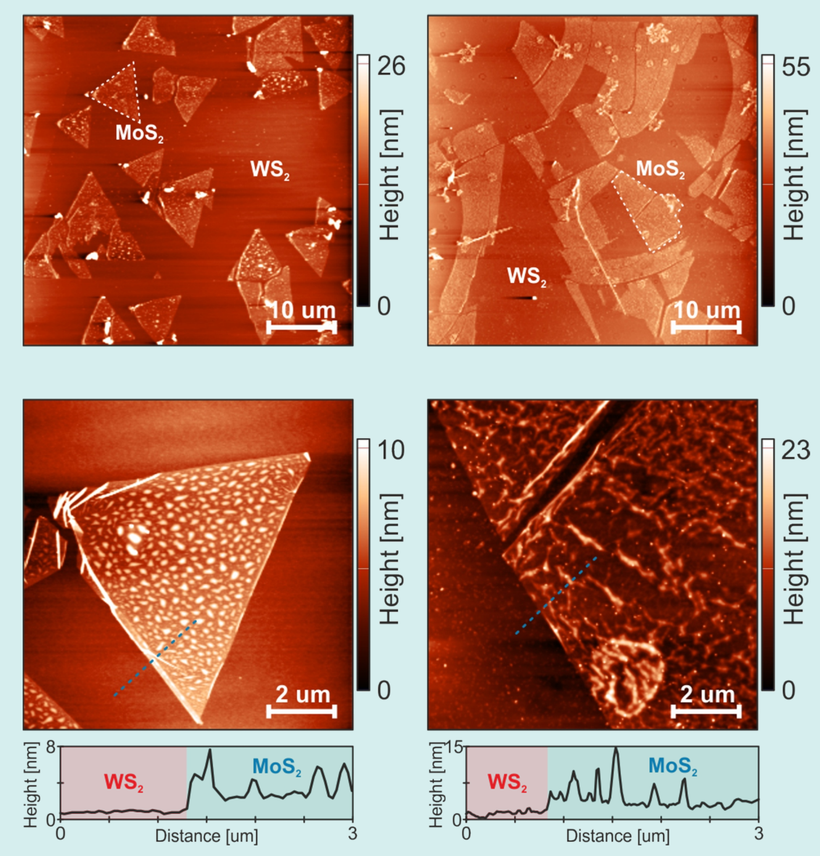
Optical microscopy images of van der Waals heterostructures made out of monolayers of WS_2 and MoS_2.



Raman spectra of (a) WS_2, (b) MoS_2/WS_2 and (c) MoS_2 where is clearly seen that VdWh exists.

