Probing local potential dynamics by ultrafast photoelectron pulse emitted from STM probe

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Semiconductor devices are being miniaturized to nanoscale, and the operating speed is increasing up to GHz. To properly evaluate the insight of device behavior, it is essential to develop a technique to track high-speed charge transport phenomena on the nanoscale spatially and ps–ns temporally.

Measuring local surface potential is effective to discuss charge transport. Currently reported measurement methods have high spatial resolution on the nm scale, however, time resolution is still on the μs range, so slow transport dynamics such as hopping conduction in organic semiconductors are visualized[1]. On the other hand, band conduction dynamics is difficult to evaluate on the nm scale because it occurs on the ps-ns scale range. Here, we developed a method to evaluate ultrafast surface potential dynamics by utilizing photoelectron that is generated by irradiating femtosecond pulsed laser to a STM probe apex.

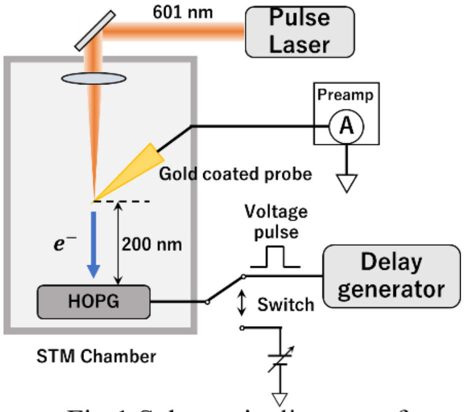

Fig.1 Schematic diagram of measurement system

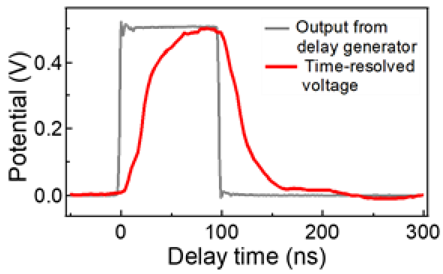

Fig.2 Time-resolved measurement results

As shown in Fig. 1, by focusing fs pulsed laser on the STM probe apex, a photoelectron pulse was obtained (laser intensity: 1.5 mW, spot diameter: 5 μm). Since the photoelectron current depends on the potential barrier between the probe and the sample, the instantaneous sample potential can be estimated from the amount of current. A voltage pulse with a time width of about 100 ns is applied to the sample from the voltage source. The pump-probe measurement result using photoelectrons as a probe is shown in Fig. 2. Although the sample potential waveform is rounded because of the high-frequency impedance of wire in the vacuum chamber, the potential dynamics was successfully evaluated by photoelectrons. The optical pulse width was about 400 fs, which is sufficiently higher temporal resolution than conventional methods. The development of this high spatiotemporal resolved method will enable to measure the potential dynamics by carrier migration, etc. For example, evaluating the dynamics in combination with nanoscale observation by STM, it is expected to become a powerful tool for semiconductor device analysis.

[1]. K. Kajimoto, *et al.*, *J. Phys. Chem. A*, 124, 5063-5070 (2020)