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PHYSICS

# "MAGNETO-MECHANICAL PROPERTIES OF IRON - RARE EARTH QUATERNARY RFe2 TYPE POLYCRYSTALINE ALLOYS"

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**ABSTRACT** Magnetostriction is Magneto-Mechanical phenomenon observed in ferromagnetic materials at temperatures below Curie temperature. There is change in the length $\Delta l$ that is the strain produced due to applied field is measured in micro strains. The variation in strain with applied magnetic field is similar to magnetization of sample, it increases with applied field and gets saturated. Magnetostriction of Terfenol-D is observed to be the maximum and for a polycrystalline sample it is around 1500 micro strain at room temperature. The coercivity is found to be very low and hence showed low losses. In this research paper the Magnetostriction Properties of Terfenol like Samples are discussed. Newly formed alloys of four metals showed Giant Magnetostriction at room temperature with very low coercivity but high Magnetization. The alloys made from Terbium, Gadolinium and Dysprosium with Iron as a main constituent ($Tb_{0.3}R_xR''_{1-x}Fe_2$) [R- Rare Earth Metals] showed Giant Magnetostriction with Coercivity one fourth to that of Terfenol-D.

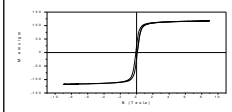
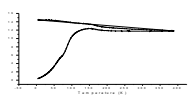
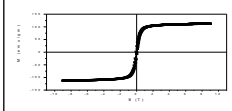
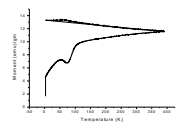
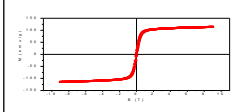
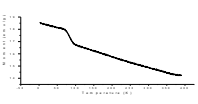
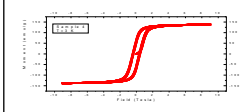
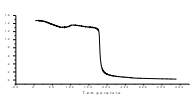
**KEYWORDS :** Magnetostriction, Magnetization, Coercivity.

**Introduction:**

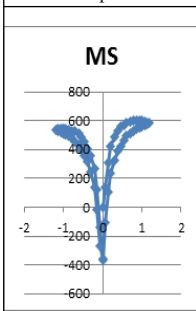
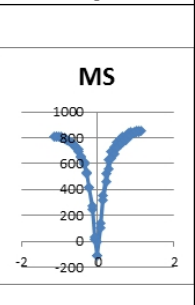
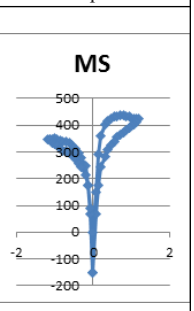
Magnetostriction is the change in the dimensions of ferromagnetic materials under the applications of Magnetic field. The effect is similar to that of magnetization [3,4,]. The Magnetostriction that is the change in the length along the direction of applied field increases and saturates at higher field. Terfenol-D [$Tb_{0.3}Dy_{0.7}Fe_{1.97}$] the alloy formed by Clark et al [3,4,5] is the alloy showing maximum Magnetostriction at high temperature with low coercivity so far known. In this research the Ternary Quaternary alloys were made with Rare earths and Iron.

The newly formed alloys showed Giant Magnetostriction at temperatures above 400K at the same time showed very low coercivity. One sample showed coercivity much less than Terfenol-D. The adding the Gadolinium was found to be very successful [1, 2]. The relative percentage of Dysprosium is changed with Gadolinium by keeping percentage of Terbium in Terfenol-D same. The percentage of Terbium should not be changed as it decreases the Magnetostriction in sample. The replacement of Iron by Cobalt not only increases coercivity but also decreases Curie temperature (179K) and hence is not recommended for Industrial applications [1, 2]. The XRD, Magnetization data was taken in IIT Bombay, while observations on Magnetostriction were done in B N Bandodkar College of Science, Thane.

**Observations:** Refer [1,2] Hysteresis loop and variation of Magnetization with Temperature

| Samples | B-H Loop | M Vs T |
|---|---|---|
| (i) |  |  |
| (ii) |  |  |
| (iii) |  |  |
| (iv) |  |  |

Magnetostriction: Magnetostriction Vs Applied Magnetic field at Room Temperature

| Sample 1 | Sample 2 | Sample 3 |
|---|---|---|
|  |  |  |



**Summary:** Refer [1, 2]

| 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 |
|---|---|---|---|---|---|
| | Coercivity Tesla | Residual Magnetization emu/ gm | | | |
| 1) $Tb_{0.3}Dy_{0.5}Gd_{0.2}Fe_{1.97}$ | 0.093 | 20.1 | 12.1 | 601/ (991) | -390 |
| 2) $Tb_{0.3}Dy_{0.3}Gd_{0.4}Fe_{1.97}$ | 0.041 | 10.1 | 13.0 | 808/(958) | -150 |
| 3) $Tb_{0.3}Dy_{0}Gd_{0.7}Fe_{1.97}$ | 0.02 | 6.0 | 14.2 | 430/(580) | -150 |
| 4) $Tb_{0.3}Dy_{0.7}Co_{1.97}$ | 0.41 | 52 | Zero | Nil | Nil |

**Discussions:**

1] The samples XRD shows the samples were homogenous and showing Cubic Laves phase structure. Also there is no loss of any materials during forming of alloys [1,2].

2] The combinations of Iron and rare earth elements made in Terfenol-D were found to be giving maximum Magnetostriction with very low coercivity. This is because even though the Magnetostriction of $TbFe_2$ is Maximum ($T_C$=431°C) but the coercivity is also large as anisotropic constant is negative and high that is $K_1$=-6.3 KJ/$m^3$. The anisotropic constant of $DyFe_2$($T_C$= 362 °C)is positive that is 2.1 KJ/$m^3$. So when Tb and Dy were added in relevant proportions the result is Terfenol-D having high Magnetostriction and very less coercivity. [3,4,5]

3] But replacement of Gadolinium instead of Dysprosium is also one of the options as Net Magnetostriction at room temperature is of several micro strains with even less coercivity and residual magnetization [1,2].

4] It is seen that the coercivity and residual magnetization decreases with increase in percentage of Gadolinium. Thus one can replace Gadolinium with Dysprosium. Also it gives interesting negative Magnetostriction of the order of 200 micro strains at zero magnetic fields. Thus these new alloys showed very low coercivity and residual magnetization which results in negligible losses. The combination $Tb_{0.3}Dy_{0.3}Gd_{0.4}Fe_{1.97}$ is found to be good as it gives less coercivity, half than that of Terfenol-D than Terfenol and also Magnetostriction of nearly 1000 micro strain at Room Temperature. The combination $Tb_{0.3}Dy_{0}Gd_{0.7}Fe_{1.97}$ is also good as it gives almost zero coercivity that is one fourth of Terfenol-D but Magnetostriction is less than it.

**Conclusion:**

1] The combinations with ferromagnetic elements other than Iron must be avoided as these combinations turns out to be paramagnetic at Room temperature [1] and hence cannot be used for applications like ultrasonic generators and transducers.

2] The samples made by varying relative percentage of Gadolinium were also Ferromagnetic at temperatures far above room temperature, having very less coercivity and residual magnetism, and hence can be of good use for industrial applications.

3] The samples can be used in Ultrasonic generators. This is because the coercivity is found to be very small and hence losses. Note that the change in the shape took place from zero to 0.5 Tesla, is almost linear and the total strain of around 500-900 microstrains were observed.

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