Magnetic Properties and Magnetocaloric Effect in $La_{1-x}Ce_xFe_{10.5}Si_{2.5}$ (x = 0.2, 0.4, 0.6) Alloys

Wen-Zhe Nan[1], Tae-Soo You[2], Seong-Cho Yu[1]
[1]Department of Physics, Chungbuk National University, Cheongju 361-763, South Korea
[2]Department of Chemistry, Chungbuk National University, Cheongju, 361-763, South Korea

The magnetocaloric effect (MCE) is an intrinsic property of a magnetic material. This effect is dependent on temperature (T), and is usually largest near the magnetic phase transition temperatures. Basically, the MCE is related to a magnetic entropy change (ΔS_M) in a magnetic material under the application or removal of an external magnetic field. Magnetic refrigeration based on the MCE is currently a potential technology that can replace the conventional technology based on gaseous compression and expansion cycles. Unlike the conventional technology, the MCE-based technology shows up some advantages of environmental pollution reduction, energy saving, and low noise. To promote this technology, however, it is necessary to fabricate successfully MCE material with a large ΔS_M in low applied fields and a controllable working temperature range (around magnetic phase transition regions). Additionally, to get a clear idea about the performance of materials used in magnetic refrigeration devices, it is necessary to understand how their MCE evolves in desired temperature and magnetic-field ranges.

In this report, we present a detailed studies on the magnetic properties and MCE of $La_{1-x}Ce_xFe_{10.5}Si_{2.5}$ (x= 0.2, 0.4, 0.6) alloys. The samples were prepared from pure (99.9%) La, Ce, Fe and Si metals by an arc-melting method in a high purity argon atmosphere. And then, the products were sealed in a fused-silica jacket under vacuum and annealed at 1323 K for a month. According to the powder X-ray diffraction patterns, the crystal structure of an as-cast sample displayed the elemental Fe-type structure, but after the annealing process, they were transformed into the $NaZn_{13}$-type structure.

Magnetic measurements versus temperature (T = 100-300 K) and magnetic field (H = 0-10 kOe) were performed on a vibrating sample magnetometer (VSM). Fig. 1 shows the $M(T)$ curves for samples, one can see that all the samples exhibiting a ferromagnetic-paramagnetic (FM-PM) phase transition at Curie temperature T_C = 250, 239, and 230 K for x = 0.2, 0.4, and 0.6, respectively. This FM-PM phase transition can be seen more clearly if H/M is plotted versus M^2 [1]. The nonlinear parts in the low field region at temperatures below and above T_C are driven toward two opposite directions, revealing the FM-PM phase separation. A negative slope corresponding to a first-order phase transition according to Banerjeer's criteria [2] has been observed in H/M versus M^2 curves. Based on isothermal magnetization data, $M(H, T)$, we have calculated $\Delta S_M(T)$ data for samples under an applied magnetic field change H = 10 kOe as shown in Fig. 2. As a function of temperature, the $\Delta S_M(T)$ curves show a maximum (denote as $|\Delta S_{Mmax}|$) at around their T_C. With H = 10 kOe, the values of $|\Delta S_{Mmax}|$ are found to be 3.0, 2.8, and 1.6 $J\times kg^{-1}\cdot K^{-1}$ for x = 0.2, 0.4, 0.6 samples, respectively. The nature of magnetic properties and MCE in the $La_{1-x}Ce_xFe_{10.5}Si_{2.5}$ alloys will be discussed thoroughly by mean of the effect of Ce-doping concentration.

References

[1] A. Arrott, “Criterion for ferromagnetism from observations of magnetic isotherms”, Phys. Rev., 108(6) 1394, (1957).

[1] S. K. Banerjee, “On a generalised approach to first and second order magnetic transitions”, *Phys. Lett.* 12, 16, (1964).