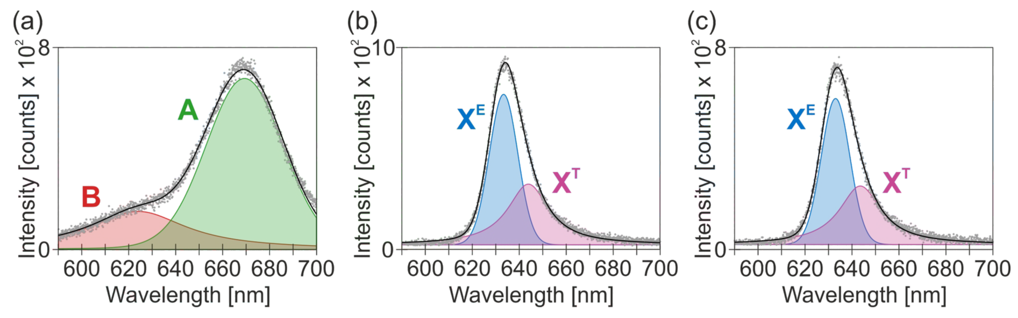
Characterization of VdWh

AFM Imaging

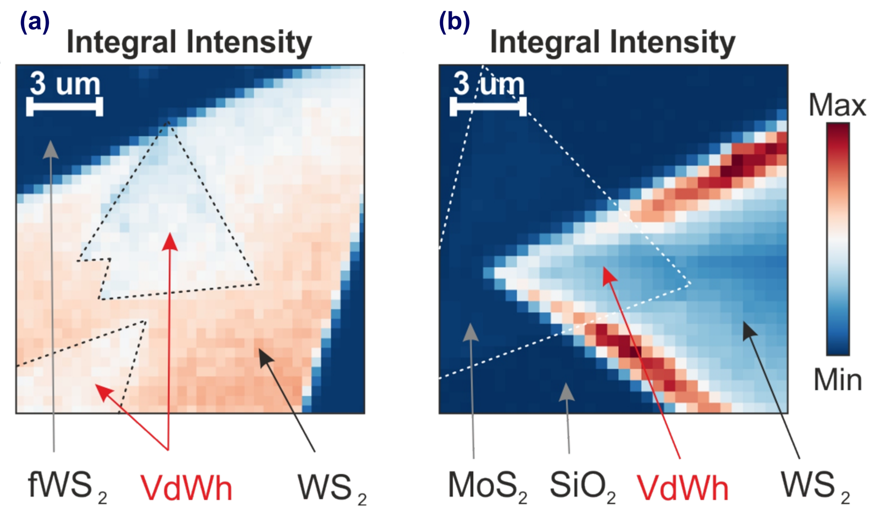


AFM topography images of MoS_2/WS_2 VdWh. MoS_2 has bubble- and worm-like features spreading across the entire flake. These bubbles are formed below the MoS_2 layer. Presence of interlayer contaminants is a common WTM problem which cannot be avoided [4-7].

