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Magnetic and Magnetostrictive properties of Gadolinium-Terfenol-D Alloys

KEYWORDS: Terfenol-D, Magnetostriction, Magnetization.

Jitendra Pendharkar
K J Somaiya College of Science and Commerce, Vidyavihar, Mumbai.

Manohar Nyayate
B N Bandodkar College of Science , Thane.

ABSTRACT *It was observed that RFe2 compounds exhibits large Magnetostriction effects (1,2) at room temperature, and Terfenol-D which is a composition of Tb0.3Dy0.7Fe1.97 exhibits maximum Magnetostriction of 1450 micro strain at room temperature in polycrystalline form. The change in the magnetic and magnetostrictive properties has been studied (5,6) by changing its composition. The Dysprosium is replaced by Gadolinium which is another rare earth element in lanthanide series. The relative percentage of Dysprosium is changed with Gadolinium. The change again gives good Magnetization at 3oK as well as low corecivity. The Iron is not changed with any other element as it was observed that the resultant compositions turns out to be Paramagnetic at temperature above 180 oK. the effect of increase in Gadolinium is observed in Terfenol-D sample. The Magnetostriction was found to be several hundreds of micro strains at room temperature in all the samples. The addition of less amount of Gadolinium showed more residual magnetization and negative Magnetostriction.*

Introduction:t
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. The percentage of Gadolinium is changed and then magnetic and magnetostrictive properties are measured and are compared with Terfenol-D.

Objectives:
Following objectives were made for this research:

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

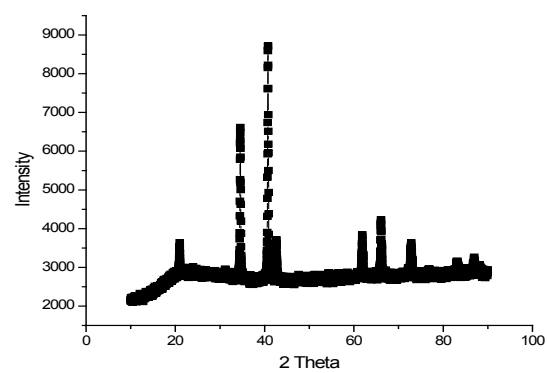
Study of Magnetostrictive properties of new alloys, and its comparison with Terfenol-D.

Experimental Details:
The samples with respective elements mentioned above 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.

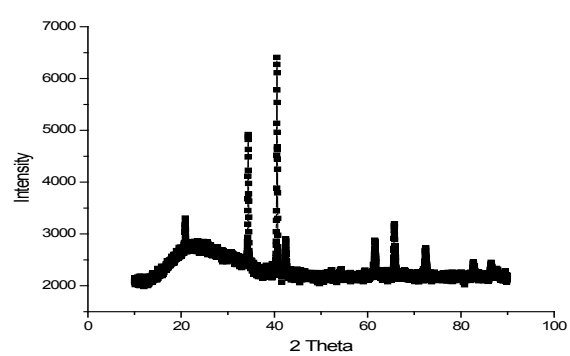
The M-H loop is traced at 3 °K, while Magnetization is observed with varying temperature up to 400 °K, in the laboratory of Physics, IIT Mumbai. The Magnetostriction is observed using the data logger circuit in which strain is measured using strain gauges pasted with special adhesive on the samples,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

XRD Measurements: XRDs of following samples were found to be free of impurities and matched well with desired combinations. The structures of all these alloys were found to be cubic and similar to the structure of Terfenol-D.

i) $Tb_{0.3}\,Dy_{0.5}\,Gd_{0.2}\,Fe_{1.97}$:



ii) $Tb_{0.3}\,Dy_{0.3}\,Gd_{0.4}\,Fe_{1.97}$:



iii) $Tb_{0.3}\,Dy_0\,Gd_{0.7}\,Fe_{1.97}$:

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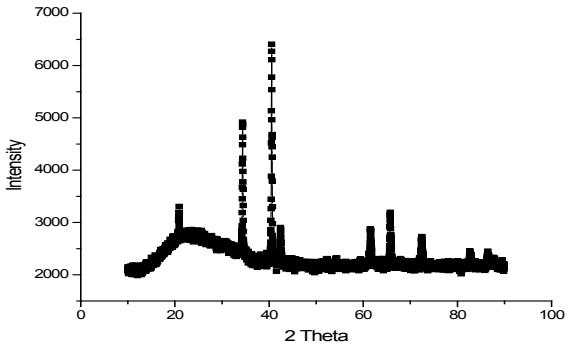
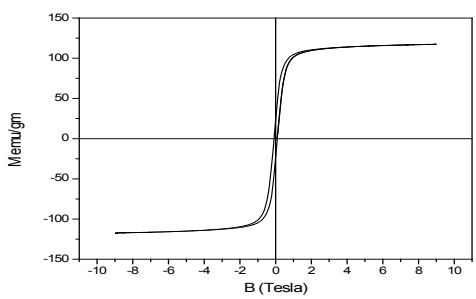


