SEM imaging by selective e-beaming using photoelectron beams from semiconductor photocathodes

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Electron beam source is becoming an important key technology in electron beam lithography and inspection using electron beam in semiconductor manufacturing process. In such equipment using electron beam, either thermionic cathode or field emission cathode is used. A higher beam current is an essential solution to get higher throughput of such equipment. However, there is a trade-off relationship in principle between beam current and electrons monochromaticity in existing thermionic cathode and field emission cathode. It is expected that the electron beam from semiconductor photocathodes can solve the trade-off relation on beam performance. Semiconductor photocathodes have progressed in high-energy accelerators, and achieved spin polarization of 90%[1], emission current of 9 mA[2], pulsed beam with pulse width of pico-seconds[3] and electron energy spreads below 0.05 eV[4].

In this study, SEM images were obtained using DC and pulsed electron beams from a semiconductor photocathode using the SEM equipped with a photocathode electron gun (PC-SEM) shown in Fig.1 (a). The electron gun has an accelerating voltage of 0.5 to 30 kV, a maximum emission current of 80 μA, and a laser diode capable of generating continuous to pulsed laser as a light source for generating electron beams from semiconductors by photoexcitation. The InGaN semiconductor used as the photocathode material can generate DC beams and pulsed electron beams with minimum pulse width of 7ns and maximum repetition rate of 10MHz. The spatial resolution of PC-SEM at an acceleration voltage of 15 kV shown in Fig. 1 (b) was 3.4 nm.

SEM imaging by selective e-beaming system shown in Fig.1 (c) using pulsed electron beams was performed as an unconventional scanning method. As shown in Fig.3., the PC-SEM has succeeded in selective electron beam scanning with arbitrary probe current for an arbitrary irradiation area in pixel units in the electron beam scanning process in the field of view.

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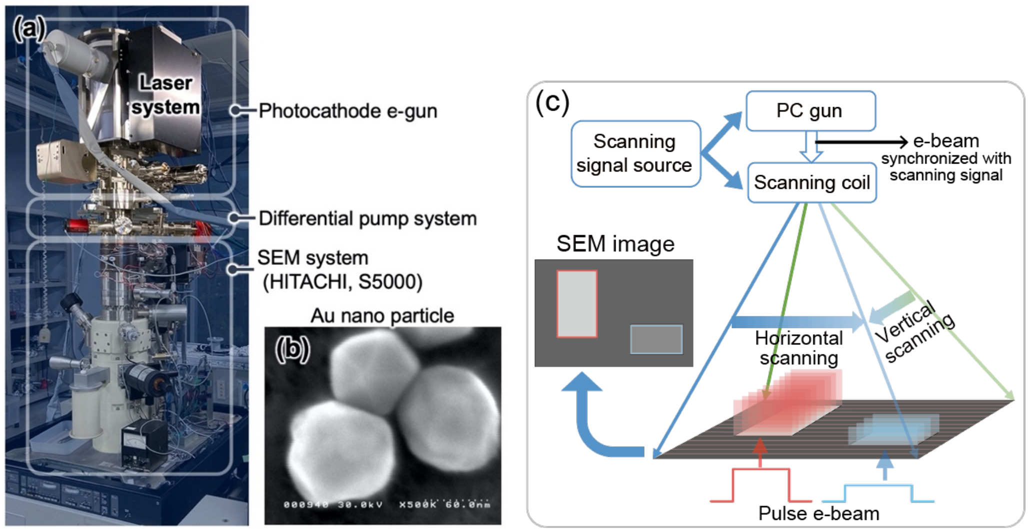

Figure 1: (a) Scanning electron microscope equipped with the PC-gun, (b) SEM image of Au nano particle and (c) a schematic diagram of the selective e-beaming system: (a) The cold cathode field emission electron gun of the scanning electron microscope (Hitachi High-Tech S5000) is replaced by the photocathode electron gun (PeS-2020 e-Beam system). (b) The spatial resolution derived from SEM image of the Au nanoparticle at an acceleration voltage of 15 kV was 3.4 nm. (c) The scanning signal from the SEM system is used as the trigger for the laser irradiation to excite the photocathode, and the laser can be synchronized with the SEM scanning. The laser irradiates the photocathode according to the set intensity and timing, and the photocathode produces an electron beam synchronized with the scanning. As a result, the scanning-synchronized electron beam produces an SEM image that is selective in area and intensity.

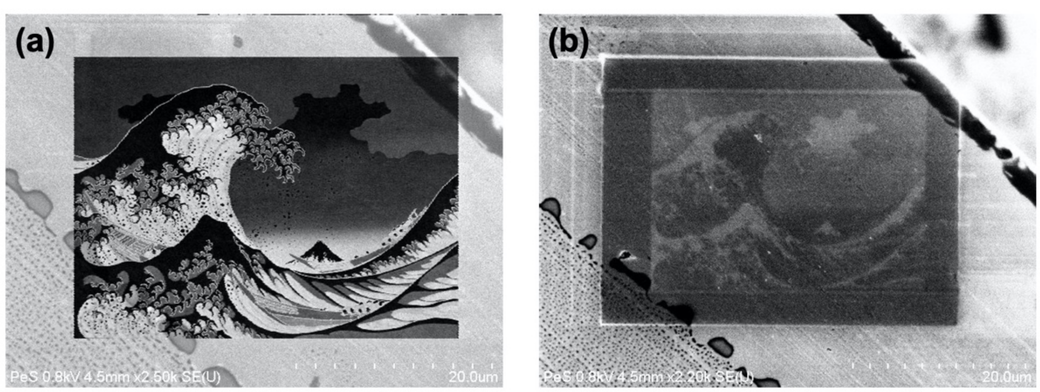

Figure 2: (a) SEM image with the contrast and shape of the input image (Hokusai Katsushika's painting) obtained by the selective e-beaming system and (b) Carbon contamination produced by the selective electron beam irradiation at an acceleration voltage of 0.8 kV.: The carbon contamination was obtained by selective electron beam irradiation with a maximum intensity of 100 pA for 10 minutes.