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Atomic Resolution Dynamics of NiO Nano-Particle Studied by Low Dose In-line 3D Holography

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Nanoparticles are interesting for many different fields of application. Normally they consist of a few nanometers (>5nm), and their properties depend on their size, shape and atomic distribution in volume and surface. Their physical and chemical properties are different from those of the bulk. Their crystal structure and atomic distribution account for such differences. Advancements of aberration-corrected electron optics and data acquisition schemes have made TEM capable of delivering images of nanoparticles with sub-Ångström resolution and single-atom sensitivity. However, it has been shown that high energy electron beam may alter the shape and surface structure at atomic level [1, 2]. On the other hand, taking advantage of electron-sample interaction, the electron beam can play a role as a stimulus for studying the dynamics of nanoparticle at atomic resolution while remaining structure unchanged under well controlled electron doses. In the present work, through focal series images of a nanoparticle made of NiO and Pt are recorded with TEAM05 at low dose mode. The dose rate was controlled by a monochromator in the downstream of electron gun. Fig. 1 show the phase images of three reconstructed exit wave functions. Each of them is reconstructed from 20 through focal series images. The dose rates associated with each reconstructed exit wave function are 56, 92, and 185e/Å.sec, respectively. The total times of particle under exposure of electron beam are 1, 6 and 9 minuets, respectively. As we can see that the particle not only changes the shape but also rotates as a function of time due to the electron beam interaction. The 3D shape of the particle at atomic resolution is reconstructed using the method given in one of our previous publication [3, 4]. The algorithm of atomic resolution shape reconstruction basically involves determination of the "z" height of the atoms at the exit surface and quantification of the mass at each atomic column [4]. The "z" height can be determined from maximum propagation intensity alone in our previous method [4], but in my talk, a new algorithm based on phase information will presented. Combination of the intensity and phase method offers a more robust and precise method to determine the "z" height. The phase angle in the Argand plot is related to the mass (number of atoms in an atomic column). It is interesting to show that in the edge of the nanoparticle always associated with less number of atoms. An example of the Argand plot and mass map in for exit wave at Fig. 1(a) is shown in Fig. 2(a) and (b), respectively. Detail of the structural evolution at 3D will be presented in this talk.

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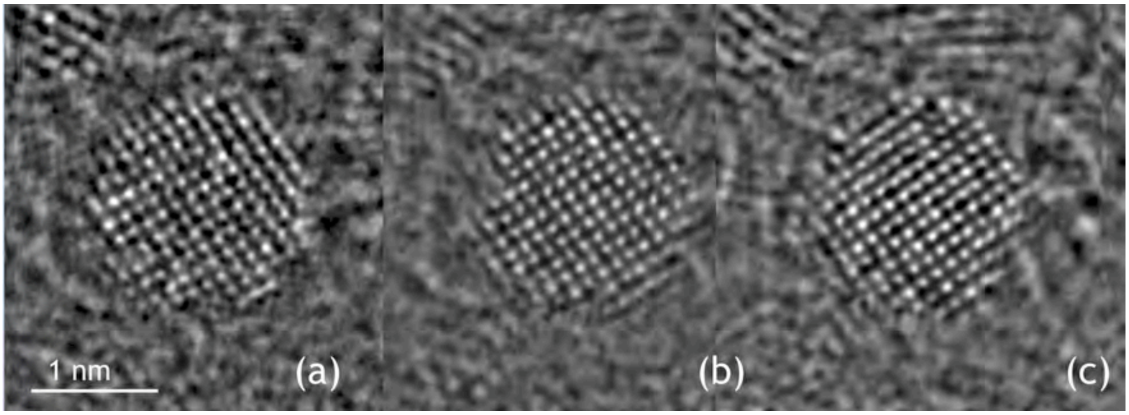

Figure 1. Phase images of three reconstructed exit wave functions. Each of them is reconstructed from 20 through focal series images. The dose rates for (a), (b) and (c) are 56, 92, and 185e/Å.sec, respectively. The total times of particle under exposure of electron beam are 1, 6 and 9 minuets, respectively.

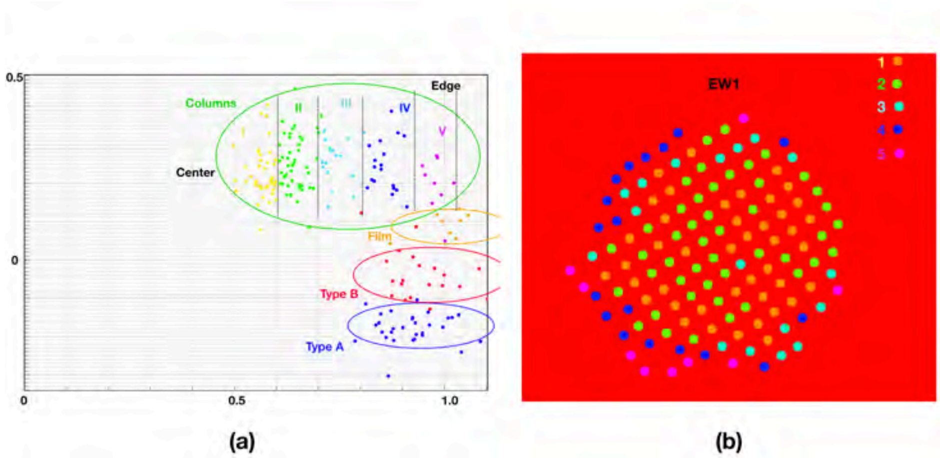

Figure 2. (a) the Argand plot of the atomic columns (within green circle) and valleys (red and blue circles). There are 5 zones, I-V, within the green circle. The value of phase angle is the greatest in zone I and decreases toward zone V. (b) shows the spatial distribution of phase angle within 5 zones in the NiO nanoparticle.

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