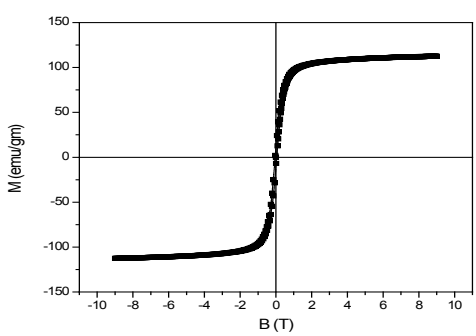
Magnetic Measurements:

Hysteresis Loop: Variation of Magnetization with applied magnetic field were studied for the following samples:

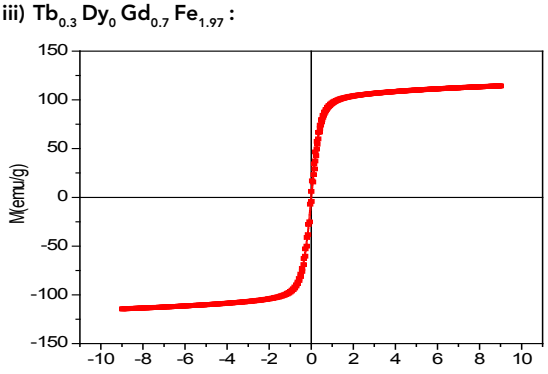
i) $Tb_{0.3}\ Dy_{0.5}\ Gd_{0.2}\ Fe_{1.97}$:



ii) $Tb_{0.3}\ Dy_{0.3}\ Gd_{0.4}\ Fe_{1.97}$:



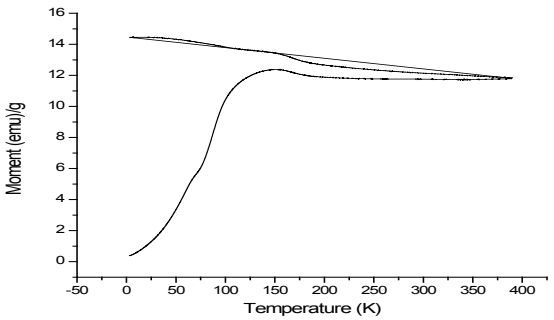
iii) $Tb_{0.3}\ Dy_{0}\ Gd_{0.7}\ Fe_{1.97}$:



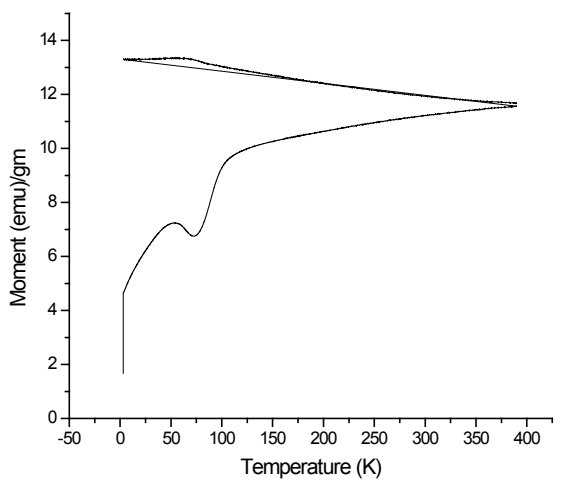
Variation of Magnetization with Temperature:

Variation of Magnetization with Temperature was observed for following samples. It was expected that the samples should remain ferromagnetic for temperature well above room temperature.

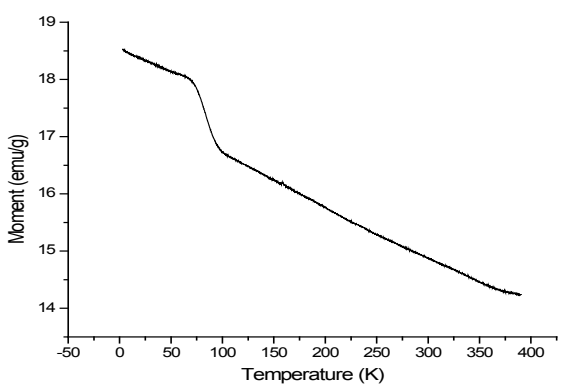
i) $Tb_{0.3}\ Dy_{0.5}\ Gd_{0.2}\ Fe_{1.97}$:



ii) $Tb_{0.3}\ Dy_{0.3}\ Gd_{0.4}\ Fe_{1.97}$:



iii) $Tb_{0.3}\ Dy_{0}\ Gd_{0.7}\ Fe_{1.97}$:



