Vol 5 Issue 2 Aug 2015 ISSN No :2231-5063

International Multidisciplinary Research Journal

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RNI MAHMUL/2011/38595 **ISSN No.2231-5063**

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Golden Research Thoughts
ISSN 2231-5063

Impact Factor : 3.4052(UIF)
Volume - 5 | Issue - 2 | Aug - 2015

MAGNETIC AND MAGNETOSTRICTIVE PROPERTIES OF TERFENOL-D LIKE ALLOYS

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ABSTRACT

It was observed that RFe_2 compounds exhibits large Magnetostriction effects (1,2) at room temperature, and Terfenol-D which is a composition of $Tb_{0.3}Dy_{0.7}Fe_{1.97}$ exhibits maximum Magnetostriction of 1450 micro strain at room temperature in polycrystalline form. The change in the magnetic and magnetostrictive properties has been studied by changing its composition. The Iron is replaced by Cobalt which is another d block ferromagnetic element in first case and in second sample Dysprosium is replaced by Gadolinium which is another rare earth element in lanthanide series. The change again gives good Magnetization at 3oK as well as low coercivity. But due to cobalt the combinations turns to be paramagnetic at room temperature. Adding Gadolinium instead of Dysprosium causes net change of 600 micro strain but showed negative strain of 150 micro strains.

KEYWORDS : *Terfenol-D, Magnetostriction, Magnetization.*

INTRODUCTION :

Giant Magnetostrictive effect was observed in RFe_2 compounds and it was observed that strain produced in such polycrystalline alloys or single crystals can be of the order of few hundreds of micro strains under strong magnetic fields. The maximum Magnetostriction was found in Terfenol-D which is around 1500 micro strains at room temperature. Here is an attempt in knowing about magnetic and magnetostrictive properties of similar compositions. Observations were made by changing certain elements having similar properties (5,6) and also added in similar proportions. Initially dysprosium is replaced by Gadolinium which shows helical orientations of magnetic moment but is rare earth element of similar type, and in second attempt Iron is replaced by cobalt which is again d block ferromagnetic element. The M-H loop, Magnetization and Magnetostrictive properties were observed for each sample.

Objectives:

Following objectives were made for this research:

1)Study of Magnetic properties like M-H loop, change in Magnetization with temperature of sample with Gadolinium, and its comparison with Terfenol-D.

2)Study of Magnetic properties like M-H loop, change in Magnetization with temperature of sample with Cobalt, and its comparison with Terfenol-D.

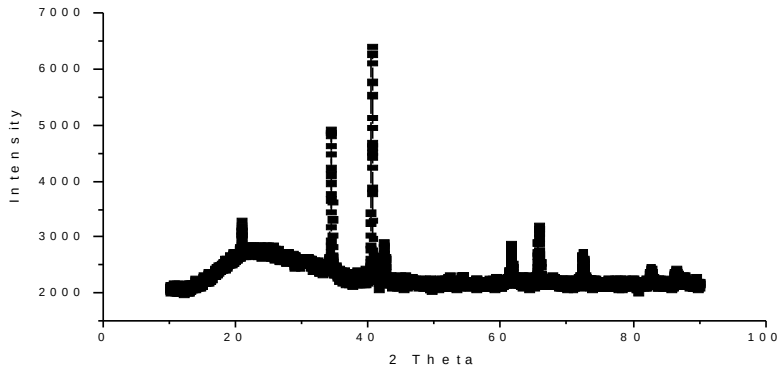
Experimental Details:

The samples with respective elements were prepared with desired compositions and alloys are formed under high vacuum in Furnace. No weight loss is observed after alloy formation. The XRD confirms the formation of alloys without any impurity and structure is found to be cubic which is similar to Terfenol-D sample.

