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HRTEM and HRSTEM Study of Nanostructured Materials Prepared by Pulsed Laser Deposition

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Nanostructured materials, such as nanoparticles, thin films etc., have attracted increased attention of the scientists due to their unique properties for applications [1]. Among them, the magnetic nanoparticles are particularly interesting because of their potential wide range of possibilities for nano engineering and devices [2]. Moreover, superconducting material is very important for fundamental and theoretical studies in solid state physics [3]. In this work we studied the microstructures of Ni nanoparticles and Bi/Ni thin films prepared by pulsed laser deposition (PLD). A JEOL JEM-ARM200CF aberration-corrected scanning transmission electron microscope (STEM), at Lehigh, and a FEI Titan aberration-corrected high resolution transmission electron microscope (HRTEM), at ASU, have been used to investigate the prepared nanomaterials.

Magnetic Ni nanoparticles have been prepared in Ar and O_2 atmosphere and they show very different shape and structure as shown in Fig. 1 and 2. The cubic nanoparticle clearly shows a faceted single crystal structure with a size of ~ 6 nm in which the (200) planes runs entirely across it. In contrast, the Ni nanoparticle prepared under O_2 exhibits a spheroidal shape and a diameter of ~ 10 nm. The spheroidal nanoparticle contains, in fact, several crystalline clusters as lattice planes with different orientation are observed, which is very different from the single crystal cubic nanoparticle. The formation of the cubic and spherical nanoparticle is mainly due to different optimization process of nucleation rate and surface energy minimization by faceting taking place under different atmospheres.

Another sample studied in this work is a Bi/Ni bi-layer. The thin film has been prepared at room temperature by PLD and the TEM sample has been prepared by FEI FIB system. From fig. 3 one can see clearly the deposited layers (the dark layer is the 40 nm Bi layer with 2 nm Ni above) and the protecting Pt layer deposited during the sample preparation with FIB. The line scan of the Bi-Ni cross-section shows that the Ni and Bi layers are mixed already. From the high resolution image (fig. 4) one can identify that the two layers have grown epitaxial but there is not a clear defined interface between Bi and Ni layers, which confirms the result of fig. 3. The absence of a clear interface could be due to the interdiffusion during the deposition of Ni layer on top of Bi. The superconducting properties of Bi/Ni bi-layers, currently under investigation, is the subject of a separate report [4].

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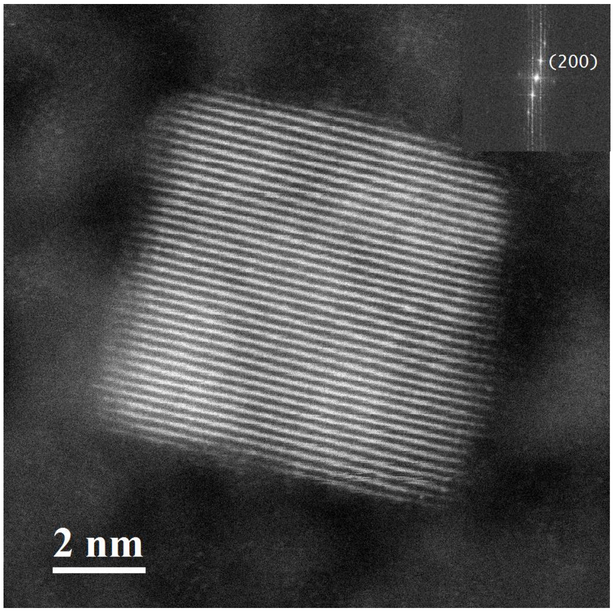

Figure 1. HRSTEM annular dark field (ADF) image of Ni nanoparticle prepared in Ar atmosphere. The (200) planes are clearly visible. Inset: FFT of the image.

