Carrier dynamics of p-WSe2 measured by time-resolved STM

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Understanding and control of carrier dynamics in nanoscale structures are the key factors for advancing nanoscale science and technology. Recently we have developed shaken-pulse-pair excited STM (SPPX-STM), which enables us to visualize ultrafast carrier dynamics of semiconductor devices in nanoscale spatial resolution. However, the most of previous studies have been carried out on n-type semiconductors and less has been focused on p-type semiconductors.

In this study, we have investigated SPPX-STM spectra of p-WSe_2 to establish a physical interpretation of SPPX-STM spectra on p-type semiconductor. WSe_2 is known as indirect transition type semiconductor, whose minority carrier lifetime is longer than µs. Fig.1 shows SPPX-STM spectra of p-type WSe_2 obtained under different tunneling current setpoint. Since the change in tunneling current ΔI corresponds to the density of photo-generated minority carriers, exponential decay of ΔI against delay time reflects the lifetime of minority carriers in the semiconductor. In SPPX-STM spectra, two exponential decay (fast decay τ_1 ~nS and slow decay τ_1 ~300nS) could be observed, and the fast decay τ_1 became dominant when the tunneling current was increased. In contrast, when the optical intensity was increased, a fast decay disappeared and only a slow decay could be observed. Thus, the decay process of minority carriers is determined by the amount of tunneling current and optical intensity. Though τ_1 varied inversely with tunneling current, the τ_2 did not change with tunneling current (Fig.2). Therefore, we conclude that fast decay τ_1 reflects the process of direct tunneling of minority carriers from surface accumulation layer to STM tip and slow decay τ_2 reflects bulk side carrier decay due to carrier recombination and diffusion as illustrated in Fig.3.

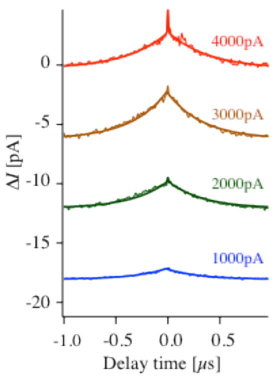

Fig.1: SPPX-STM spectra under different tunneling current

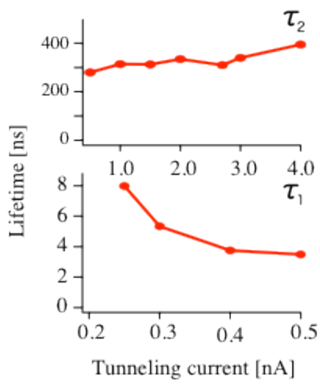

Fig.2: Dependence of fast decay (τ_1) and slow decay (τ_2) vs tunneling current

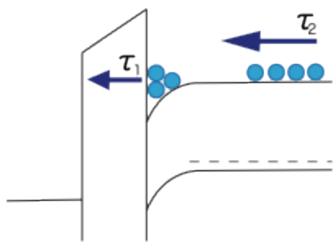

Fig.3: Band diagram of tunnel junction under illumination