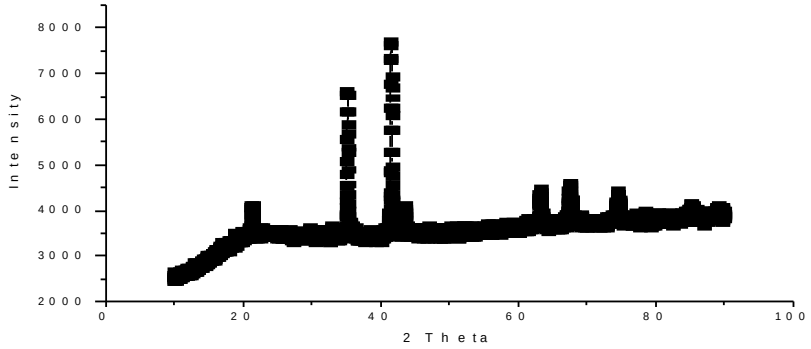
The M-H loop is traced at 3 ^{o}K, while Magnetization is observed with varying temperature up to 400 ^{o}K, in the laboratory of Physics, IIT Mumbai. The Magnetostriction is observed using the data logger circuit in which strain is measured using strain gauges pasted with special adhesive on the samples, with the least count of 1 micro strain at room temperature.

XRD Measurements:

1)XRD for $Tb_{0.3}Gd_{0.7}Fe_{1.97}$ showed cubic structure which is similar to the structure of Terfenol-D.



2) XRD for $Tb_{0.3}Dy_{0.7}Co_{1.97}$ also showed cubic structure similar to Terfenol-D.

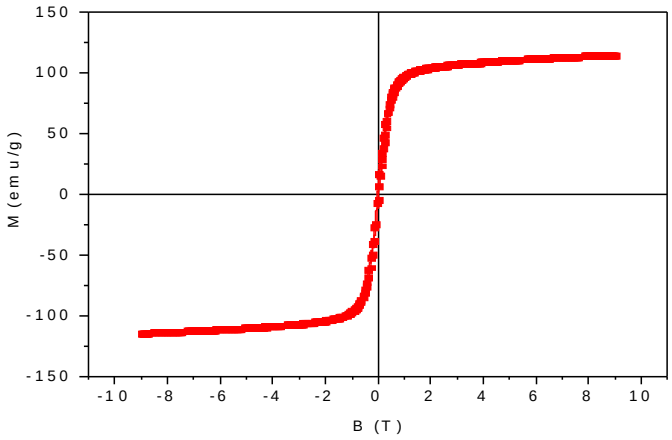


Magnetic Measurements:

A)Consider sample $Tb_{0.3}Gd_{0.7}Fe_{1.97}$:

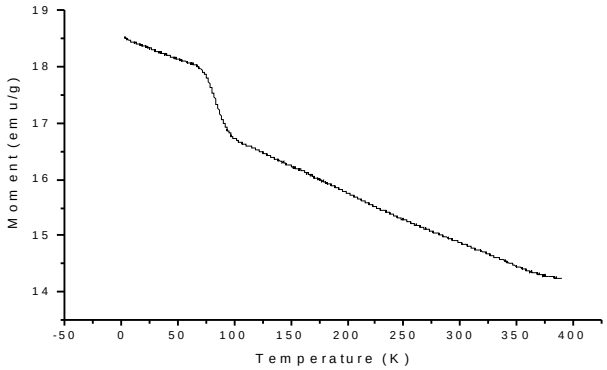
i)Hysteresis Loop:

M-H loop for $Tb_{0.3}Gd_{0.7}Fe_{1.97}$ shoed very low corecivity and magnetization gets saturate at around 125 emu/gm after 1 Tesla at 3°K. The corecivity was found to be only 0.02 Tesla while residual magnetization was observed to be only 6.16 emu/gm. Thus this combination can have very large scope for application as there can be negligible losses with it.



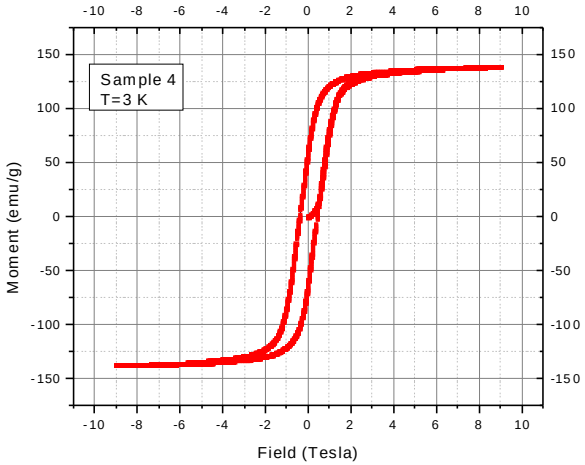
ii) Variation of Magnetization with Temperature:

The combination showed high magnetic moment even at 400 °K and this shows it remained ferromagnetic even at high temperature. This means one can use its magnetic properties at high temperature also. One can guess from graph that it can show ferromagnetic properties up to around 700 °K or so.

