IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861,
PP 15-18
www.iosrjournals.org

Large Magnetocaloric Effect with a Wide Working Temperature Span in the Intermetallic Compound Nd_4PtMg

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Abstract: *The magnetic and magneto-caloric properties of intermetallic compound, Nd_4PtMg have investigated by magnetization and heat capacity measurements. The compound exists in prototype Gd_4RhIn cubic type structure. It has been observed that Nd_4PtMg changes from paramagnetic to ferromagnetic state with a second order magnetic phase transition at Curie temperature of T_C ~ 26 K. The compound shows a large reversible magneto-caloric effect around T_C. In the varying magnetic field, Nd_4PtMg undergoes magnetic entropy change with a maximum value of21.3 J/kg-K.*
Keywords: *Magneto-caloric Effect, Phase transition, Curie temperature*

I. Introduction

Recent research on magnetic refrigeration based on the magneto caloric effect (MCE) has fascinated much attention. Many are concentrating on MCE technology because of its higher energy efficiency and lower environmental hazard (eco-friendly) concern when compared to the conventional gas compression method. Magnetic materials with large magneto-caloric effect have been studied in a detailed fashion in both experimental and theoretical methods for the better understanding the properties of the materials [1-16]. MCE near to the room temperature is used for industrial refrigeration [17], which can reduce the greenhouse gases. So that only researchers are giving importance to search magnetic refrigerants at room temperature [18]. The rare earth (RE) intermetallic compounds of the type RE_4TX (T = transition metal; X = Mg), crystallize in the cubic Gd_4RhIn – type structure have attracted much attention because of their fascinating magnetic & magneto-caloric properties [19] and wide practical applications. When a magnetic field is applied to a magnetic material, a remarkable change will be induced in the material's polarization. The magnetic materials which have the first order magnetic and structural transition show large MCE. The decrease in the refrigeration efficiency of the intermetallic material is due to the thermal and magnetic hysteresis connected with the first order magnetic structural transition.The MCE is a magneto-thermodynamic phenomenon which displays as an isothermal magnetic entropy change or an adiabatic temperature change when the magnetic material is exposed to a varying magnetic field. It is necessary and important to find and investigate new materials with large MCE because for better applications the large values of isothermal magnetic entropy change and adiabatic temperature change are considered. Available first ordered phase transition materials are narrow. So, for better understanding of the magneto-caloric effect and searching for such materials with large MCE, we have studied the intermetallic compound,Nd_4PtMg. In this paper, magnetic properties and MCE in Nd_4PtMg were discussed in detail.

II. Experimental

A high quality (99.9%) sample of Nd, Pt and Mg were synthesized by the induction melting method. They are in sealed Ta tubes in water cooled sample chamber. The stoichiometric amounts of Nd, Pt and Mg were melted six times to ensure the homogeneity on a water cooled copper hearth. The total weight loss of the sample is in this step was approximately 0.5%. Then the sample was annealed at 1180K for 7 days in evacuated quartz tubes to improve the homogeneity. The sample was single phase as confirmed by X – ray powder diffraction (XRD) and Energy Dispersive X – ray Spectroscopy (EDXS) analyses. The magnetic measurements were done up to 7 T field with the help of Vibrating Sample Magnetometer (VSM). The specific heat was measured by the adiabatic calorimeter. The MCE can be measured directly or indirectly either by the calculated magnetization or the field dependence of the heat capacity.

III. Results And Discussion

The temperature dependence of the zero field cooled (ZFC) and field cooled (FC) dc susceptibility (χ =M/H) under a low magnetic field of 0.1 T for Nd_4PtMg is displayed in figure-1. It is observed that paramagnetic to ferromagnetic (PM-FM) transition occurs around the Curie temperature T_C ~ 26 K and also it is observed that the compound exists in prototype Gd_4RhIn cubic type structure. The thermal hysteresis cannot be observed between ZFC and FC χ-T curve on and over the Curie temperature T_c. In the same fashion it is observed that some of the rare earth inter-metallic materials, such as RE_4PtMg [20], REAgAl [21] and so on, the thermo-magnetic irreversibility in the present Nd_4PtMg is due to the domain wall pinning effects. The magnetic entropy change ΔS_M was calculated from the temperature and field dependence of the magnetization M(H,T) using the Maxwell's thermodynamic relation.

$$\Delta S_M(T,\Delta H) = \int_0^{H^{max}} \left(\frac{\partial M(H,T)}{\partial T}\right)_H dH$$

The resulting temperature dependence of $-\Delta S_M$ with various magnetic field changes for Nd_4PtMg was evaluated. The maximum values of magnetic entropy change $-\Delta S_M^{Max}$ is calculated to be 21.3 J/kg-K. from the result of the $-\Delta S_M^{Max}$ we can conclude that the present study comes under the category of the large MCE materials. The relative cooling power (RCP) also can be calculated from $-\Delta S_M^{Max}$. RCP is defined as the product of the maximum magnetic entropy change $-\Delta S_M^{Max}$ and full width at half maximum in the $-\Delta S_M(T)$ graph. Figure-2 shows the temperature variation of specific heat and a peak observed around T_C confirms the signature of second order phase transition. From the figure – 2, it is observed that a neat Λ shape is found near the critical temperature T_c which is another typical sign of a second order phase transition. This data supplies the determination for T_c = 26.2K, which was regular with that well-known from M(T) curve.

