First-order Magnetic Phase Transition in FeRh–Pt Thin Films

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The first-order anti-ferromagnetic (AFM)-ferromagnetic (FM) phase transition in ordered FeRh alloy with CsCl structure is known to take place at about 100C.[1] This transition is accompanied by a unit cell volume expansion of 1%–2%, a reduction in resistivity, and a large entropy change.[2] The transition temperature is sensitive to composition, thus can be tuned by doping additives such as Pt or Ir to above 200C.[3] However, the physical mechanism of the transition mechanism is not well understood.

$FeRh_{(100-X)}Pt_X$ thin films ($0 \leqq X \leqq 15$) were deposited onto (100)MgO substrate by an e-beam technique using Fe, Rh, and Pt targets at substrate temperature around 450 °C. The film thickness was around 50 nm. The as-deposited films were annealed in vacuum at 800 °C for 2 h to obtain chemically ordered *CsCl* structure.

The XRD and the ϕ scan patterns of $FeRh_{(100-X)}Pt_X$ thin films confirm they are of single crystalline of the ordered CsCl structure. The temperature dependent magnetization curves for $FeRh_{(100-X)}Pt_X$ thin films with X are shown in Fig. 1. The transition temperature shifts to high temperature while the width of thermal hysteresis decreases, and there is little thermal hysteresis when X=15. The magnetization curves under different applied magnetic fields H during heating and cooling processes are shown in Figs. 2(a) and (b) for $Fe_{50}Rh_{50}$ and $(Fe_{50}Rh_{50})_{95}Pt_5$ thin films, respectively. As H increases, the transition temperatures during heating and cooling processes all decreased linearly. With X, (dT/dH) reduces from -8.6 to -3.3 K/T. This means that the effect of magnetic field is to stabilize the FM phase and consequently decrease the transition temperature. However, the effect of **H** on the AFM/FM phase transition is restrained by the addition of Pt. The result of this applied magnetic field dependence on transition temperature in $FeRh_{(100-X)}Pt_X$ thin films is similar to the behavior observed in FeRh nanoparticles, $FeRh_{(100-X)}Pt_X$ thin films, bulk FeRh alloys, and Ru-doped $CeFe_2$ alloys.[3-6] According to the magnetic Clausius–Clapeyron equation,3 the total entropy change ($FeRh_{(100-X)}Pt_X$ S) associated with the magnetic phase transition was calculated., which is shown in Figure 3. The entropy change $(\triangle S)_{lat}$ contributed by the lattice distortion is also plotted using the equation $(\triangle S)_{lat}=3\alpha(\triangle V/V)\kappa D$, where α is the thermal expansion coefficient, $(\triangle V/V)$ is a relative volume change, κ volume compressibility, and D density. It is seen that $\triangle S$ is much larger than $(\triangle S)_{lat}$. This result suggests that the lattice entropy change is not a determining factor for the first-order AFM-FM phase transition in FeRh-based alloys, but the entropy change originates from a change in the magnetic moments on Rh atoms between the AFM and FM states at the phase transition.

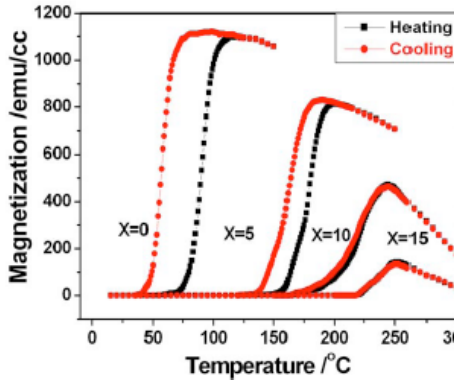

Fig.1 Temperature dependence of magnetization for heating and cooling processes of $FeRh_{(100-X)}Pt_X$ thin films ($0 \leqq X \leqq 15$).

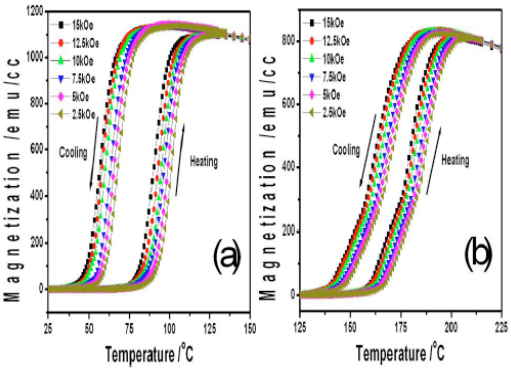

Fig.2 Magnetization curves in the presence of various applied fields in $FeRh_{(100-X)}Pt_X$ thin films..

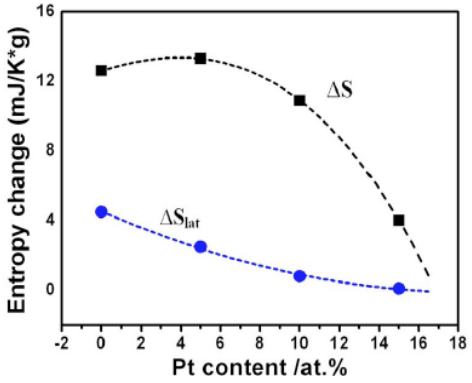

Fig.3 Compositional dependence of total and lattice entropy in $FeRh_{(100-X)}Pt_X$ thin films.

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