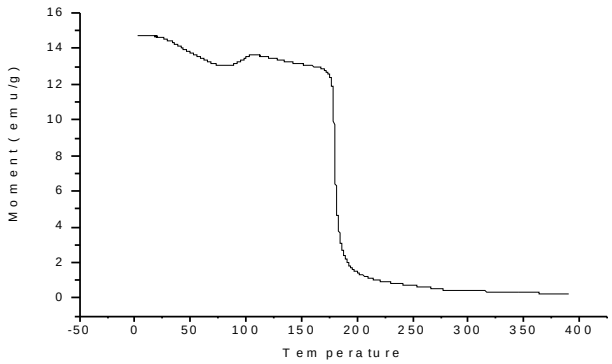


B) Consider sample$Tb_{0.3}Dy_{0.7}Co_{1.97}$:

Hysteresis loop: M-H loop for $Tb_{0.3}Dy_{0.7}Co_{1.97}$ showed very low corecivity and magnetization gets saturate at around 140 emu/gm after 1 Tesla at 3°K. The coricivity was found to be only 0.41 Tesla while residual magnetization was observed to be 52 emu/gm. Thus this combination can have very large scope for application as there can be negligible losses with it. But residual Magnetization is little higher.

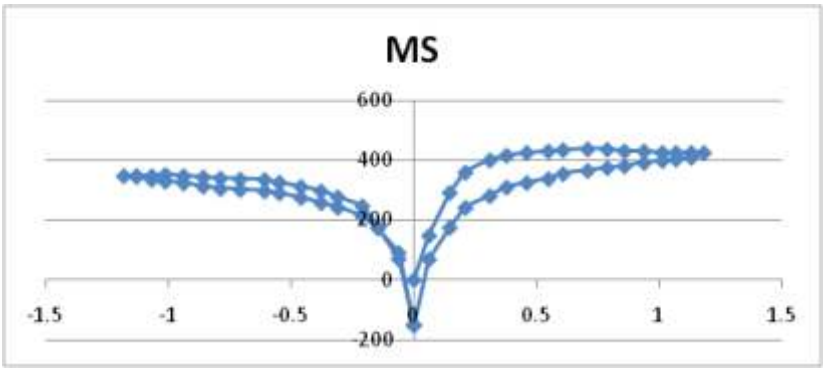


I) Variation of Magnetization with Temperature: The said combination is found to be ferromagnetic up to 179 ^{o}K and above it turned out to be paramagnetic in nature. Thus it can be used as a ferromagnetic sample only at low temperature and hence as practical applications it got limitation. The replacement of Cobalt instead of Iron is found to be not good.



Magnetostrictive Measurements:

A)Consider sample $Tb_{0.3}$ $Gd_{0.7}Fe_{1.97}$: The Variation of Magnetostriction (MS) Versus applied Magnetic field in Tesla, at room temperature is as shown. The saturation Magnetostriction is found at 0.5 Tesla. The maximum Magnetostriction is around 400 micro strains, but while reversing the field it showed negative value up to 200 micro strains, and thus in total the change of 600 micro strains is observed. Thus it can be used ultrasonic generator.



B)Consider sample$Tb_{0.3}$ $Dy_{0.7}Co_{1.97}$: The replacement of Cobalt instead of Iron is found to be wrong option as for as applications are concerned. This is because the combination loses its ferromagnetic behavior at temperature 179 0K. thus for applications one must maintain Iron.

RESULT AND CONCLUSIONS:

The combinations of Iron and rare earth elements made in Terfenol-D are found to be giving maximum Magnetostriction. But replacement of Gadolinium instead of Dysprosium is also one of the options as Net Magnetostriction at room temperature is of several micro strains. Also it gives interesting negative Magnetostriction of the order of 200 micro strains at zero magnetic fields. The combinations with ferromagnetic elements other than Iron must be avoided as these combinations turns out to be paramagnetic at Room temperature and hence cannot be used for applications like ultrasonic generators and transducers. These new alloys showed very low corecivity and residual magnetization which results in losses.

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ACKNOWLEDGEMENT:

We are thankful to Prof. G. Suresh from IIT Mumbai, for providing the Laboratory and necessary chemicals for making ferromagnetic samples.

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