International Symposium of Research Students on Materials Science and Engineering
December 20-22, 2004, Chennai, India
Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras

EFFECT OF Al ON MAGNETIC PROPERTIES OF $Nd_3Fe_{27.5}Ti_{1.5}$

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ABSTRACT

The effects of Al substitution on the structural and magnetic properties of $Nd_3Fe_{27.5}Ti_{1.5}$ compound have been investigated. The compounds are formed in monoclinic 3:29 phase with 1:12 phase as the secondary phase and traces of α-Fe. The lattice parameter is found increase with the substitution of Al because of larger atomic radii of Al. The saturation magnetization at room temperature and the Curie temperature are found to decrease with the addition of Al which is explained on the basis of charge transfer between the valance band of the Al and the 3d band of Fe.

Keywords: Magnetic materials, 3:29 intermetallics, Saturation magnetization, Curie temperature

1. INTRODUCTION

The Rare Earth (R) and Transition Metal (TM) intermetallic compounds crystallize in a wide range of compositions. The novel $R_3(Fe,M)_{29}$ (3:29) where R is one or combination of Ce, Pr, Nd, Sm, Gd, Tb, Dy and Y and the stabilizing element M is one of Ti, V, Cr, Mo, W and Mn have been investigated for their interesting intrinsic magnetic properties for permanent magnet applications[1,2]. These compounds are found to form in $Nd_3(Fe, Ti)_{29}$ type monoclinic structure with A2/m space group [3], with alternate stacking of rhombohedral Th_2Zn_{17}(2:17) and tetragonal $ThMn_{12}$ (1:12) type segments. There are two inequivalent sites for R and eleven inequivalent sites for (Fe, M) [4]. Shah *et al* have reported an increase in the Curie temperature when part of Fe is substituted by Co and observed uniaxial anisotropy in $Pr_3(Fe_{0.9}Co_{0.1})_3Ti_{1.5}$ [5]. They have also located rare earths with differing values of second order Steven's constants in the two inequivalent sites [6]. Substitution of Al for Fe in the related 2:17 compounds has been reported to increase magnetization, Curie temperature and anisotropy [7]. Venkatesh *et al* have reported the effect of Al Substitution at the Fe site on the magnetic properties of $(Sm_{0.9}Pr_{0.1})_3Fe_{27.5}Ti_{1.5}$ [8]. In this paper the effect of Al substitution on the structural and magnetic properties of $Nd_3Fe_{27.5}Ti_{1.5}$ compound are presented.

2. EXPERIMENTAL DETAILS

The compounds were prepared by arc melting the constituent elements of high purity (Nd – 99.9%, Fe – 99.95%, Al – 99.9% and Ti - 99.99 %) in an arc furnace under argon atmosphere. The compounds were melted several times to ensure good homogeneity. The weight loss after the final melting was found to be less than 0.5%. The melted ingots were wrapped in tantalum foil, sealed in quartz tube in vacuum (pressure < 10^{-5}), homogenized at 1323 K for 7 days and were quenched in ice water mixture. Structural characterization was done by taking powder x-ray diffraction patterns employing Fe-K_α radiation. Magnetization measurements were carried out using the vibrating sample magnetometer (Model no PAR 155). Anisotropy fields (H_A) were determined from the magnetization curves of magnetically aligned samples (parallel to the plane of the sample holder, arrested in 5 min epoxy resin) using the singular point detection method (SPD).

3. RESULTS AND DISCUSSION

X ray diffraction patterns of the compounds are shown in Fig. 1 All the compounds have formed with the 3:29 phase as the major phase with 1:12 phase as the secondary phase and traces of α-Fe. The lattice is seen to expand with Al concentration**;** this increase is in accordance with the atomic radii of Fe and Al, as reported in 2:17 compounds [9, 10].

Fig.2 shows magnetization curves at room temperature where, the saturation field decreases with increasing Al concentration. The saturation magnetization (M_s) determined from Honda plots are found to decrease with Al substitution [Table 1]. This may be viewed along with the fact that the anisotropy too has decreased with Al substitution as seen from Fig.3 which gives the magnetization curves for the magnetically aligned samples. In the related R_2Fe_{17} intermetallics, the valence band of Al when substituted for Fe has been shown to occupy the bottom of the 3d band of Fe, thus modifying the density of states (DOS) of the 3d band [11]. The decrease in magnetic moment with Al in the present case may be attributed to transfer of charges between the 3d band of Fe and 3p band of Al.

