What are we probing using time-resolved scanning tunneling microscopy?

Yasuhiko Terada, Shoji Yoshida, Hiroyuki Kondo, Atsushi Okubo,
Osamu Takeuchi, and Hidemi Shigekawa
Institute of Applied Physics, CREST-JST, University of Tsukuba, Tsukuba, 305-8573 Japan

Pulse-Paired excited scanning tunneling microscopy (PPX-STM) [1] is a nanoscale imaging technique that enables us to directly reveal how carriers behave in, for example, semiconductors with a subpicosecond time resolution. PPX-STM is the combination of STM with optical excitation using femtosecond laser pulse pairs (Fig. 1(a)), which provides ultimate spatial and temporal resolutions. In PPX-STM measurements, the tunnel gap of STM is illuminated by a sequence of paired pulses and the corresponding change in tunneling current is measured as a function of delay time between the pulse pair. We have succeeded in detecting ultrafast signals from various semiconductor samples [1]. In most cases, a signal exhibits two components, and the decay time of the faster one corresponds to the minority carrier lifetime estimated from optical pump-probe measurements. However, the questions arose; what is the origin of the slower component? Under what mechanism can we observe the carrier decay in PPX-STM measurements? Here we will discuss the mechanism of PPX-STM measurements and give the answers to those questions.

Figure 1(b) shows PPX-STM signals from GaAs samples for different laser intensities. Each signal exhibits two components. Taking into account the time evolution of band structures upon illumination, the faster and slower components are attributed to carrier and surface photovoltage decays, respectively. These components have different characteristics. The time constants of each component are almost the same independent from the laser intensity, whereas the amplitude of the faster (slower) component increases (decreases) with the laser intensity (Fig. 1(c)). This behavior can be explained by the nonlinearity originated from the mechanism of photovoltage. Details will be discussed at the colloquium.

(a) (b) (c)

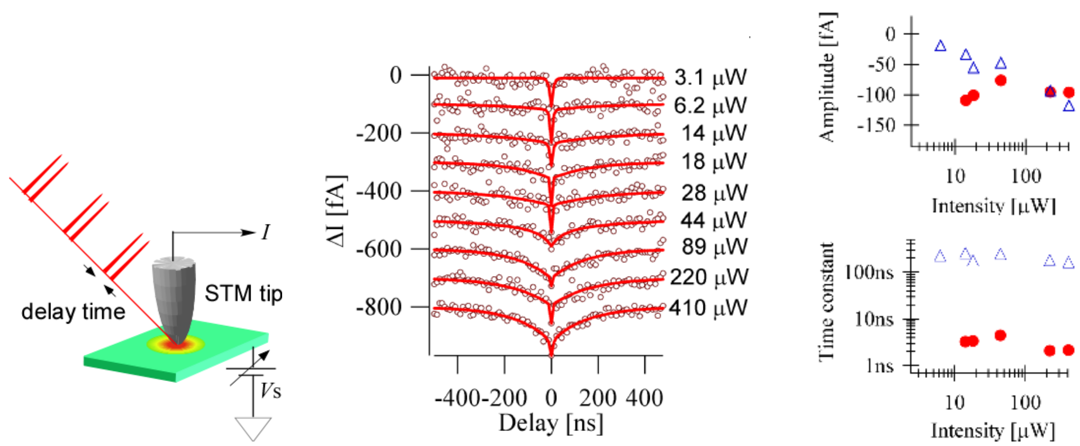

Fig. 1 (a) Schematic of PPX measurement. (b) Time-resolved tunneling current signals for different laser intensities. (c) Amplitudes and time constants derived from signals shown in Fig. (b) using fitting procedures.

References

http://dora.ims.tsukuba.ac.jp/

1) Y. Terada, M. Aoyama, H. Kondo, A. Taninaka, O. Takuechi and H. Shigekawa, Nanotechnology **18**, 44028 (2007).