Development of Time-resolved Multiprobe STM and Applications for atomic layered materials

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The multiprobe method is a powerful tool for realizing highly flexible measurement on the local area. For example, charge and spin transport of low-dimensional systems such as nanowires and surface states, etc. have been successfully measured in steady state[1,2]. In recent years, atomically thin transition metal dichalcogenides (TMDCs) have been attracting considerable attention. The features are the strong light-matter interaction and the presence of highly stable exciton even at room temperature[3]. It is expected to realize the integrated photonic circuits using exciton flow control by strain and gate voltage. However, with the conventional optical techniques, it is not easy to analyze the exciton dynamics with nm-scale resolution.

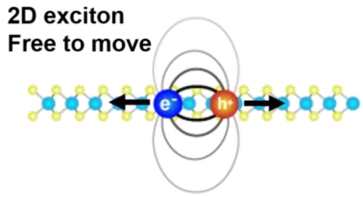

Fig. 1 free exciton in TMDCs

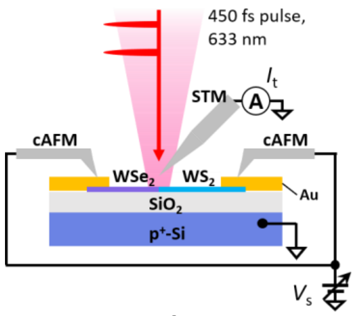

Fig. 2 Setup of time-resolved MPSTM

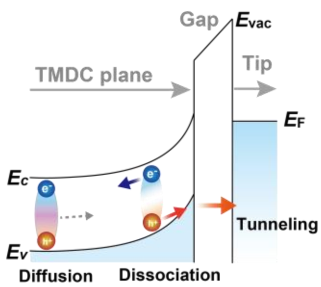

Fig. 3 Band diagram and exciton dissociation model by STM

To overcome the limitation, we have developed a measurement method that combines multiprobe STM (MPSTM) and ultrafast pulsed laser system using a novel approach[4, 5]. Here, we have succeeded in visualization of the spatiotemporal dynamics of free excitons (Fig.1) on a spatial scale of nm and a ps to ns time scale. As the sample, monolayer WS_2/WSe_2 in-plane heterostructure grown by chemical vaper deposition on a SiO_2/Si substrate was used. The measurement setup and probing model are shown in Fig. 2 and 3, respectively. Excitons are dissociated by the tip-induced electric field and can be detected as a tunneling current. Based on this mechanism, we have applied an improved optical pump-probe method to some kinds of nanoscale structures, and as a result, we could get the characteristic exciton dynamics for each structure. This method is expected to accelerate research on exciton dynamics and the development of applications directly based on the analysis of experimental results at the nanoscale. Details will be introduced at the conference with the related photo-excited multiprobe techniques.

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