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Automatic Hologram Acquisition of Pt Catalyst Nanoparticles on TiO_2 Using Particle Detection with Image Processing and AI Classification

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Catalysts of metal nanoparticles have attracted much attention for various applications, such as air purification, hydrogen production, and fuel cells, and clarifying the mechanism of the catalytic activity is important. Electron holography is a microscopic method that detects the phase change that an electron wave undergoes when it propagates in an electromagnetic potential. The mechanism of catalytic activities is revealed by measuring the electric field around nanoparticles using electron holography. However, a measurement with a high signal-to-noise (SN) ratio is required because the amount of phase change due to the electric field around the nanoparticles is very small. The phase measurement sensitivity should be improved by integrating and averaging a large number of phase images reconstructed from holograms. Therefore, we have developed an automatic acquisition system that detects particle positions using image analysis with post AI classification and that obtains hologram images at those positions.

A 1.2-MV atomic-resolution holography electron microscope that was developed in the FIRST project [1] was used for testing the automatic acquisition system. Pt nanoparticles (5 to 10 nm in diameter) supported on a TiO2 (110) facet were used as a specimen. The specimen was set in a vacuum of the microscope after plasma cleaning, and holography observations were carried out at room temperature. During the automatic measurement, a low-magnification transmission electron microscope (TEM) image was acquired, the coordinates of the particles in the TEM image were detected, the field of view was moved using an image shift deflector for each coordinate, and high-magnification holograms were acquired at those positions. An image around the coordinate with a high correlation value in pattern matching was cut out using the zero average normalization cross correlation (ZNCC) for particle detection, and whether or not the image contained particles was determined using a classifier with a convolutional neural network (CNN).

Figure 1 (a) shows a TEM image acquired at low magnification. The squares in the TEM image indicate the location where the particles were detected by pattern matching. The coordinates where particles were detected can be seen; however, coordinates with no particles were also detected. In addition, the red squares are the coordinates that the classifier discriminated from them. The classifier's correct answer rate was very high, at about 92%. Figure 1 (b) to (e) shows the high-magnification holographic images acquired at the detected coordinates in Fig. 1 (a). All the holograms contain Pt nanoparticles, indicating that the position control using the image shift can be achieved with sufficiently high accuracy. Fig. 1 (f) is a reconstructed phase image of the particle from Fig. 1 (d). Lattice fringes were observed as shown in Fig.

1 (d), and the results indicate that the developed system can achieve automatic measurements with atomic resolution.

We believe that this method can be utilized for automatically acquiring a large number of atomic resolution holograms for not only catalysts but also for other nano-sized materials and electronic devices.

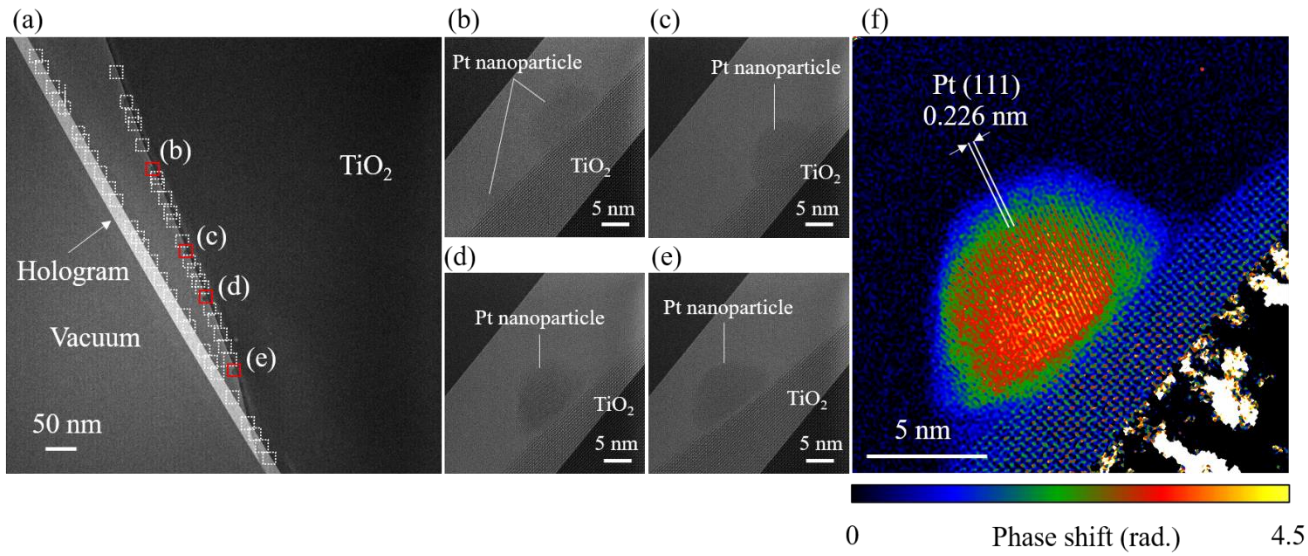

Figure 1. Figure 1. (a) TEM image acquired at low magnification, (b) to (e) high-magnification holographic images the detected coordinates in (a), (f) reconstructed phase image of the particle from (d)

References

[1] T. Akashi et al. Appl. Phys. Lett., **106** (2015) 074101.

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