Dynamic observation from continuous to well-controlled pulsed electron beams in Nagoya University

Nobuo Tanaka[1,2], Makoto Kuwahara[1], Shigeo Arai[1,2] and Koh Saitoh[1]
[1]Ecotopia Science Institute and Graduate School of Engineering, Nagoya University, 464-8603, Nagoya, Japan
[2]Nanostructure Research Laboratory, Japan Fine Ceramics Center, 456-8587, Nagoya, Japan

In-situ electron microscopy has been tried for a long time since the 1960's, which has greatly contributed the study of mechanical properties of materials. Recently, we have reached a new stage of the in-situ experiment. Those are uses of high-sensitivity TV cameras and well-designed environmental cells which enable the electro-chemistry experiments in the column such as studies about electrodes of fuel-cells and batteries. Since the installation of a Reaction Science HVEM(JEM-1000KRS) in 2010, we have performed various kinds of in-situ experiments in Nagoya University[1]. The keywords of our studies are (1)advanced in-situ observation, and (2)observation by controlled electron beams and new kinds of electron probes such as spin-polarized/pulsed beams and vortex beams for detecting new kinds of physical properties.

In this talk, selecting the data obtained by two instruments such as the RSHVEM and spin-polarized(SP)/pulsed TEM for dynamic observation of nanomaterials, we would like to discuss about future possibility of a new kind of electron microscopy, particularly, focusing on well-controlled and pulsed electron beams.

Figure 1 shows an external view of the 1 MV RSHVEM[1]. We have performed in-situ observations such as oxidation process of copper particles, porous platinum catalysts reacted with carbon mono-oxide gas[2], stress-fracture of a copper/silicon interface in hydrogen atmosphere, and heat-transformation of Pd-Nb hydrogen transparent films with time-resolution of 1/10 s. The characteristics of the HVEM are (1)TEM/STEM compatibility with energy filtering and EELS mapping, electron tomography of samples thicker than 3 μm. In the next stage, we should pay attention to decrease and estimate quantitatively the irradiation effects of electrons. We have designed and installed a high-speed beam blanking system with electrostatic beam deflectors and high-speed mode of CCD camera, which is a kind of controlled pulse beam. We succeeded in obtain 0.2 nm lattice resolution in the blanking mode[1].

Another beam blanking experiment was performed in 30kV spin-polarized/ pulsed(SP)-TEM[3,4]. Figure 2 shows the SP-TEM developed by us with the support by Hitachi Central Research laboratory. The electron source is a photo-cathode of GaAs/AlGaAs strained super lattice driven by a circular polarized laser beam with 730-780 nm in wavelength[3]. By using acoustic optical modulator(AOM) and Ti-Sapphier pulse-laser, we have routinely electron pulsed beam with 1-60 μs[4]. This electron gun can approach ns time domain with help of the pulsed laser. One of the advantages of the present SP-TEM is a high coherent illumination in comparison with previously reported pulsed gun using LaB_6, which gives us Young's interference fringes by using a electron bi-prism. This enables us to perform the world-first electron holography with spin polarized electrons and pulsed electrons[5]. In these items and their advantages, time-related physical and chemical phenomena such as chemical reaction of molecules[6] and reverse process of magnetic moments in nm-sized areas can be clarified by using such well-controlled pulsed electron beams.

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[1]N. Tanaka et al., Microscopy, **62**(2013), 205
[2]T. Fujita et al., Nature Mater., 12, August, 2012.
[3] M. Kuwahara et al., Appl. Phys. Lett. **101** (2012) 03310.
[4]M. Kuwahara et al., Microscopy, **62**(2014),607.
[5]M. Kuwahara et al., to be submitted (2014).
[6]J.M. Thomas and P. Midgley, Chemical Physics, **385** (2012), 1.

Fig. 1 : External view of 1 MV RSHVEM with a high-speed beam-blanking system.

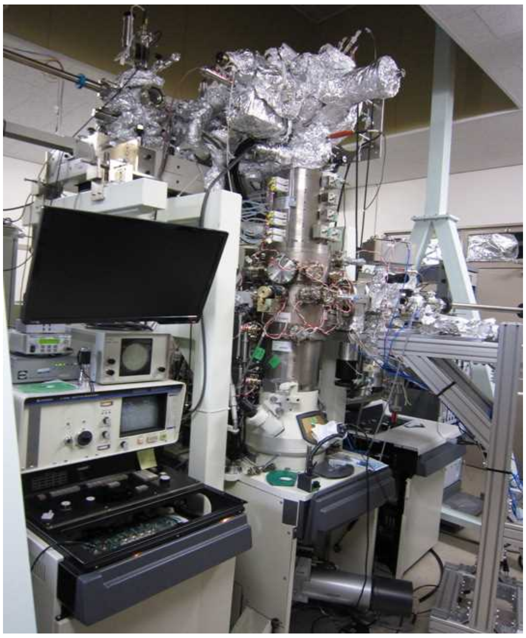

Fig. 2 : Photo of 30 kV spin-polarized/ pulsed and holographic TEM driven by Ti-pulsed laser.