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RELATIONSHIP BETWEEN STATIC AND DYNAMIC MAGNETORESISTANCE BEHAVIOR OF METALLIC ARTIFICIAL SUPERLATTICES

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Abstract- By using the ac field source which can change the applied field magnitude, frequency and dc offset field, the dynamic magnetoresistance characteristics of permalloy based multilayers which have different R-H(resistance-magnetic field) curves were monitored and compared with static magnetoresistance curves that were measured with electromagnet of VSM. Output of each sample according to the external field strength was identified and optimum bias position could be obtained.

I. INTRODUCTION

Generally, the former reports of R-H curve have been obtained using the electromagnet of VSM or Helmholtz coil which supply homogeneous and slowly changing field(we call it static magnetoresistance in this paper)[1-3]. When the GMR(giant magnetoresistance) materials are used for read head or field and position detection sensor, they are located at the inhomogeneous field varied with time. In this work, the responses of permalloy based patterned samples were measured using the ac field source(we call it dynamic magnetoresistance in this paper) and compared with the static R-H curves for the fundamental study of applying the GMR materials to devices.

II. EXPERIMENTAL PROCEDURE

Three kinds of multilayers as listed in Table 1 were fabricated using the 3-gun magnetron sputtering system. Each sample was patterned into 2mmx100μm by photolithography and four point aluminum electrodes were defined. Using the electromagnet of VSM, the static magnetoresistance was measured. VCR head and function generator were used to produce the ac field as shown in Fig. 1. The frequency, field amplitude and dc offset field were changed. Positioning of the sample was controlled by xyz stage. All the measurements were done at room temperature.

III. RESULTS AND DISCUSSION

The R-H curves and differentiated magnetoresistance curves with respect to the field of three samples (a, b and c) are shown in Fig.2. Generally, slope from the minimum resistance to the maximum resistance value is steeper than the slope from maximum resistance to minimum resistance. And the field that shows maximum resistance value is different because of hysteresis. The resistance of sample (a) gradually varied in the wide field range and the resistance of sample (b) and sample (c) changed rapidly small field range. The resistance of sample (c) which has small number of bilayers change step-wisely. Thus, there are many peaks in MR change rate curve.

Table 1. Three kinds of multilayers used in this study

	Sample designation
sample (a)	$[Cu(20\ Å)/NiFeCo(40\ Å)]_{20}$ Cu(200 Å)/Si(100)
sample (b)	$[Cu(20\ Å)/NiFe(50\ Å)]_{10}$ Cu(50 Å)/Si(111)
sample (c)	$[Cu(20\ Å)/NiFe(20\ Å)]_{5}$ Cu(50 Å)/Si(111)

The output changes of each MR film according to the relative change of applied magnetic field were shown in Fig. 3. We could not measure the field from VCR head gap exactly but could obtain the relative change of MR output by changing the input voltage to the VCR head. The dimension of each sample was same and each sample was located at the same position with respect to the VCR head. Thus, we speculate that the effective applied magnetic field to the each sample was same. When the applied magnetic field increased, the output signal changed following minor loop in static MR curve. The output of sample (a) increases most rapidly in the ±20 Oe ~ ±40 Oe field range which is correspondent to the maximum MR change region. When the applied magnetic field was over ± 50 Oe, output