Magnetostrictive Measurements:

The change in strain produced in the alloys forms under the application of applied field was measured and the variation observed is plotted as follows:

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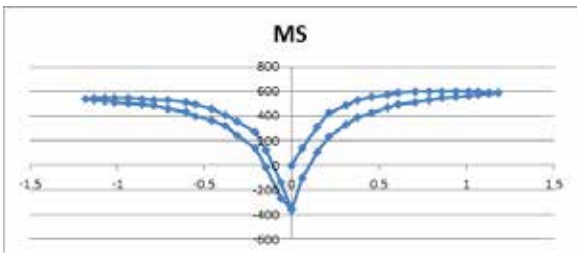
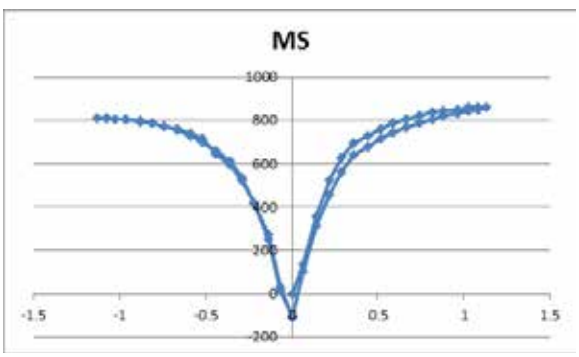
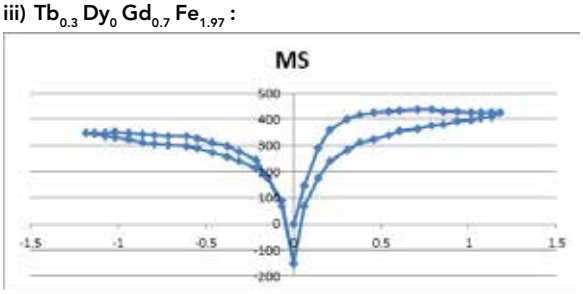
i) $Tb_{0.3}\ Dy_{0.5}\ Gd_{0.2}\ Fe_{1.97}$:



ii) $Tb_{0.3}\ Dy_{0.3}\ Gd_{0.4}\ Fe_{1.97}$:



iii) $Tb_{0.3}\ Dy_{0}\ Gd_{0.7}\ Fe_{1.97}$:



Result and Conclusions:

The Magnetostriction of Terfenol (1,2) was observed to be 1500 micro strains at room temperature. The corecivity was observed to be 0.085 T and residual magnetization (6,7) was observed to be 6.1 emu/gm. Since it is ferromagnetic at higher temperatures also it showed large number of applications. Also it was observed that adding small amount of other elements changes magnetic and magnetostrictive properties very drastically (6,7). For example when we add Boron (2%) in Terfenol it reduces Magnetostriction to 1140 micro strains but also brings negative values up to 172 micro strains when field retraced to zero from maximum, and when boron addition is of 4% then Magnetostriction further reduces to 800 micro strains with negative strain of 50 when field reduces to zero from maximum.

The samples newly made by varying relative percentage of Gadolinium were also Ferromagnetic at temperatures far above room temperature and hence can be of industrial applications. The comparative data was as shown.

Samples	M Vs H loop at 3°K		Magnetization At 400 °K emu/gm	Magnetostriction at Room Temperature, Zero Reference/ (Absolute value) Micro strains	Magnetostriction when field retraced to zero from Maximum Micro strains
	Corecivity Tesla	Residual Magnetization emu/gm			
$Tb_{0.3}\ Dy_{0.5}\ Gd_{0.2}\ Fe_{1.97}$	0.093	20.1	12.1	601/ (990)	-390
$Tb_{0.3}\ Dy_{0.3}\ Gd_{0.4}\ Fe_{1.97}$	0.041	10.1	13.0	808/(958)	-150
$Tb_{0.3}\ Dy_{0}\ Gd_{0.7}\ Fe_{1.97}$	0.02	6.0	14.2	430/(580)	-150

It was observed that as percentage of Gadolinium increases as compared to Dysprosium the corecivity and residual Magnetization decreases, Magnetization increases but Magnetostriction decreases.

Acknowledgement:

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