Structure and magnetic properties of iron nanoparticles synthesized by chemical vapor condensation

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Recently, many researches have been carried out to fabricate nanoparticles because they have many potential applications owing to their unique properties which are different from those of the bulk solid. Among various techniques that have been proposed to fabricate nanoparticles, chemical synthesis of the nanoparticles is a rapidly growing field because of its applicability to almost all materials with high rate of production capability. In this study, iron nanoparticles were synthesized by chemical vapor condensation (CVC) at various reaction temperatures ranging from 400 °C to 1,000 °C and characterized by means of XRD, Mössbauer spectroscopy, TEM, and VSM.

The powder synthesized at 400 °C was a mixture of amorphous phase and crystalline α-Fe due to insufficient reaction energy. Volume ratio of the amorphous phase and the crystalline α-Fe was estimated to be approximately 57:43. Fully crystallized iron particles were then obtained at and above 600 °C. When the reaction temperature reached at 1,000 °C, however, γ-Fe was also stabilized together with α-Fe resulting in degradation of magnetic properties. The synthesized particles were nearly spherical regardless of the reaction temperature but the average particle size increased with the increase of the temperature. The average size of the particles synthesized at 400, 600, 800, 1,000 °C was approximately 10, 20, 70, 100 nm, respectively. Furthermore, it was found that the synthesized particles mostly had the core-shell type structure, and this core-shell structure was more clearly observed from the crystallized particles. The shell enclosed the iron core was identified as a thin layer of Fe_3O_4. When the particles were coated with a polymer, however, this surface oxide layer was rarely formed. Except for the one synthesized at 1,000 °C, the iron nanoparticles were not fully saturated with the maximum applied field of 10 kOe, partially exhibiting superparamagnetic behavior. The intrinsic coercivity measured from the particles synthesized at 600 °C was about 1.2 kOe.