Visualizing the transient response of local potentials on photoconductive antennas using ultrafast scanning electron microscopy

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Ultrafast scanning electron microscopy (SUEM) is a time-resolved observation method using pulsed probe electrons from an ultrafast laser.[1] SEM has an advantage in investigating various specimens because of a large specimen chamber and an exquisite sensitivity to surface charge. We constructed SUEM utilizing a photon pump-electron probe based on a commercial SEM. Laser emission electron beams have the advantage of high time resolution and the ability to operate at a lower vacuum than conventional SEM(10^{-8}-10^{-10} Pa). In this study, we report on a 47 ps time-resolved imaging of the surface carrier diffusion process on the GaAs.

The schematics illustration of our SUEM setup is shown in Figure.1. We used Pharos as a laser source, which has a central wavelength of 1030 nm, pulse width of 190 fs, the average intensity of 10 W, and a repetition rate of 100 kHz. The probe beam energy was converted 4.8 eV and focused onto a ZrO/W emitter with an intensity of 40 mW. The filament current was completely off, and ZrO coating on the emitter was removed to suppress energy dispersion. In our system, the average electron beam current achieved 450 pA, and each pulse contained about 28,000 electrons. Spatial resolution was limited 1 μm due to space charge effect of the electron pulse. The electron pulse (15 kV) spends ~10 ns from emitter to specimen plane. The laser path length was adjusted so that the probe electron beam and pump light arrived at the sample plane simultaneously. Fig.2 shows SEM images of an interdigital array antenna (IAA). An electrode of IAA was connected to the ground, and another side was applied DC 20 V (Fig. 3a). Pump laser was converted 2.4 eV, which is higher than GaAs gap band (1.4 eV). When pump laser irradiate to IAA, GaAs were excited and the potential between electrode was induced relaxation. Then, SEM contrast difference became decreased (Fig.2b) due to diffusion charging induced by pump laser. We measured the brightness of pixel in the electrode SEM image every 5 ps time delay

between pump laser and electron pulse (Fig.3). GaAs relaxation time is estimated 47 ps. Our SUEM method is expected to be a crucial technique that enables experimental time-resolved observation of high-frequency electronic devices, carrier diffusion and surface plasmonic devices.

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

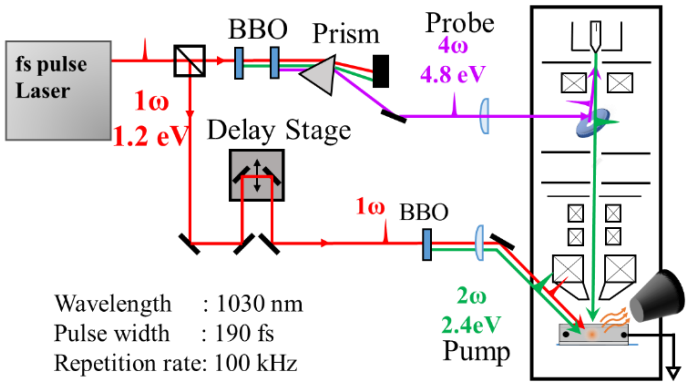

Fig.1, The schematics of SUEM setup

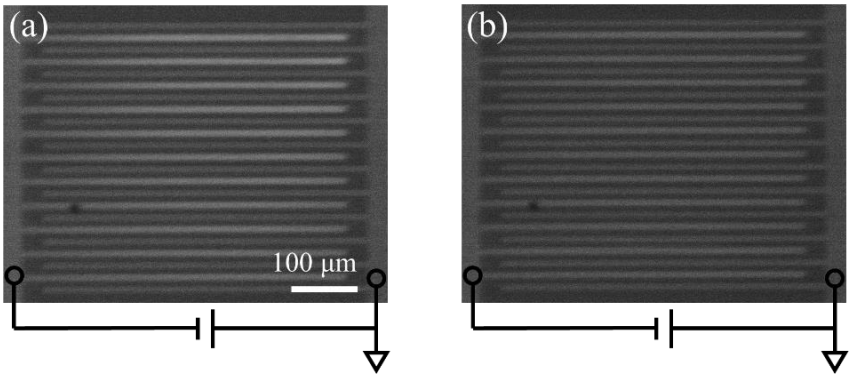

Fig.2, SEM images of IAA applied DC voltage
(a)Before pump irradiation, (b)After pump irradiation

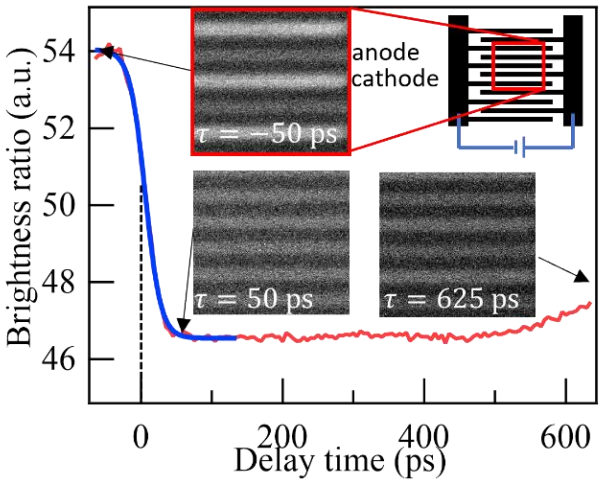

Fig.3, Relation of cathode brightness to delay time