Fig.4 shows temperature dependence of magnetization for the compounds $Nd_3(Fe_{1-x}Al_x)_{27.5}$ in a magnetic field of 200 Oe . The Curie temperature T_C is given in the table.1. The higher T_C in the 3:29 system than in the 2:17 system may be due to the fact that 3:29 system contains more Fe than the 2:17 system. The Curie temperature is found to decrease as the concentration of Al is increased. Such results have been observed in 2:17 systems through band structure calculations. Suresh *et al* [12] have reported an increase of T_C of $ErPrFe_{17}$ and subsequent decrease with Al substitution. From the above comparisons, it seems likely that there is a critical Al to R ratio for which T_C reaches a maximum value. The modification of DOS near the Fermi level leading to a net decrease in the exchange splitting of the spin-up and spin-down bands could be reason for the decrease of Curie temperature. Since 3:29 phase is structurally related to 2:17 phase a similar effect can be expected in the case of 3:29 compounds as well.

4. SUMMARY AND CONCLUSIONS

The substitution of Al in $Nd_3Fe_{27.5}Ti_{1.5}$ leads to an expansion of lattice. The saturation magnetization, Curie temperature and anisotropy decrease with Al addition and is attributed to the modification of DOS of 3d band by the hybridization with the 3p band of Al.

ACKNOWLEDGEMENT

One of the authors, Ravi, thanks the Indian Institute of Technology Madras for the financial support.

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TABLE

Table 1 Variation of Lattice parameters, Magnetization, Anisotropy field and Curie temperature with Al concentration in $Nd_3(Fe_{1-x}Al_x)_{27.5}Ti_{1.5.}$

x	**a** (Å)	**b** (Å)	**c** (Å)	β **(deg)**	$\mathbf{M_s}$ **(emu/g)**	$\mathbf{H_A}$ **(kOe)**	$\mathbf{T_C}$ **(K)**
0	10.631	8.577	9.743	96.97	133	35	432
0.1	10.705	8.613	9.747	97.08	121	25	420
0.2	10.708	8.617	9.753	97.09	116	23	415

