Systematic study concerning to phase transition and structure of nanoparticles

Osamu Kido

The structures and the phase transition mechanism of crystalline and quasicrystalline nanoparticles prepared by a gas evaporation method have been elucidated by the transmission electron microscopy. The in-situ structural analysis method has been established for a nanoparticle.

There are three typical crystal habits in manganese nanoparticles prepared by gas evaporation method. Although they are tristetrahedral α-Mn nanoparticle, rhombic dodecahedral β-Mn nanoparticle and rod shaped nanoparticle, the structure of rod shaped Mn nanoparticles has been unknown. By using the high resolution electron microscopy, it was found that the structure of the rod shaped Mn nanoparticles consisted of α- and β-Mn structures, and they were formed by the coalescence growth among the β-Mn nanoparticles. The β-Mn nanoparticles are metastable phase at room temperature because it is high temperature phase above 700°C. They transformed completely into the α-Mn phase above 500°C without the alteration of the shape of rhombic dodecahedron. It was also found that the α-Mn nanoparticles transformed into β-phase at the well-known transition temperature of 700°C.

The Cr nanoparticles prepared by the gas evaporation method have the characteristic structure, called A-15 type structure or δ-Cr. Their phase transition temperatures into α-phase showed the size dependence. As a result, it was found that the phase transition temperature became higher with decreasing the particle size. The experimental equation between particles size and the phase transition temperature have been determined on the bases of the systematic experimental results. It has been said that the α-Cr nanoparticles prepared by gas evaporation method include the numerous oxygen impurities. It was found that the α-Cr nanoparticles include the 20-30 at% oxygen in a particle, which was estimated form the volume of the oxide layer formed on the surface of nanoparticles by annealing the α-Cr nanoparticles.

The α-Fe_2O_3 nanoparticles covered with γ-Fe_2O_3 layer were produced and showed the characteristic phase transition mechanism. The mantle layer of γ-Fe_2O_3 transformed into α-Fe_2O_3 phase at 650°C, which is 200°C higher than balk value.

Although the quasicrystal thin films were formed by annealing the Al-Mn successive deposition thin film, it was not formed when the deposition sequence was the reverse. By using the boundary reaction between nanoparticle and deposited cluster, it was found that the generation condition of quasicrystal was determined by the diffusion of Al into Mn cluster. It was also necessary to form Al_6Mn alloy phase to generate the quasicrystal.

Al-Mn or Al-Cr quasicrystal nanoparticles prepared by advanced gas evaporation method exist as the metastable single grain of quasicrystal structure at room temperature. By annealing them, the phase transition temperatures into a stable crystal phase were investigated. As a result, the phase transition temperatures of quasicrystal nanoparticles were about two times higher than that of balk.