Atomic scale characterization of MOCVD grown TMDC monolayer by STM

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Transition metal dichalcogenides (TMDCs) have been attracting considerable attention because of their desirable physical properties for semiconductor devices. pn junctions and quantum wells, which are essential building blocks for electronic and optoelectronic devices, have been realized by growth of lateral and vertical heterostructure based on a wide variety of TMDC such as MoS_2, WS_2, $MoSe_2$, WSe_2. Recently, Metal organic chemical vapor deposition (MOCVD) techniques has been developed for the growth of various TMDCs materials. Compared to the conventional powder precursor based CVD techniques, MOCVD is a highly controllable and reproducible process, and is suitable for large-area deposition [1]. However, atomic scale characterization related to point defects and impurities, which is essential for the growth of high quality films, has not yet been carried out for MOCVD grown TMDC.

In this study, we performed STM/STS measurements on MoS_2 grown on graphite substrates by MOCVD. Fig. 1 shows large area STM image of MoS_2 monolayer which was grown of 700℃. Triangular monolayer with approximately 500 nm in size was formed on graphite substrate with small 2nd and 3rd layers. Fig. 2 shows a magnified view of monolayer region in Figure.1. The monolayer has high densities of defects that exhibit dark round shape in the empty state image reflecting their negative charge. However, we revealed that those defects can be significantly decreased by using a growth catalyst in MOCVD process. Fig. 3 is a STM image of catalyst-assisted grown MoS_2 monolayer and it shows that charged defects decreased down to below 10% compared to the monolayers obtained by conventional way. Further details will be discussed in the presentation.

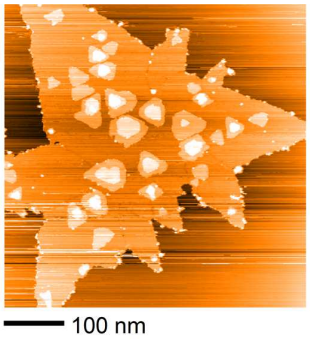

Fig. 1 Large area STM image of MoS_2 monolayer

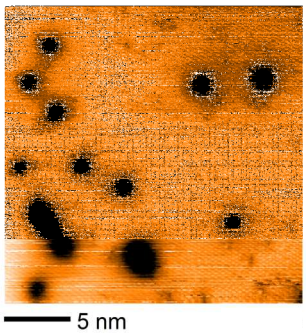

Fig. 2 A magnified view of monolayer region in Fig. 1

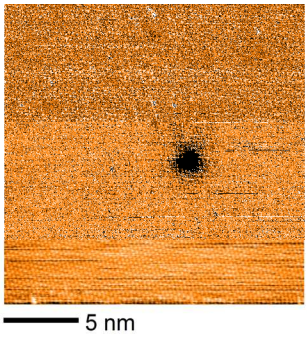

Figure 3 STM image of catalyst-assisted grown MoS_2 monolayer.

[1] K. Kang *et al.*, Nature, **520**, 656 (2015).