

Anisotropic magnetoresistive study in bilayer NiFe-NiO for sensor applications

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Abstract. Related with the detection of weak magnetic fields, the anisotropic magnetoresistive (AMR) effect is widely utilized in sensor applications. Exchange coupling between an antiferromagnet (AF) and the ferromagnet (FM) has been known as a significant parameter in the field sensitivity of magnetoresistance because of pinning effects on magnetic domain in FM layer by the bias field in AF. In this work we have studied the thermal evolution of the magnetization reversal processes in nanocrystalline exchange biased Ni₈₀Fe₂₀/Ni-O bilayers with large training effects and we report the anisotropic magnetoresistance ratio arising from field orientation in the bilayer.

Introduction

Related with the detection of weak magnetic fields, the anisotropic magnetoresistive (AMR) effect is widely utilized in sensor applications. Various sensor designs and electronic evaluation circuits have been developed to overcome temperature dependence, offset, and hysteresis [1, 2].

Exchange coupling between an antiferromagnet (AF) and the ferromagnet (FM) has been known as a significant parameter in the field sensitivity of magnetoresistance because of pinning effects on magnetic domain in FM layer by the bias field in AF [3].

The AF NiO film has received some attention in giant and anisotropic magnetoresistance (GMR, AMR) because of their structural stability [4]. Much effort has been made on the exchange biasing field in NiFe/NiO system, relating to the influencing parameters involved during fabrication process such as structure, annealing and surface roughness by measuring M-H loop and MR profile under the magnetization in easy- and hard-axis direction.

In this work we have studied the thermal evolution of the magnetization reversal processes in nanocrystalline exchange biased Ni₈₀Fe₂₀/Ni-O bilayers with large training effects and we report the anisotropic magnetoresistance ratio arising from field orientation in the bilayer [5].

Experimental and results

Ni₈₀Fe₂₀ (20 nm)/Ni-O (20 nm) bilayers were deposited by RF sputtering technique onto glass substrates kept at room temperature in Ar atmosphere. TEM structural characterization revealed typical grain sizes of around 4 nm for Ni-O layers and 14 nm for Ni₈₀Fe₂₀ grains.

Figure 1 shows hysteresis loop measured at 400 K.; both exhibiting the typical displacement towards negative fields. This hysteresis loop does not present displacement and the value of the coercive field is 7 Oe. This shows that there is exchange coupling at this temperature between the oxide and Permalloy.

After heating the sample at 450 K we proceeded to cooling with a magnetic field applied of 900 Oe. The cycle Hysteresis measured at 50 K has a value of the coercivity field, H_c, 63 Oe and a value of the displacement field, H_e, -48 Oe, as shown in Figure 2.