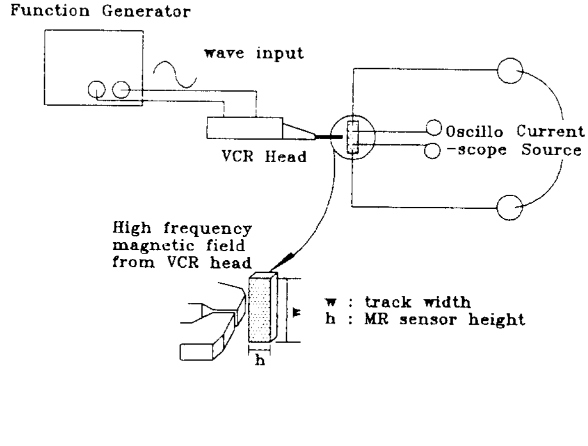
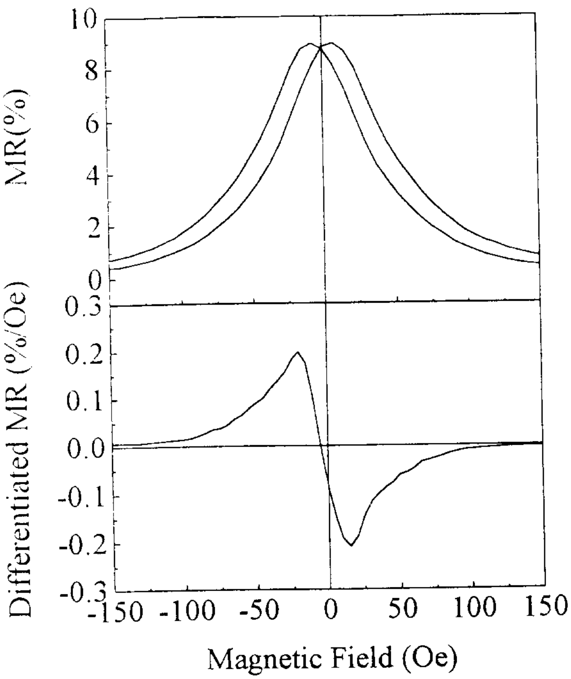
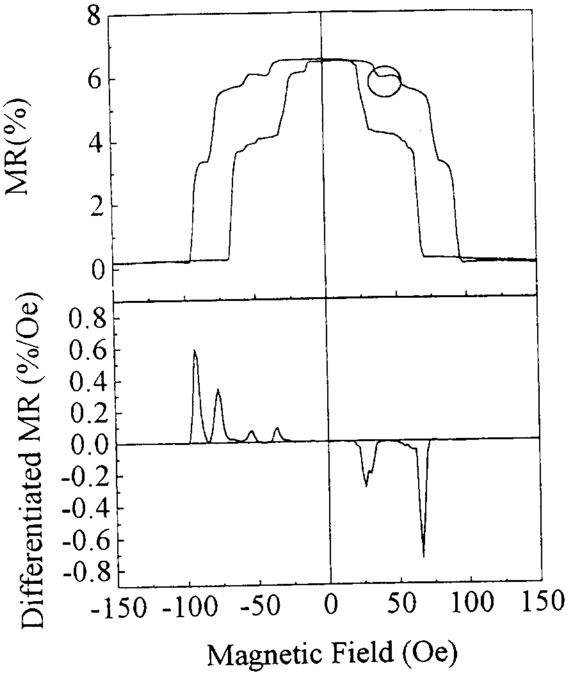


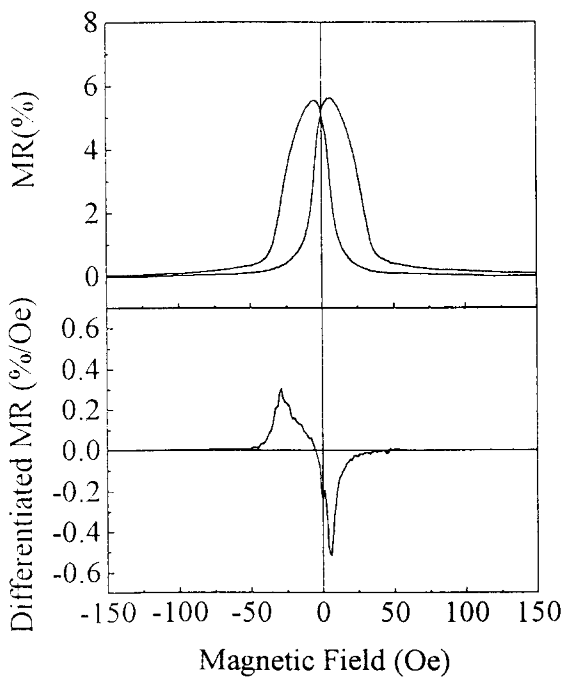
Fig. 1. Schematic illustration of ac field source used in this work



(a)



(c)



(b)

Fig. 2. MR responses and their differentiated curves with respect to the field. (a) sample (a), (b) sample (b), (c) sample (c).

increased gradually and the film was not fully saturated maximum applied field. The output of sample (b) also increased rapidly in ± 20 Oe ~ ± 40 Oe field range and when the applied field was over 60 Oe, the output was almost saturated. Though the MR values of sample (a) and (b) are different, the total thickness of sample (b) is smaller than that of sample (a) and the resistance of sample (b) is higher than that of sample (a). Thus, when the same current was applied, the outputs of sample (a) and (b) were almost same though they have different MR value. When the noise and output level are considered, the optimization of number of bilayers and total thickness of GMR film is needed to apply these multilayers to actual devices. The sample (c) did not show any output up to about ± 30 Oe applied field because sample (c) has relatively long and flat maximum resistance region and up to this field level, the field that was applied to the sample was smaller than the field needed to show output. When the applied magnetic field was over the flat region, output increased much more rapidly than the sample (a) or (b) because sample (c) has high resistance and MR change rate.

