Visualizing the transient response of the local potential on photoconductive antennas using time-resolved SEM

K. Kawasaki, S. Jeong, Y. Emoto, Y. Yamamoto, Y. Kishibe, Y. Arashida, K. Akada, S. Yoshida, and J. Fujita

Institute of Pure and Applied Sciences, University of Tsukuba, Tsukuba 305-8751, Japan

fujita.junichi.fu@u.tsukuba.ac.jp

Scanning ultrafast electron microscopy (SUEM) is a time-resolved observation method using pulsed probe electrons from an ultrafast laser.[1] The wide space of SEM chamber allows the freedom of the size and shape of the specimen, and had the advantage of high detection sensitivity of the local potential. We demonstrated ultra-fast visualizing of the time-resolved potential variation on gold electrodes and GaAs substrates, where the femto-second-pulse laser induced the moduration of surface conductance of the GaAs.

The schematics illustration of our SUEM setup is shown in Figure 1. We used laser pulses with a wavelength of 1030 nm, a pulse duration of 100 fs, average power of 10 W, and a repetition rate of 100 kHz. The optical pulses were split into two beams for the probe and the pump. The probe pulses were converted into ultraviolet with the photon energy of 4.8 eV (4ω) and the power of 40 mW which was focused onto a ZrO/W emitter to generate electron pulses.
Whereas the normal operation of the 7200F-SEM carrired out under thermal emission mode, we turned off the filament current, also the ZrO coating of the emitter was fully removed to suppress energy spread of the electrons.

The average electron beam current achieved 450 pA, and each pulse contained about 28,000 electrons. The spatial resolution of SEM images were about 1 μm. We adjusted the irradtion timing of the pump pulses about 10 ns behind the probe light at the specimen surface by tuning the optical path length. We applied DC 20 V to a photoconductive antenna with the structure shown in Figure 2(a). The pump pulses were converted to 2.4 eV (2 ω) to exceed the 1.4 eV of the GaAs band gap. The photocarriers excited in the GaAs decreased the potential between electrodes, and the SEM contrast of the antenna decreased due to local potential changes induced by the pump laser. Figure 2 (a to d) showed the time resolved antenna images. We estimated the potencial relaxation of the GaAs surface was 47 ps as shown in Figure 3.

Our SUEM method open up a new field of ultra-high spped phenomenon that occurs on electron devices such as carrier diffusion on the 2D materials, plasmonic wave guides, and meta-material Terahertz resonators.

[1] O. F. Mohammed., *J. Am. Chem. Soc* **133**, 7708 (2011).

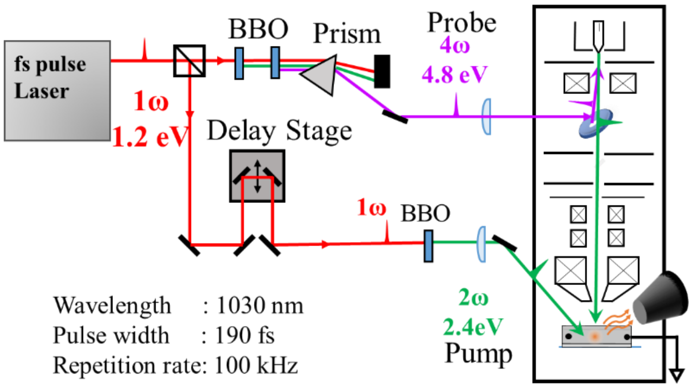

Figure 1 The schematics of SUEM setup

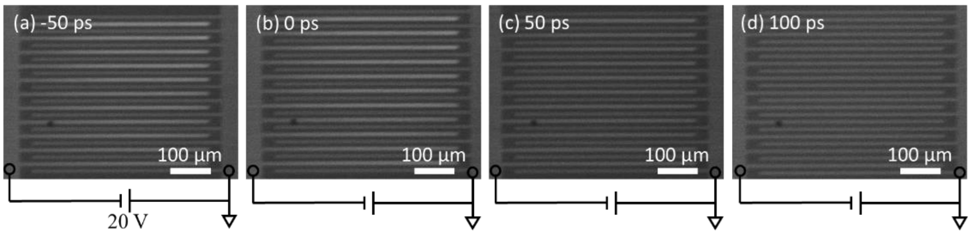

Figure 2 SEM images of photoconductive antenna with different delay time τ of (a) Before pump irradiation and after pump irradiation of (b) τ = 0 ps, (c) τ = 50 ps, and (d) τ = 100 ps.

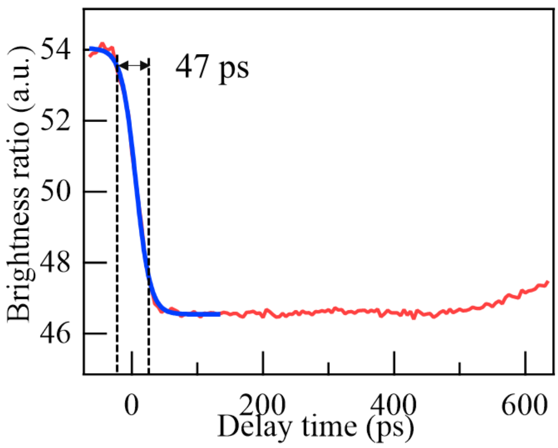

Figure 3 Relaxation of the Antenna potential. The Red curve shows the brightness ratio of the cathodes and the anodes as a function of the delay time. The blue curve is the result of fitting by sigmoid function.