PL Spectroscopy

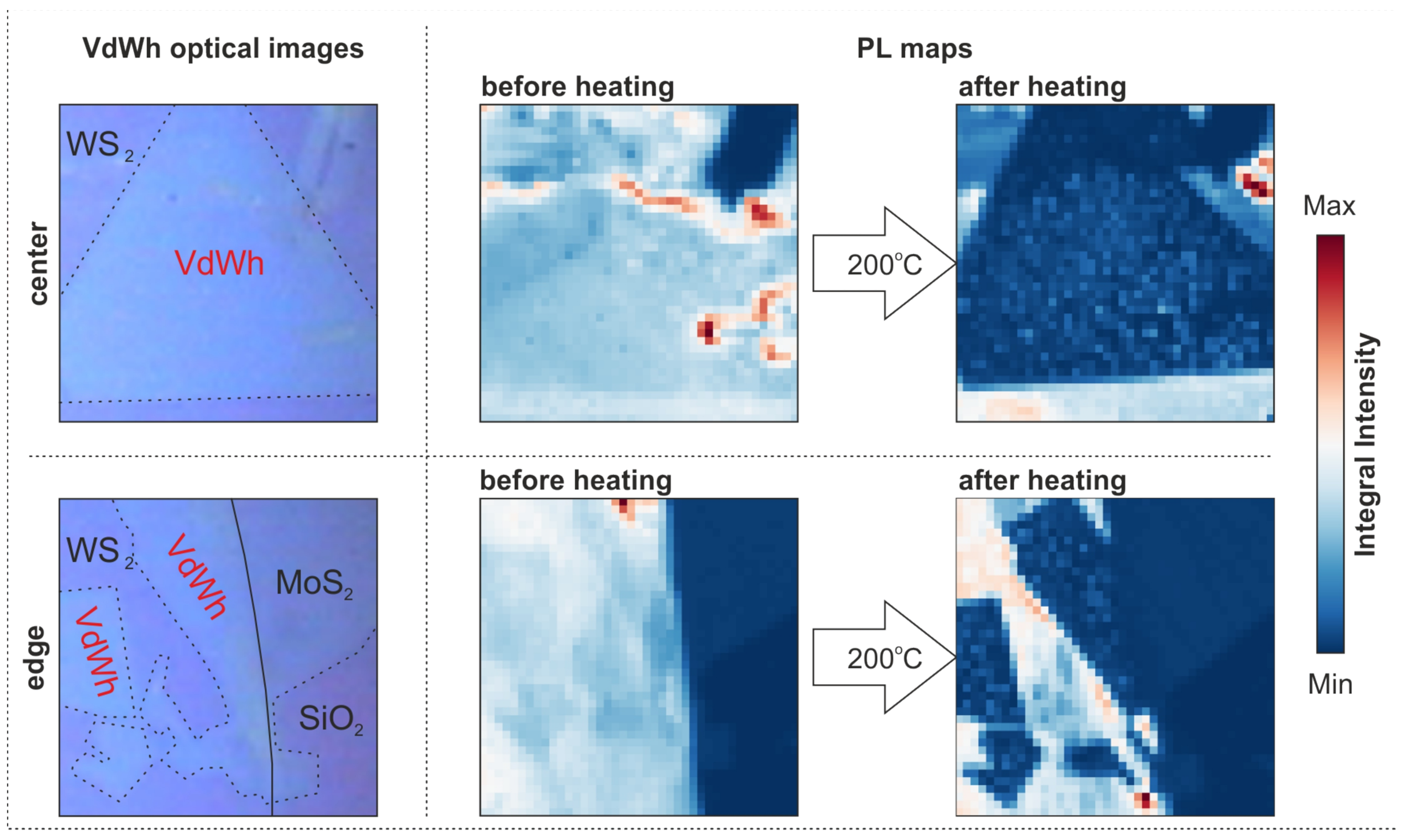


Photoluminescence spectra of (a) MoS_2, (b) WS_2 and (c) MoS_2/WS_2 VdWh

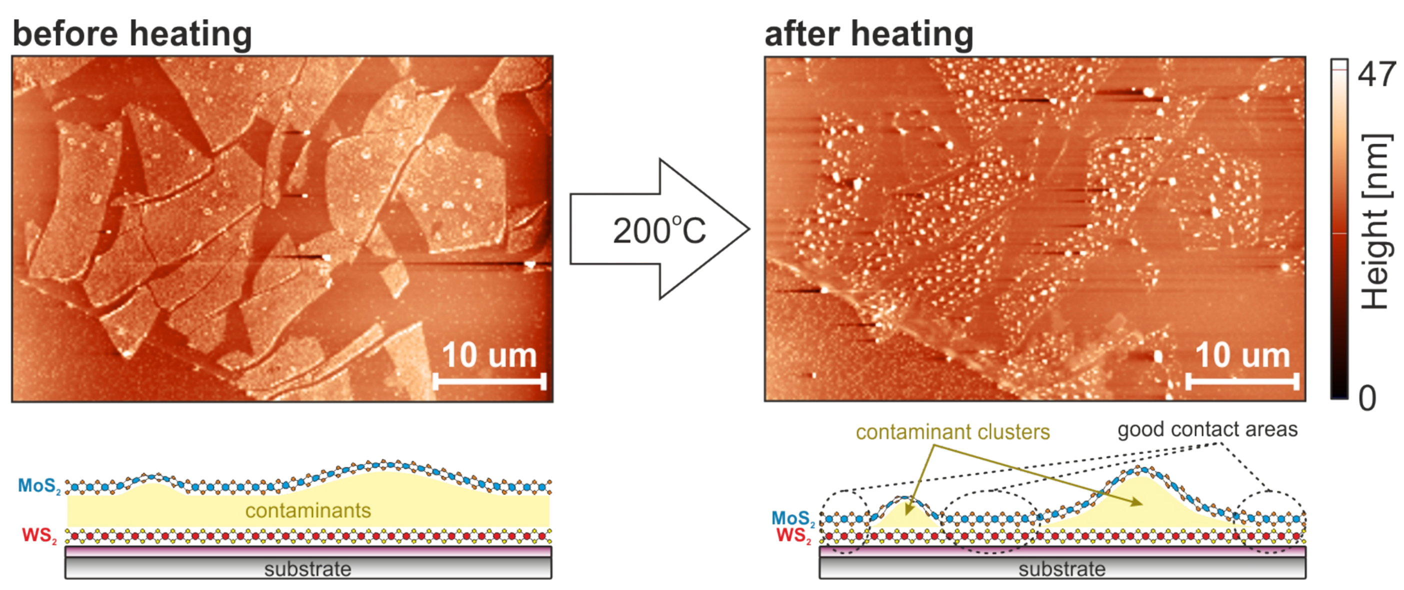


PL maps of MoS_2/WS_2 VdWh recorded (a) in the center and (b) at the edge of the large WS_2 monolayer

Thermally annealled VdWh



Optical microscopy images of MoS_2/WS_2 VdWh at two different positions with coresponding PL maps before and after temperature annealing



AFM topography of MoS_2/WS_2 VdWh before and after temperature annealing. Heating does not remove the contaminants, but they diffuse into large clusters, so there are areas between the clusters where a good contact between monolayers is achieved.

References

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Conclusion

A modified variation of the wet transfer method to fabricate MoS_2/WS_2 VdWh has been used and the heterostructures have been inspected using AFM, Raman and PL spectroscopy. The analysis of the results obtained by all the characterization methods shows that fabricated MoS_2/WS_2 vertical heterostructures have relatively clean surfaces with low amount of PDMS residue and uniform PL and unchanged crystal structure which is the same as the crystal structure of the MoS_2 and WS_2 monolayers before the transfer.
The main problem with the MoS_2/WS_2 VdWh is the presence of trapped interlayer contaminants which can hinder the interaction between the MoS_2 and WS_2 monolayers. It has been found that the influence of the interlayer contaminants on the relevant optical properties of MoS_2/WS_2 VdWh can be reduced by thermal annealing of the sample.

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