We could obtain the output signal change under biased state by changing the dc offset voltage as shown in Fig. 4.

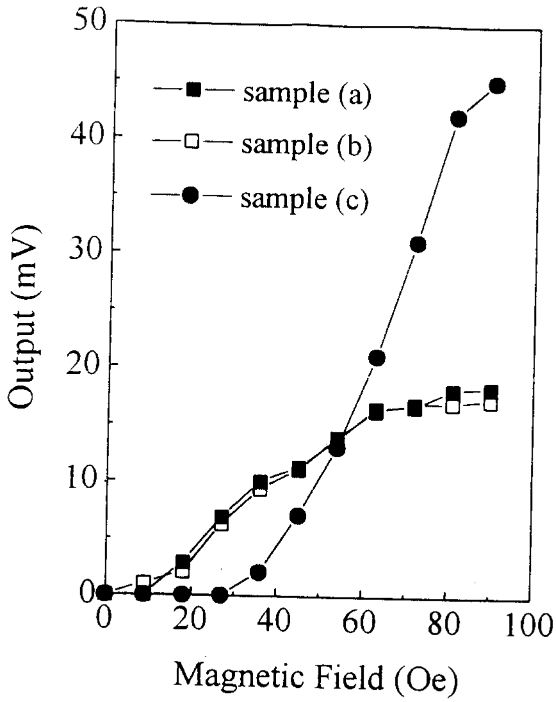


Fig. 3. Dynamic MR output changes according to the external field magnitude

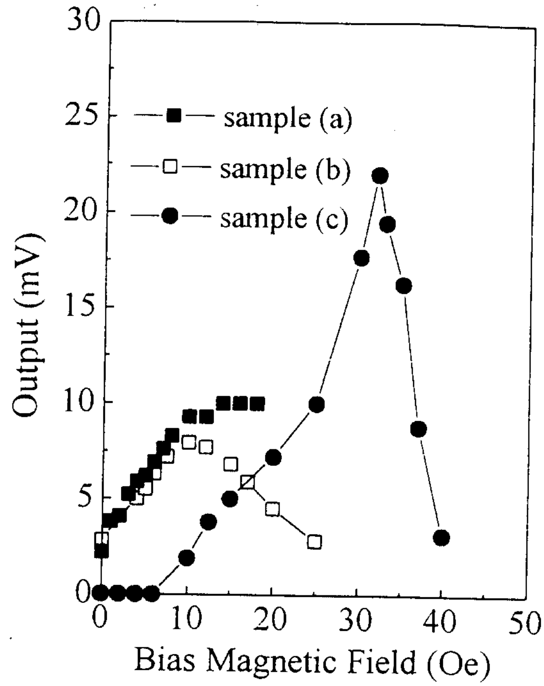


Fig. 4. Dynamic MR output changes with respect to the bias field. Bias field was applied by applying dc offset voltage to the sine wave.

Bias field was calculated using the measured magnetic field in Fig. 2. The range of applied field without bias field was ± 20 Oe. In the case of sample (a) or (b), the maximum output was obtained under 10 Oe bias field. Almost same output was maintained when the bias field was over 10 Oe in case of sample (a) because sample (a) has relatively long range of gradual change of resistance. However, the output of sample (b) was reduced when the bias field was over 10 Oe because over this bias field, one tail of output was in the saturated region and the field range was out of maximum resistance change region. In case of the sample (c), the bias field was critical to change the output voltage. Because of the flat maximum resistance region, the out was almost zero with the bias field under 10 Oe. Over this field, the output increas -ed abruptly for its relatively high MR change rate. However, when the bias field was over 30 Oe, the output was decreased rapidly. Because over 30 Oe bias field the operating point is located in the circular region in Fig. 2 (c). When the operating point is located at the indicated region in Fig. 2 (c), the applied field was not effective to use the MR change rate. This is mainly due to the step wise change of MR. Thus, the output of the sample (c) was more dependent on the change of operating point than the sample (a) or (b) when it is used sensor.

IV. CONCLUSION

Using ac field source, the dynamic characteristics of GMR materials were measured. In order to use GMR multilayers to devices, the number of bilayers and total thickness of sample must be optimized to obtain the proper output level. By applying dc offset voltage to the main sine wave in generating the ac field source, the response of biased state could be monitored and was well correspondent to the static R-H curve.

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