Chemical Synthesis of (Sm,Zr)(Fe,Co,Ti)$_{12}$ Magnetic Mesoscopic Particles

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Multielement (Sm,Zr)(Fe,Co,Ti)$_{12}$ ($ThMn_{12}$, *I*4/*mmm*) compounds have the potential to meet current demands for rare-earth-element-lean permanent magnets with ultra-large energy product and operating temperatures of 150–200 °C. However, their magnets with substantial coercivities have not been realized yet despite their impressively large magnetic anisotropy field and enormous research efforts. The following critical issues make it extremely challenging to practically realize their hard magnetic potential: unoptimized particle size and shape, especially in the mesoscopic scale; introduction of inappropriate intergranular boundary phases resulted from the simultaneous formation of equilibrium ferromagnetically soft phases (e.g., Fe, Co, FeCo) along with the typical (Sm,Zr)(Fe,Co,Ti)$_{12}$ phase; difficulty in fabricating anisotropic magnets using liquid-phase sintering due to relatively high melting temperature of the compounds. Herein we present our recent achievements in the advanced chemical synthesis of ultrafine (Sm,Zr)(Fe,Co,Ti)$_{12}$ mesoscopic particles with controllable grain-size and composition. As a result, their average size of *ca.*1 μm was obtained by thermodynamic control (Fig. 1A, B). Interestingly, we could simultaneously introduce a thin Sm surface (*ca.*2 nm) (Fig. 1A), which can serve as a non-magnetic intergranular boundary. Although the resultant particles exhibited relatively low remanence and coercivity, they were highly susceptible to magnetic-field alignment (Fig. 1C), promising a high potential for the fabrication of anisotropic magnets using a rapid low-temperature current sintering method. Synthetic prospects will move a step forward in the size control through kinetics to obtain their particle size in the range below 1 μm, where an ultra-large coercivity could be achieved.

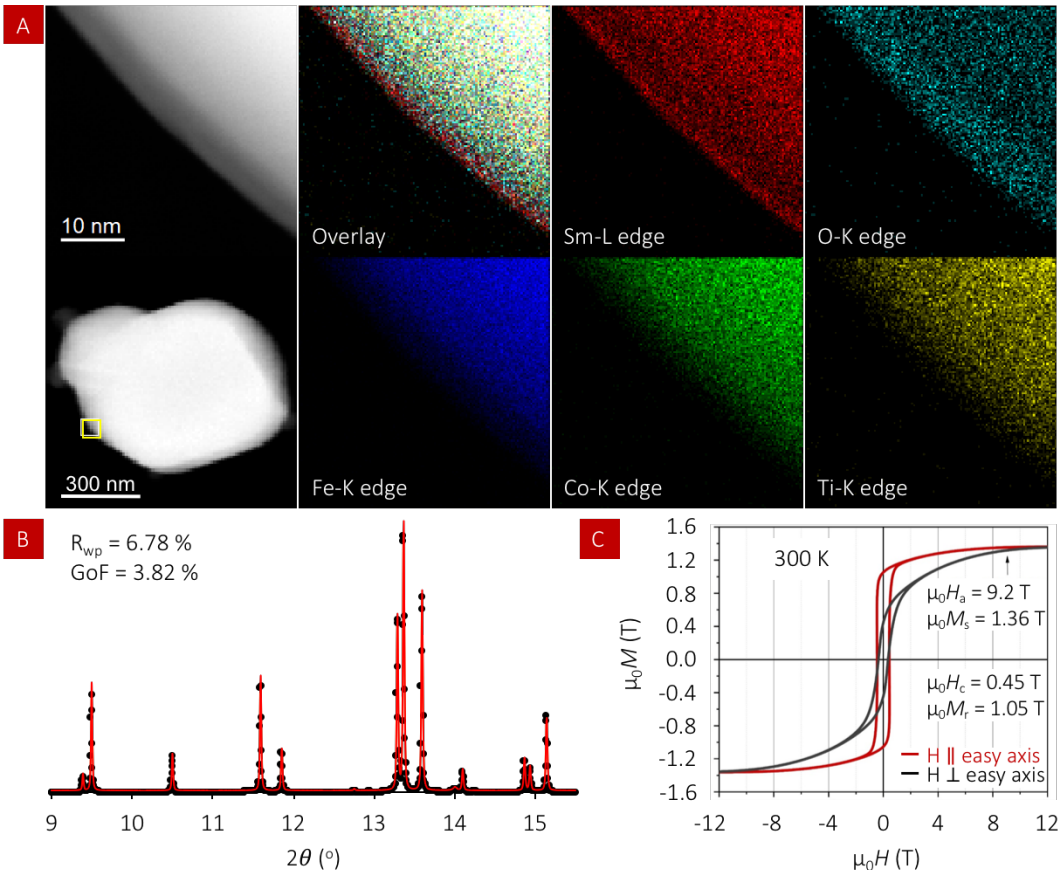

Fig. 1 Structural analysis and magnetic properties of chemically synthesized Sm(Fe$_{0.8}$Co$_{0.2}$)$_{11}$Ti@Sm core@shell mesoscopic particles: (A)HAADF and EDS elemental mapping image, (B) Rietveld refinement synchrotron XRD pattern, and (C) M–H curves.