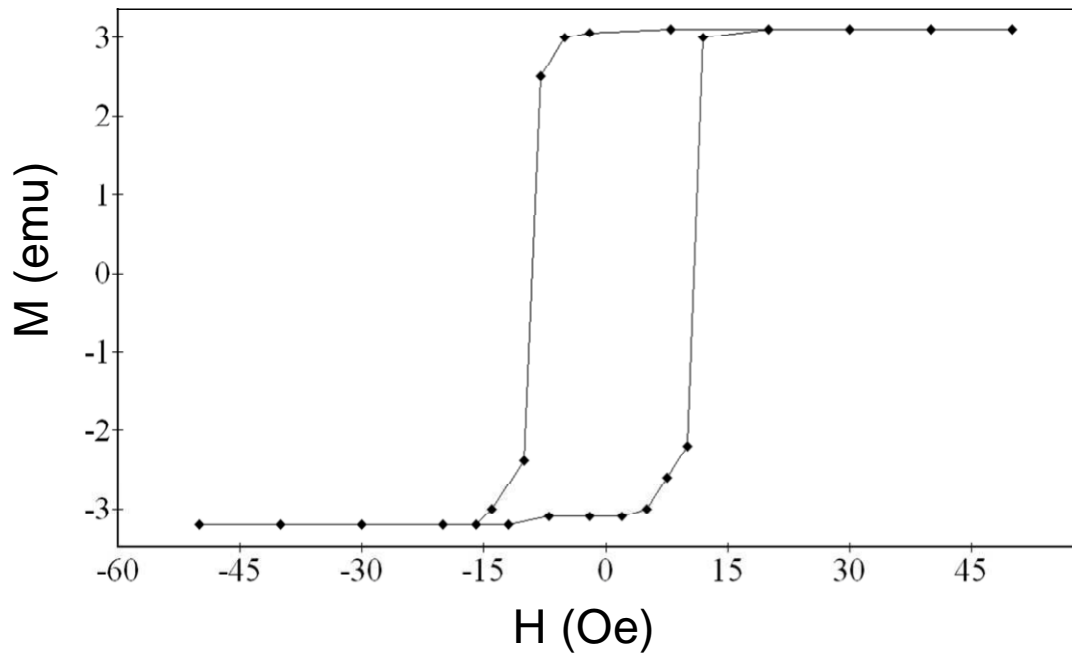


Fig. 1. Hysteresis loop measured at a temperature of 400 K.

Hysteresis loops were measured at different temperatures, occurring two temperature ranges in which the behaviour becomes different H_c field. Between 50 K and 300 K the displacement that presented is the usual, ie, negative and its value decreases progressively with temperature increase. The coercive field also decreases with temperature. However, above 300 K there is a change of sign in displacement of the hysteresis loop, which is positive throughout the range. The value H_c maximum is reached at 350 K, temperature from which H_c starts decrease until it becomes zero at 400 K. All these results can be seen by the values of H_E and H_c shown in Figure 3 and Figure 4.

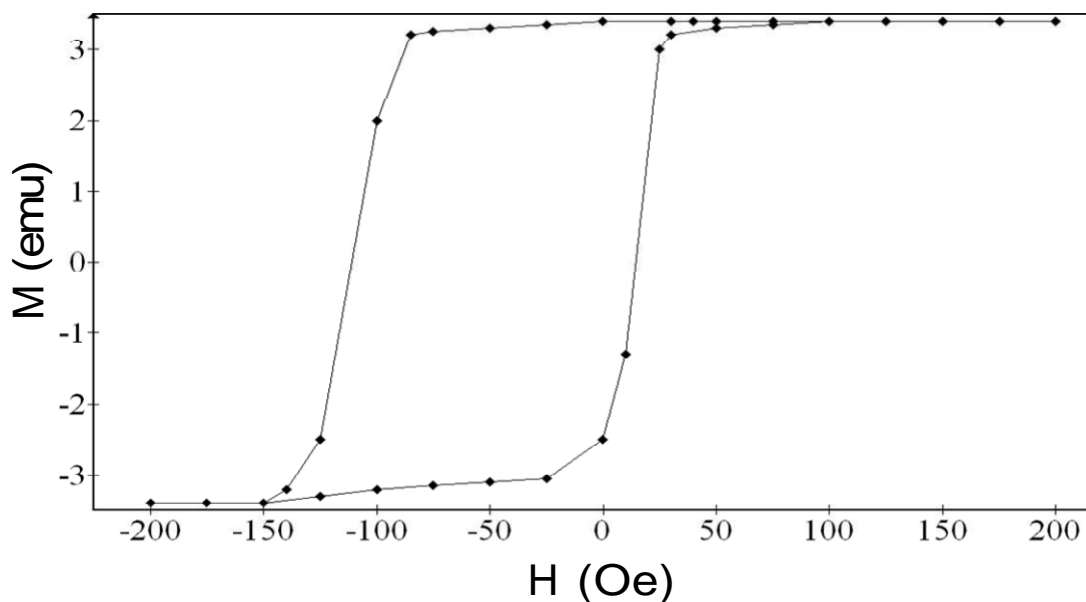


Fig. 2. Hysteresis loop measured at a temperature of 50 K.

