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Depth-Resolution Imaging of Crystalline Nano Clusters on/in Amorphous Films Using Aberration-Corrected TEM

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The improved image resolution in the depth direction (the electron incident direction) should be another advantage using aberration-corrected TEM. We have demonstrated the availability for obtaining 3D information of nano materials in the previous papers [1,2], in which the detection of tilt of a carbon nanotube (CNT) and the selective imaging of each side-wall lattice of a single-wall CNT were successfully achieved.

In the present study, the features and capabilities of the depth-resolution imaging were investigated using image simulations and experiments for two types of samples [3]. The first sample was gold clusters attached on an amorphous carbon film. The experimental through-focal series indicated that the focal plane for the cluster was shifted 3 nm from that for the supporting film (Fig. 1(a) and (b)). This difference is due to the depth-resolution imaging of the cluster and film, the mid-planes of which are separated by 3 nm along the depth direction. On the basis of this information, the three-dimensional configuration of the sample, such as the film thickness of 2 nm, was successfully illustrated in Fig. 1(c).

The second sample was a $Zr_{66.7}Ni_{33.3}$ metallic glass including a medium-range-order (MRO) structure, which was approximately considered to be a crystalline cluster with a diameter of 1.6 nm. In the experimental through-focal series, the lattice fringe of the MRO cluster was visible at limited focal conditions (Fig. 2(a) and (b)). Image simulations reproduced well the focal conditions (Fig. 2(d) and (e)) and also indicated a structural condition for the visualization that the embedded cluster must be apart from the mid-plane of the matrix film. Similar to the case of the first sample, this result can be explained by the idea that the “effective focal planes” for the film and cluster are at different heights. This type of depth-resolution phase contrast imaging is possible only in aberration-corrected TEM and when the sample has a simple structure and is sufficiently thin for the kinematical scattering approximation.

References:

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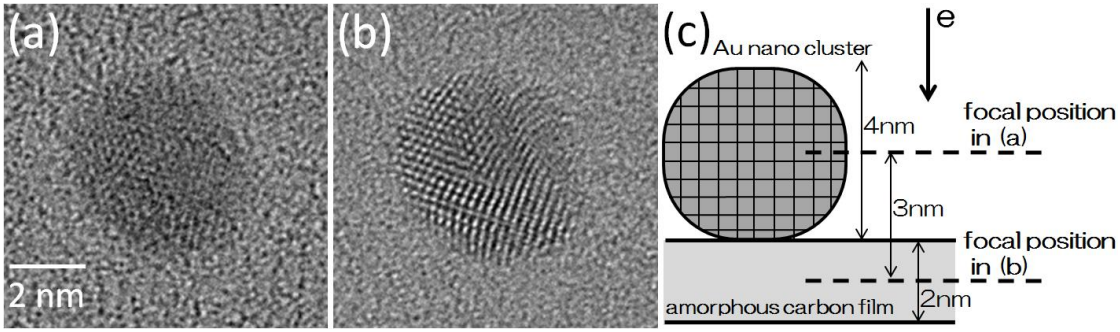

Figure 1. (a),(b) Aberration-corrected TEM images of a Au cluster on an amorphous carbon film taken at different focal positions, the distance of which is 3 nm. (c) Schematic of the sample configuration derived based on the focal distance and the diameter of the Au cluster.

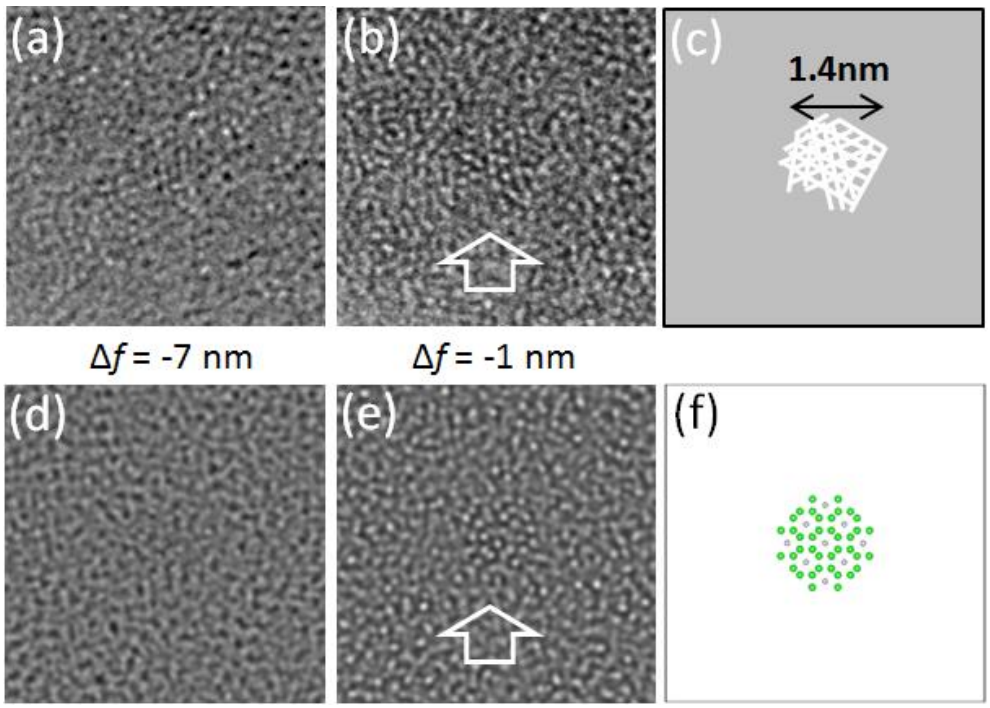

Figure 2. (a),(b) Aberration-corrected TEM images of a $Zr_{66.7}Ni_{33.3}$ glass taken at the different focal positions indicated below the images. (c) The approximate trace of the lattice fringe in the cluster indicated by the arrow in (b). (d),(e) Image simulations reproducing (a) and (b), respectively. They were calculated using a structure model of amorphous $Zr_{66.7}Ni_{33.3}$ including inside the crystalline cluster shown in (f).