구두발표 II-2

SYNTHESIS AND MAGNETIC PROPERTIES OF SiC-COATED Fe NANOCAPSULES

Korea Institute of Machinery and Materials P. Z. Si*, C. J. Choi, P. Y. Park, S. Kang, J. W. Lee

Van der Waals Zeeman Institute, University of Amsterdam E. Brück

Institute of Metal Research, Chinese Academy of Sciences Z. D. Zhang

1. Introduction

Encapsulation of active nanocrystallite with inactive materials has attracted great interest recently because of its potential for use in many fields such as protecting the nanocrystallite or modifying the particle properties. To date, many different materials, including polymers [1], silica [2], carbon [3, 4], boron nitride [4], alumina [5], boron [6], etc., have been used for encapsulating the nanoparticles. On the other hand, the magnetic properties of low dimensional systems are usually different from those of their bulk counterparts. Here we report on the synthesis, structure and magnetic properties of a novel SiC encapsulating Fe nanocapsules.

2. Experimental

In analogy to our previous work [3, 6], the traditional arc-discharge method was employed for the synthesis of SiC-coated Fenanocapsules. The anode was composed of Fe (37.5 g) and SiC (10 g), where the SiC and Fe powders were mixed uniformly. The arc discharge was performed under Ar gas and a discharge current of 120-160 A using a tungsten electrode. X-ray diffraction (XRD) experiments were conducted to determine the phase compositions. The as-prepared nanocapsules were characterized using transmission electron microscopy (TEM). Magnetization M(T, H) measurements in applied magnetic fields between +5 T and -5 T and at temperatures ranging from 5 to 350 K were performed with a Quantum Design superconducting quantum interference device (SQUID) magnetometer.

3. Result and discussion

The XRD results indicate that the as-prepared nanocapsules were mainly composed of SiC and Fe. TEM observations reveal that most of the as-prepared nanocapsules are spherical in shape with a narrow size distribution. The size of the nanocapsules ranges from 10 nanometers to 60 nm, with an averaged value of 35 nm, as shown in Fig. 1. Most of the nanocapsules show a distinct shell/core structure, the size of the core ranging from several nanometers to 50 nm, while most shells are approximately 7 nm in thickness.

Fig. 2 reveals the temperature dependence of the magnetization of the sample obtained under zero-field-cooling (ZFC) and field-cooling (FC) conditions, in which a magnetic field of 0.01 T was applied. These curves exhibit the main features of superparamagnetic systems. The ZFC magnetization of the sample increases sharply at temperatures below 60 K with increasing temperature, indicating a blocking process of the small Fe particles. The blocking temperature T_B is defined as the temperature above which a particle has enough time, within the observation time, to reverse its magnetization. Based on the trend of the ZFC and FC curves, it is estimated that T_B of the SiC-coated Fe nanocapsules is approximately 350 K. The broadening of the ZFC curve near T_B should be attributed to a size distribution of the magnetic nanocapsules.

The insert of Fig. 2 shows the hysteresis loops of the nanocapsules measured at 5 K. The sample can be saturated above the magnetic field of 0.8 T. The saturation magnetization of the nanocapsules (5K) is approximately 73 Am^2/kg, which is much lower than that of bulk Fe. The reduction of magnetization should be mainly due to the presence of SiC in the nanocapsules. Atomic disorder present at the surface of the metallic Fe nanocrystallite might also result in the reduction of the magnetization. The coercivity of the nanocapsules at 5 K is approximately 0.09 T, which is higher than that of pure iron owning partially to the size effect.

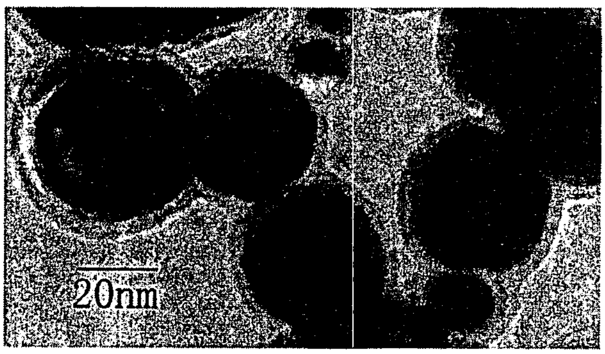

Fig. 1 TEM images of the SiC-coated Fe nanocapsues

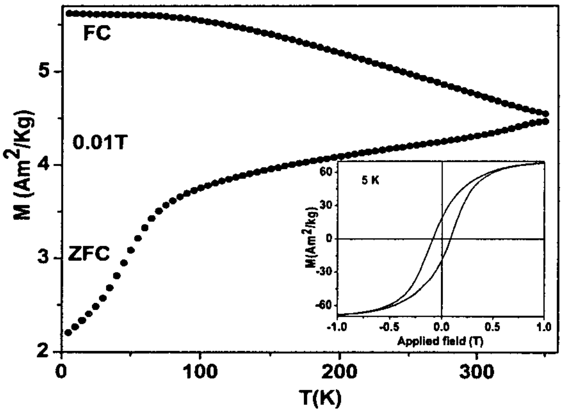

Fig. 2 M-T and M-H curves of the nanocapsules

4. Conclusions

We have enlarged the family of nanocapsules with nanocapsules consisting of SiC shells and Fe cores. The arc-discharge method using Fe+SiC mixture as cathode has been proved to be very effective in achieving uniform encapsulation of metal nanoparticles by SiC shells. Possibly, similar methods could be extended to the synthesis of other types of nanocapsules. The saturation magnetization and the coercivity of the nanocapsules have been reduced and enhanced, respectively.

5. References

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