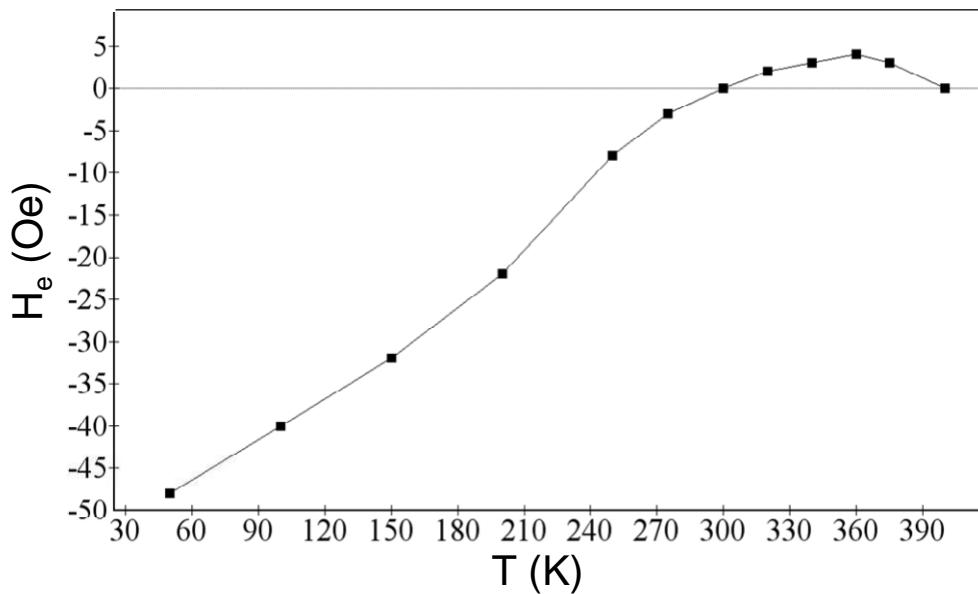


Fig.3. Thermal evolution of the exchange field of the sample after cooling with a magnetic field applied of 900 Oe.

The magnetoresistance (MR) ratio, $\Delta R/R_s$ was measured by the four-probe method as a function of magnetizing angle, θ from the bias field, where the MR was measured at perpendicular direction to the bias field. The external magnetic field of 90 Oe was applied by a planar solenoid, of which positive direction was the same as that of the bias field.

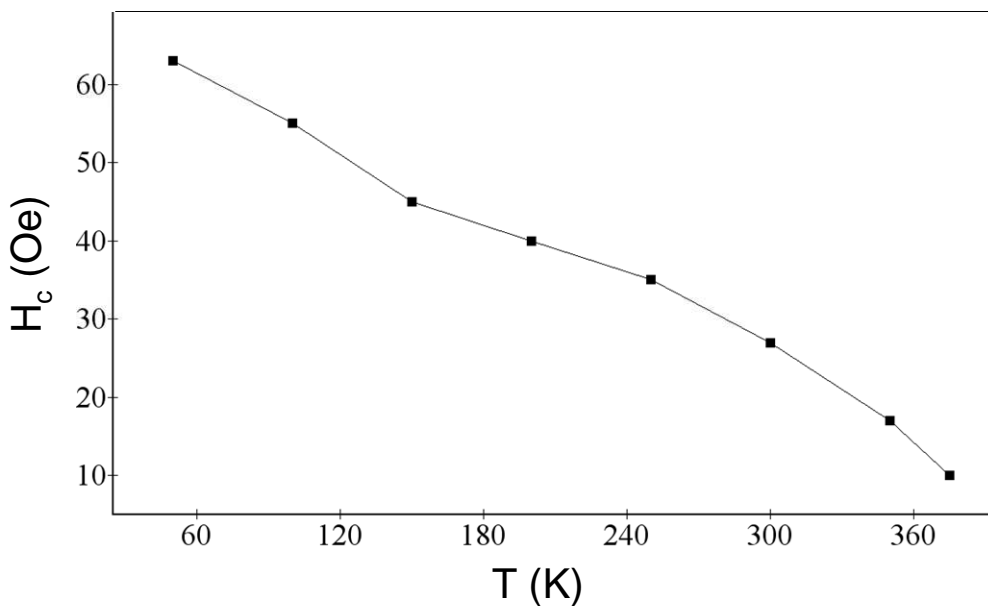


Fig.4. Thermal evolution of the coercive field of the sample after cooling with a magnetic field applied of 900 Oe.

