Photoresponse Measurements of Monolayer WSe_2/$MoSe_2$ In-plane Heterostructure by an Optically-excited Multiprobe method

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In recent years, transition metal dichalcogenides (TMDC) family such as MoS_2 and WSe_2 has attracted much attention due to their remarkable optoelectronic properties. Studying band arrignment, optical/electrical characteristics, and transient carrier dynamics is absolutely necessary. An effective approach is to apply multiprobe (MP) STM techniques, in which multiple tips are used to measure, for example, transport characteristics between two desired points, repeatably. However, the simultaneous use of MP techniques with laser technology has not been realized because of the complexities and the handling difficulties.

Here, we present a microscopy method that we have developed by combining MP techniques with optical methods. To achieve the experiment, we integrated optical zoom lens above the MP-STM system, which is used for monitoring probe/sample arrangement as well as for laser positioning and focusing with ~μm precision. As shown in Fig.1, two c-AFM cantilevers are placed on both sides of a monolayer WSe_2/$MoSe_2$ in-plane heterostructure grown on a SiO_2/Si substrate as pseudo-FET structure. As shown in Fig.2, the spatial distribution of photocurrent (I_{ph}) vs drain-source voltage (V_{ds}) was measured across the $MoSe_2$/WSe_2 interface by changing the focusing spot potision. As a result, we were able to visualize the band structure including the schottkey barrier of probe-sample interface and band shift on $MoSe_2$/WSe_2 interface. Next, we show the time-resolved measurement realized by the OPP-MP spectroscopy we have developed. The dynamics of photocarriers we have observed in the experiments by using femtosecond pulsed laser with a pulse width of ~150 fs. One of the results is shown in Fig.3. On WSe_2 region, four wide range lifetimes were obtained by fitting the signals with exponential functions (τ_1 = ~24 ps, τ_2 = ~200 ps, τ_3 = ~20 ns, and τ_4 = 500 ns <). This technique is expected to play an important role in the researches to develop advanced functional devices with microscopic structures.

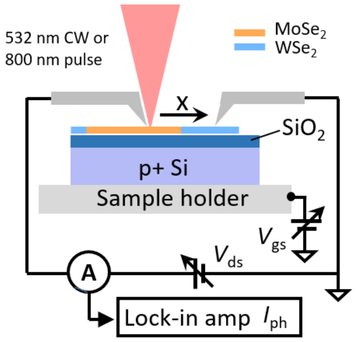

Fig. 1 Diagram of photo-excited multiprobe measurement

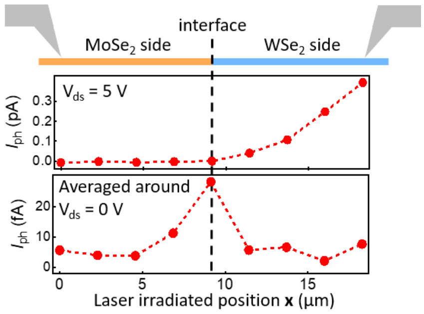

Fig. 2 Irradiating spot potision dependency of photocurrent

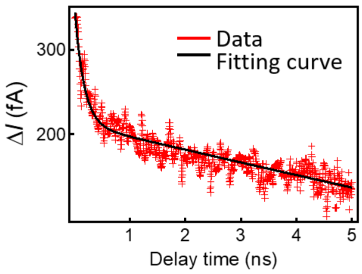

Fig. 3 Time resolved spectrum on WSe_2 region