Detecting Ultrafast Carrier Dynamics of WSe_2 monolayer by a Multi-probe Optical Pump-probe STM

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In recent years, transition metal dichalcogenides (TMDC) family such as WSe_2 and MoS_2 has attracted much attention due to their remarkable optoelectronic properties. These monolayers have direct bandgaps in a visible range and ultrafast photo response was recently reported in MoS_2 monolayer [1]. To study the transient carrier dynamics is absolute necessary to determine the ultimate limits on the speed of operation for the applications.

Here we present a time-resolved measurement technique, to probe the transient carrier dynamics in WSe_2 monolayer films on insulating substrate. The optical pump-probe STM (OPP-STM) [2] that we have originally developed, combines the well-known ultrafast pump-probe technique and STM together. We implemented the technique further by combining a OPP technique with multi-probe STM. The new system is designed for measuring the local carrier dynamics of atomically thin film by measuring optically induced current transient between probes (2 ~ 4 probes). To achieve the experiment, we integrated optical zoom lens (VH-Z100T, WD=24mm, Keyence Co., Ltd.) above the multi probe STM (MP-STM) system, which is used for monitoring probe/sample arrangement as well as for laser positioning and focusing with ~μm precision.

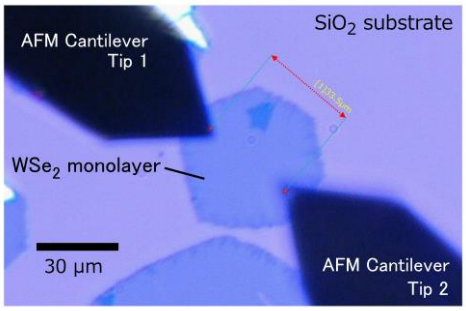

Fig. 1: Optical microscope image of the experimental setup.

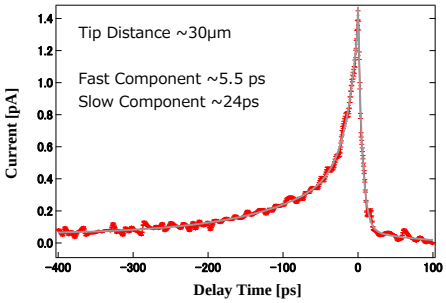

Fig. 2: Optical pump-probe spectrums obtained by laser focusing onto tip1 apex.

The sample is few-to-monolayer WSe_2 which was grown by chemical vaper deposition (CVD) on SiO_2/Si substrates. The experimental setup is shown in figure 1, where the AFM cantilever was used to make a soft contact to the monolayer and the bias voltage was applied between cantilevers. Femtosecond optical pulse (800nm 140 fs) was focused on to tip apex. By this setup, transient carrier dynamics in ~10ps scale was successfully obtained on WSe_2 monolayer as shown in figure 2. The details will be reported in the presentation.

References:

[1] H. Wang, et al *Nat. Commun.*, **6**, 8831 (2015).
[2] Y. Terada, et al. *Nat. Photonics*, **4**, 869 (2010).