High coercivity through texture formation in SmCo5/Co multilayers

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High Coercivity Through Texture Formation in $SmCo_5$/Co Multilayers

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Abstract. We have shown that high coercivity in $SmCo_5$/Co multilayer exchange spring magnet can be obtained on silicon substrates as well. This is achieved by annealing the as-grown sample at an optimum temperature that favors texture formation. This compares well with multilayers grown on MgO substrates and post-annealed at the same temperature.

Keywords: Multilayer, exchange-spring magnet, $SmCo_5$
PACS: 68.65.Ac, 75.70.Ak, 75.70.Cn

INTRODUCTION

Recent development on exchange-spring magnets, in pursuit of strong permanent magnet, has been quite noticeable. Initial idea, conceived by Kneller and Hawig [1], was to have a composite of soft and hard magnetic phases that are exchange-coupled at the interface. Fabrication process utilizes rapid quenching and subsequent annealing to form randomly oriented nano-dispersed hard and soft magnetic phases to achieve this goal. This arrangement provides an enhanced energy product $(BH)_{max}$ by virtue coupling the hard magnetic phase with good coercivity and soft magnetic phase with high remnant magnetizaton. However, difficulties in controlling microstructure in nanoscale and hence inhomogeneity in these methods, sets motivation for search for alternatives. Multilayers of hard and soft phases, where interface parameters are controllable, provide an alternative route. Sputter deposition of multilayer of hard and soft magnetic materials and subsequent annealing not only provides a reproducible method but also with enhanced energy product. In this work we show that there is a significant improvement in coerivity and remnant magnetization in post-annealed (at an optimum temperature of 550 ^oC) multilayers, deposited on both MgO and silicon substrates. Our results show that samples on silicon substrates are equally good as that grown on MgO, when optimally annealed at 550 ^oC and thus equally useful for any possible device application and have the advantage of being cheaper of the two.

EXPERIMENT, RESULTS AND DISCUSSION

Multilayer films with the structure Cr (10 nm)/ [Sm (t_{Sm} nm)/Co (t_{Co} nm)]$_{25}$/Cr (20nm) on Si (100) and MgO (100) substrates were fabricated using Ultra High Vacuum (UHV) compatible magnetron sputtering with base pressure better than 5.0 x 10^{-9} mbar. During the deposition, the substrate temperature, T_s, was maintained at 450^{o}C and in-situ post deposition annealing was carried for at different temperatures. Magnetization measures were carried in a SQUID magnetometer (Quantum Design) with the magnetic field applied parallel to the plane. X-ray diffraction was carried out using Cu-Kα in a rotating anode diffractometer.

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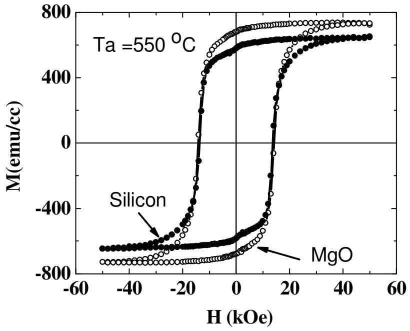

Figure 1. Room temperature M-H plot, open circle MgO, solid circle Si substrate

Figure1 shows room temperature M-H plot for both multilayers deposited on silicon and MgO substrates and subsequently annealed at 550°C. Both the samples show reasonably high coercive field of around 14 kOe. Magnetization squareness (defined as the ratio between M_{rem} and M_{sat}) is also good indicating better coupling between the soft and hard magnetic layers. However, a small kink is seen in case of silicon substrate. Figure 2 shows the XRD for both the samples. We see predominant orientation in (110) direction of $SmCo_5$ phase in case of silicon substrate. In case of MgO both (110) and (200) orientations are there, with nearly comparable proportion, and the (200) peak is split indicating possible twinning in that direction. From analysis we get estimate of grain sizes of 38 and 39 nanometer for (110) orientation, 24 and 27 nanometer for (200) orientation, for MgO and silicon substrates respectively.

Realization of a of a good exchange spring magnet is possible when the soft phase provide good remnant magnetization that is retained under field reversal up to a high coercive field provided by the hard phase. Fullerton et al [2] have demonstrated the achievement of high coercive field in Sm-Co/Co multilayers, grown on MgO substrates, using epitaxial Cr(100) buffer layer. Epitaxial Cr underlayer helps controlling the grain size of the Sm-Co hard layer. Thus, crystallinity and grain growth of the hard layer has been crucial to achieve this high coercivity. This has also been shown by many in recent past [2-4]. Many have achieved this by either depositing the film at higher substrate temperature or post-annealing the as-deposited film [5-8].

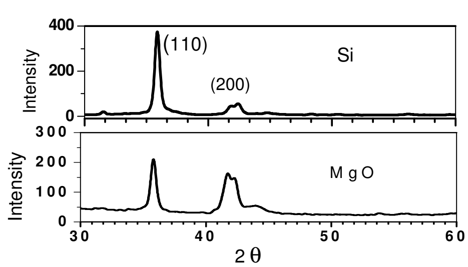

Figure 2. X-Ray Diffraction , (hkl) indices belong to $SmCo_5$ phase

In our case we have seen that annealing the multilayers, deposited on both MgO and silicon substrate, at optimum temperature of 550 °C results in textured oriented crystalline growth of $SmCo_5$ hard layer. In case of silicon substrate, it is predominantly in (110) direction whereas in case of MgO growth in both (110) and (200) direction are seen. In both cases estimated grain sizes are comparable. Corresponding hysteresis plots also show same coercive field though energy product may be less for silicon.

Thus, in conclusion we feel that silicon substrates could also be used to achieve good texture growth and hence reasonably high energy product. It being cheaper will be economically more suitable for any possible large scale device application.

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