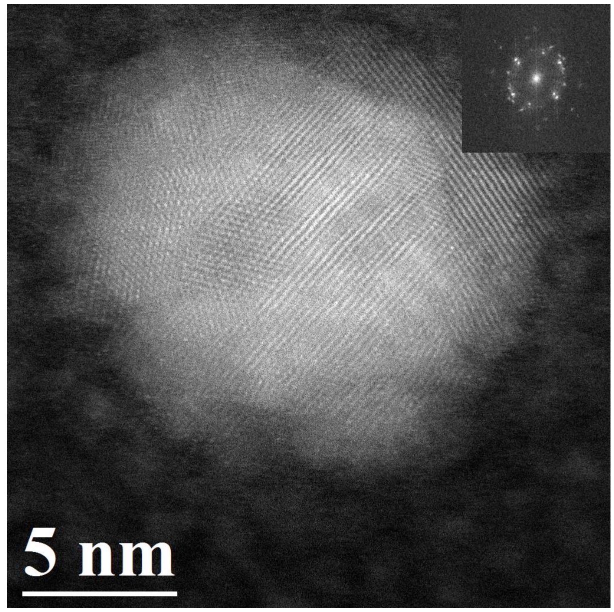

Figure 2. HRSTEM ADF image of Ni nanoparticle prepared in O_2 atmosphere. Inset: FFT of the image.

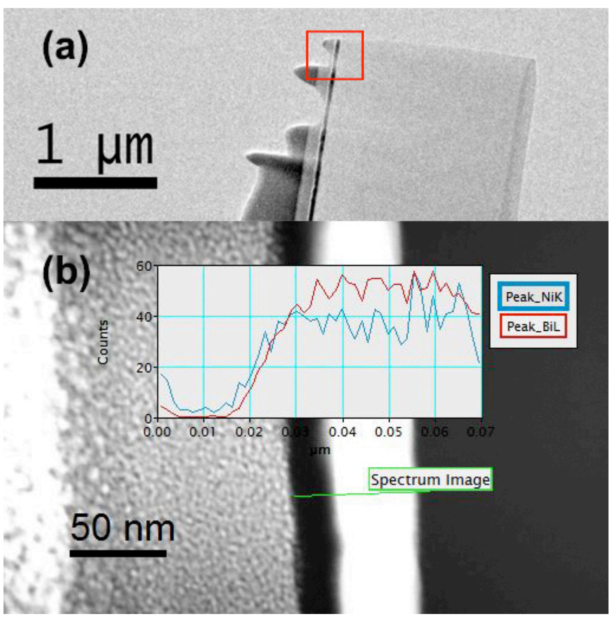

Figure 3. (a) Low magnification image of Bi/Ni bi-layers. The sample was prepared by FIB. (b) More details of the area shown in (a) and the inset gives a line scan of the Bi/Ni cross-section, showing that Ni and Bi are mixed.

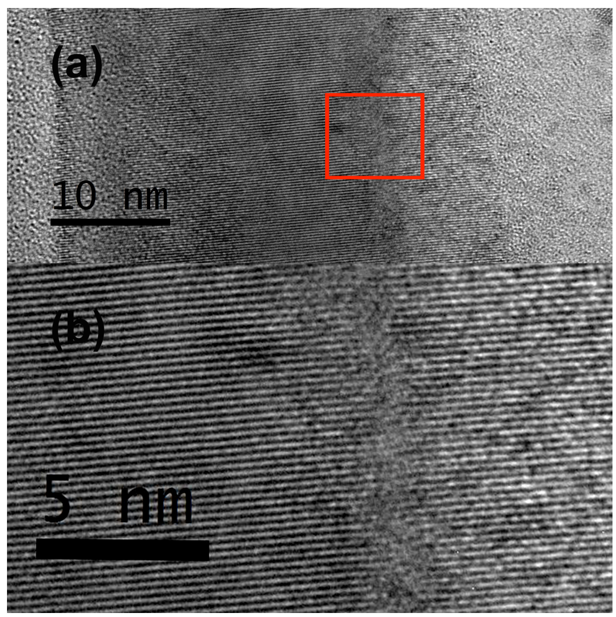

Figure 4. (a) Higher resolution image of the area showing in Fig3 (a). (b) More details of the Bi/Ni interface. There is a very narrow disordered interface between Bi and Ni. However, the Bi and Ni layers seem have epitaxial growth.

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