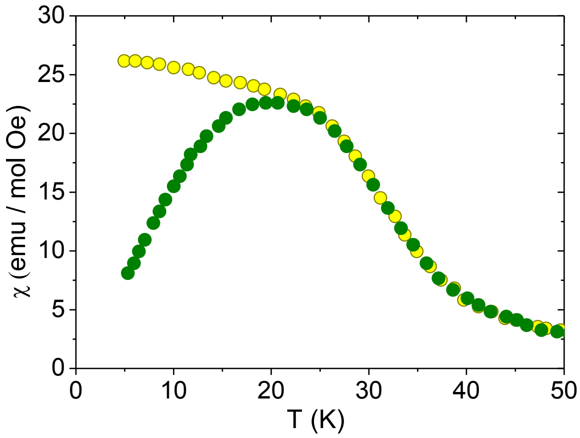

Fig.1. The temperature dependence of ZFC and FC susceptibility (χ) under a low field of 0.1 T.

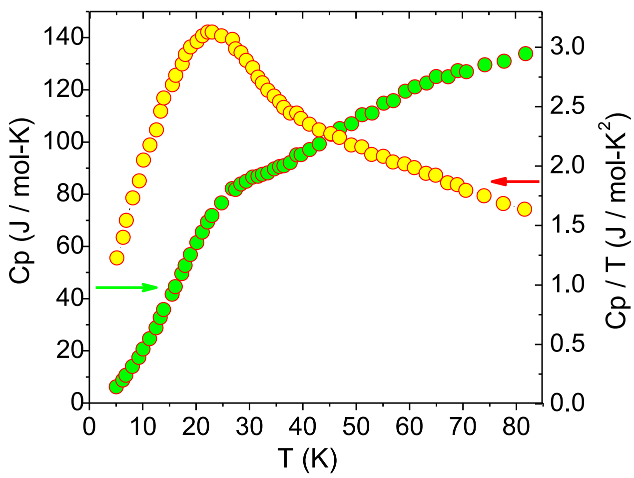

Fig.2. The temperature dependence of specific heat under zero magnetic field.

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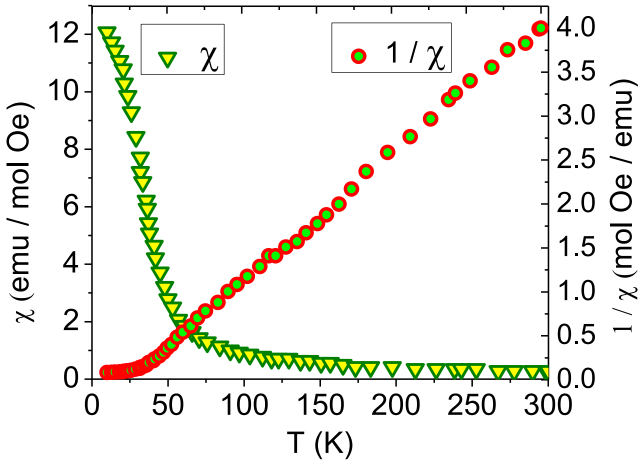

Fig.3. The temperature dependence of susceptibility.

Table1: The transition temperature (T_M) and the maximum magnetic entropy change ($-\Delta S_M^{Max}$) for Nd_4PtMg and also for various large MCE materials.

Material	T_M(K)	($-\Delta S_M^{Max}$) J/kg-K	Reference
Er_4PtMg	15	17.9	20
HO_4PtMg	28	13.4	20
$ErRu_2Si_2$	5.5	17.6	22
$GdCO_3B_2$	54	9.4	23
HoZn	72	12.1	24
HoPd	10	11.3	11
Er_3Co	13	12.0	25
Nd_4PtMg	26	21.3	Present

The susceptibility and reciprocal susceptibility is shown in figure-3.1/χ shows Curie – Weiss behavior above 100 K. the value of the effective magnetic moment μ_{eff} is identified to be 12.2 μB/RE. The related paramagnetic Curie temperature θ_P was obtained. From the result it is concluded that the magnetic states is in long range ferromagnetic interaction.

IV. Conclusion

In summary, single phased Nd_4PtMg compound has been successfully synthesized and the magnetic and magnetocaloric properties have been investigated. From magnetic measurement, it has been observed that Nd_4PtMg changes from paramagnetic to ferromagnetic state with a second order magnetic phase transition at Curie temperatures of T_C ~ 26 K and there is no thermal hysteresis found at this temperature. The compound demonstrates a large reversible magneto-caloric effect around T_C. With magnetic field reversal, Nd_4PtMg reveals a magnetic entropy change with a maximum value of21.3 J/kg-K.The present work gives remarkable information to the researchers who are searching suitable materials which exhibit two or more successive magnetic phase transitions.

Acknowledgements

We are thankful to Dr. Mahalingam college of Engg. & Tech., Coimbatore and Galgotias University, Greater Noida, for their support.

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