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IGC Fabrication and TEM Characterization of Mn Nanoparticles

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The reason for the enormous interest in nanomaterials is because they display unique and superior properties that are generally unavailable in conventional macroscopic materials. Gleiter and coworkers [1] first generated a novel solid structure with gas-like disorder, in addition to long-range order (crystalline and quasicrystalline solids) and short-range order (amorphous/glassy solids). Inert-gas condensation (IGC) is a well established nanoparticle production technique [2-4]. Figure 1 shows an IGC system equipped with magnetron sputter source and mass selector that was used in the present work. The ability to control the process parameters to fabricate metal nanoparticles with tailored size, shape, and properties is important for research in this area.

In the present work, manganese has been chosen for a material to investigate as it is one of the most interesting pure metals [5-6]. Transmission electron microscopy (TEM) is used to characterize the morphologies of Mn particles. We investigate the conditions for the formation of Mn nanoparticles with various sizes.

A series of deposition experiments with variable magnetron sputter power, ranging from 40W to 75 W, was carried out. It was found that the size of Mn nanoparticles is correlated with the magnetron sputter power, with larger the power leading to larger particle size. On the other hand, lower power will lead to a lower production rate of particles. Figure 2 shows the Mn nanoparticles produced by the IGC method with magnetron sputter power of (a) 70 W and (b) 55 W; the average particle size is 9 nm and 7 nm, respectively. In order to further reduce the size of Mn particle, the mass selector was removed to reduce the distance between the magnetron sputter source and deposition substrate. Under this experimental configuration, the Mn particle with minimum size down to 2 nm was obtained for magnetron sputter power of 40W. It is interesting to observe the morphology of Mn particles with relative large size changes under electron beam in transmission electron microscope. Dark contrast of the particles became a bright dot in the center, as shown in Fig. 2 and Fig. 3(a), and the size of particles increased slightly, which can be possibly interpreted as having the morphology of hollow structures. Electron diffraction experiments confirm that the particles are not in crystalline state; therefore, the TEM image contrast of the particle is due to the mass density. A simplified model of a hollow spherical ball is constructed and Fig. 3(b) shows the mass density contrast of such a hollow ball with a changing radius of the hollow sphere.

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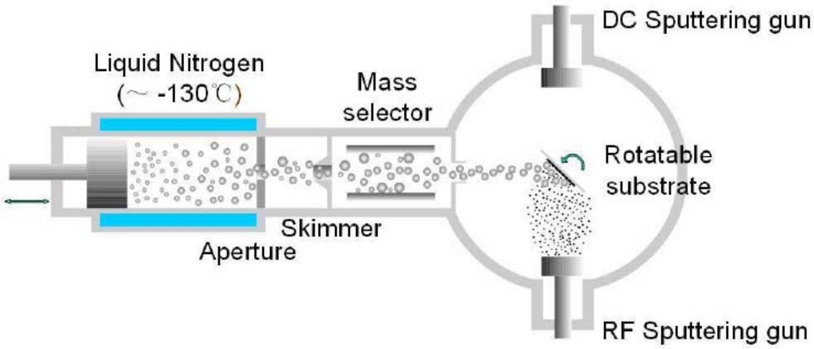

Figure 1. Schematic of the inert-gas condensation system in the present work (after Fig. 1 in [4]).

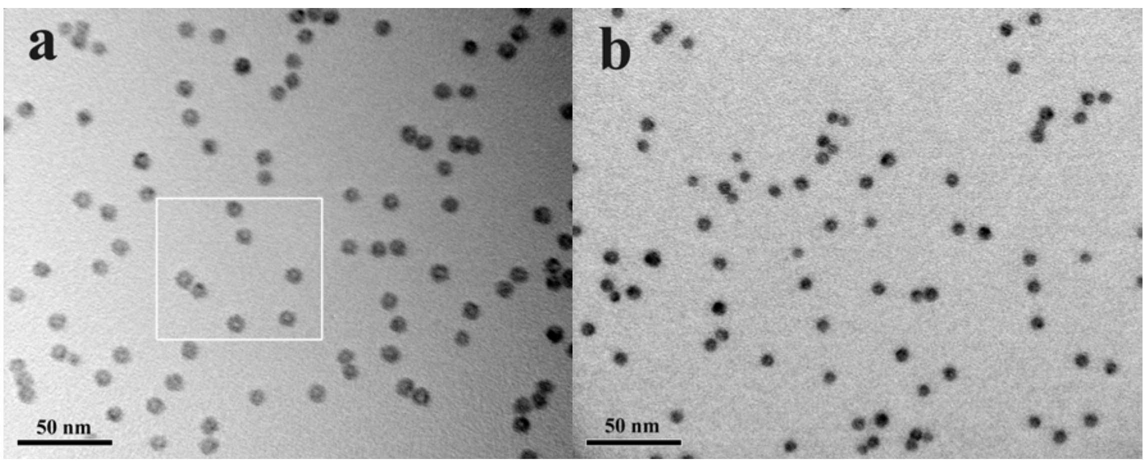

Figure 2. TEM images of Mn particles produced by the IGC method with magnetron sputter power of (a) 70 W and (b) 55 W showing the average particle size of 9 nm and 7 nm, respectively.

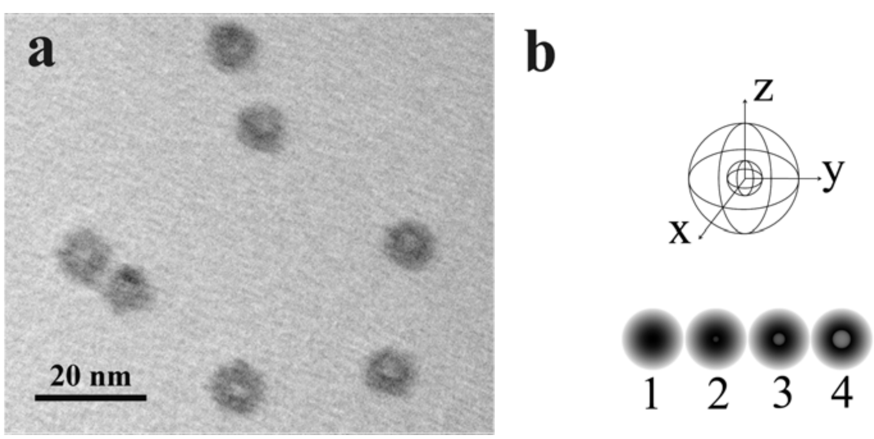

Figure 3. (a) Morphology of the hollow Mn particles in the enlarged part of TEM image in Fig. 2(a); (b) A hollow sphere ball model and simulated images with different inner hollow space, the radius ratio of outside sphere and inner sphere is 100:0, 100:10, 100:20 and 100:30 in label 1, 2, 3 and 4, respectively.