The measurement of the AMR was made on the sample polarized initial easy axis, which is also the current direction. Magnetoresistance curves were measured with a maximum applied field of ± 90 Oe depending on the angle with the easy axis. Then we have obtained that the maximum of this variation occurs in the direction $90^\circ - 270^\circ$ where that value is around 1%. The minimum value, approximately 0.3%, occurs in the easy axis.

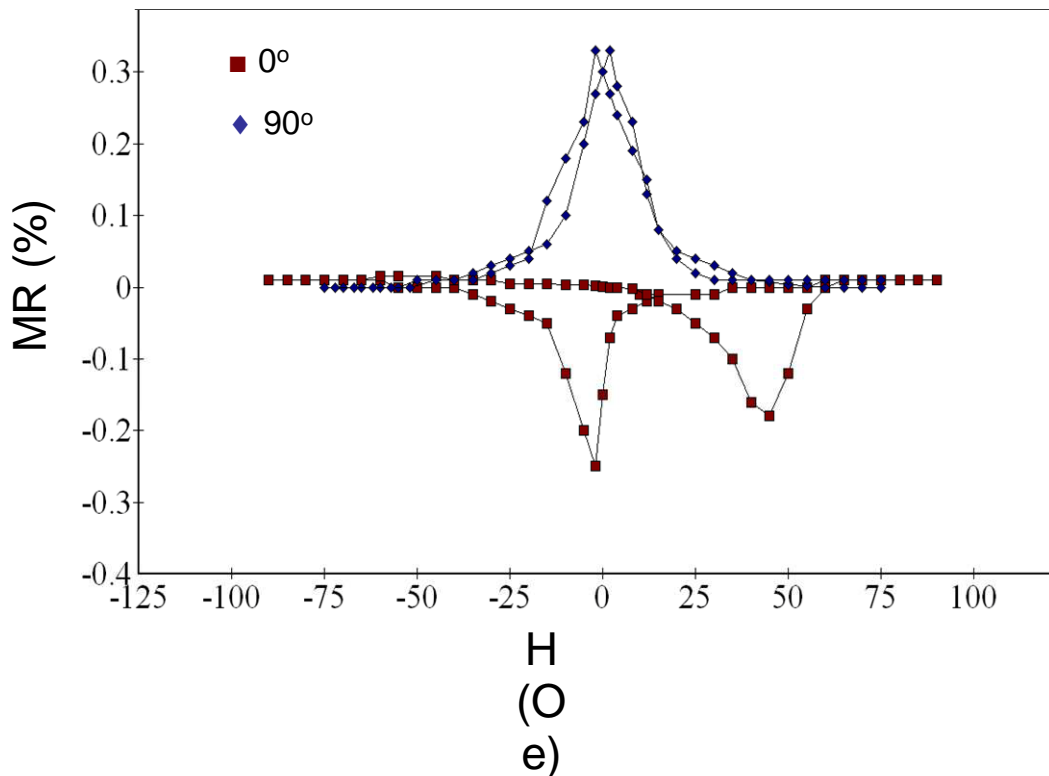


Fig.5. Magnetoresistance measured with and without exchange field.

Summary and conclusions

In summary, Ni₈₀Fe₂₀ (20 nm)/Ni-O (20 nm) bilayers were deposited by RF sputtering technique onto glass substrates kept at room temperature in Ar atmosphere. TEM structural characterization revealed typical grain sizes of around 4 nm for Ni-O layers and 14 nm for Ni₈₀Fe₂₀ grains. The magnetoresistance (MR) ratio, $\Delta R/R_s$ was measured by the four-probe method as a function of magnetizing angle, θ from the bias field, where the MR was measured at perpendicular direction to the bias field. The external magnetic field of 90 Oe was applied by a planar solenoid, of which positive direction was the same as that of the bias field. Then we have obtained that the maximum of the magnetoresistance variation occurs in the direction 90° - 270° were that value is around 1%. The minimum value, approximately 0.3%, occurs in the easy axis.

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