FIGURES

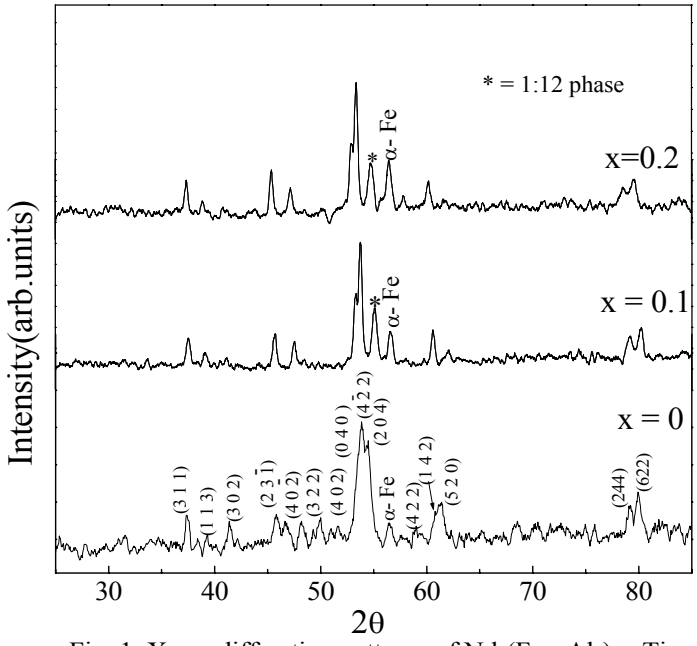

Fig. 1. X-ray diffraction patterns of $Nd_3(Fe_{1-x}Al_x)_{27.5}Ti_{1.5}$

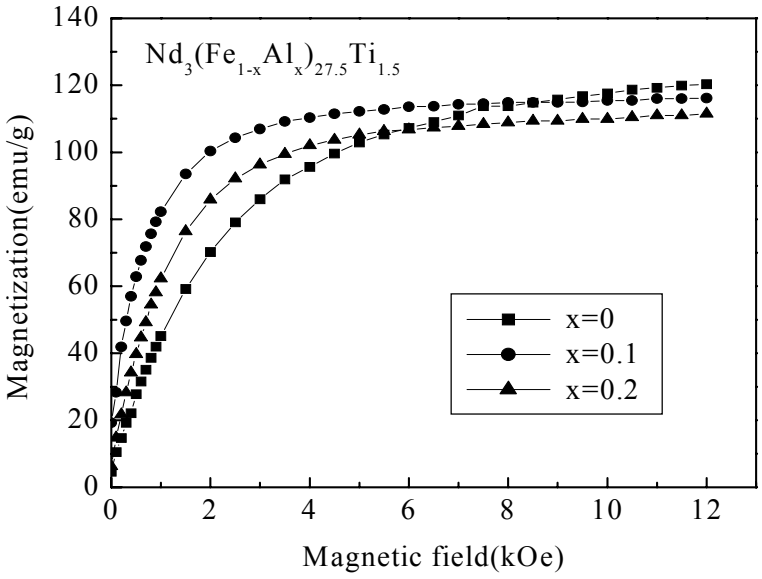

Fig. 2 Magnetization curves of $Nd_3(Fe_{1-x}Al_x)_{27.5\ at}Ti_{1.5}$ at 300K

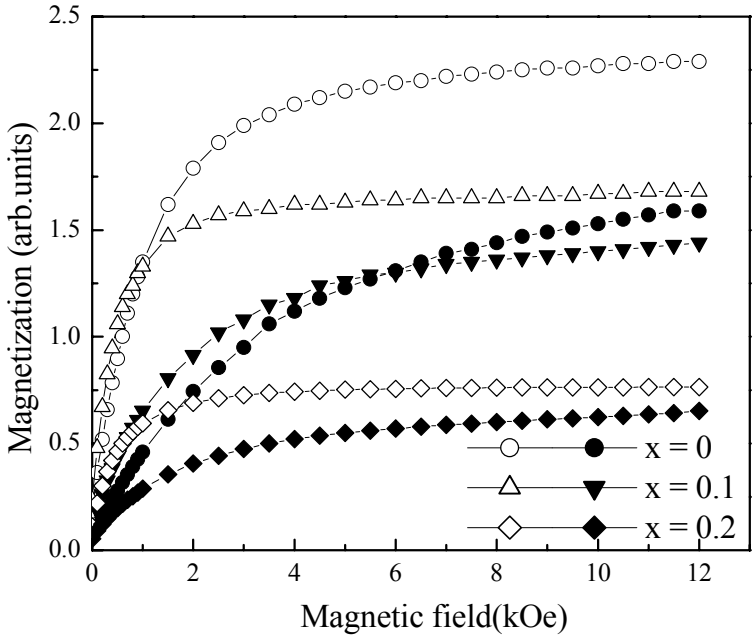

Fig. 3 Magnetization plots of magnetically aligned $Nd_3(Fe_{1-x}Al_x)_{27.5}Ti_{1.5}$ [open symbols- Magnetization parallel to the aligned direction; closed symbols- Magnetization perpendicular to the aligned direction

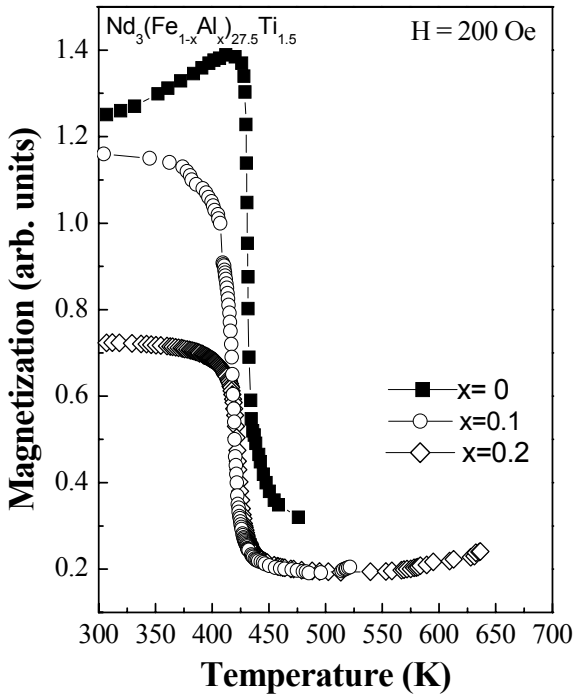

Fig. 4. Temperature dependence of magnetization for the compounds