Magnetoresistance of Bloch-Wall-Type Magnetic Structures Induced in NiFe/CoSm Exchange-Spring Bilayers

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The magnetoresistance (MR) originating from a magnetic structure with gradually rotating magnetic moments was studied using soft-magnetic (NiFe)/hard-magnetic (CoSm) bilayers. The main feature of the MR curves was explained as anisotropic magnetoresistance (AMR) effect. It was found that a giant-magnetoresistance-(GMR)-type effect coexisted, although the effect was very small in comparison with the AMR effect.

Keywords: exchange-spring multilayers/ Bloch wall/ anisotropic magnetoresistance/ giant magnetoresistance

It has been known that magnetic domain walls contribute to the electric resistance in ferromagnetic metals. The mechanism is, however, not well-elucidated yet. In order to get information about the domain wall resistance, we have investigated the magnetoresistance due to a magnetic structure with gradually rotating magnetic moments, like a Bloch wall. Such magnetic structures can be realized in "exchange-spring" bilayers, which consist of soft magnetic and hard magnetic layers with a magnetic coupling at the interface [1]. When an inverse magnetic field is applied to the saturated state, the magnetic moments in the soft magnetic layer start to rotate reversibly at a certain magnetic field (H_b), showing a magnetic structure with gradually rotating magnetic moments (Figure 1). The rotation angles can be controlled by increasing the external magnetic field, until an irreversible magnetization process due to domain wall dis-

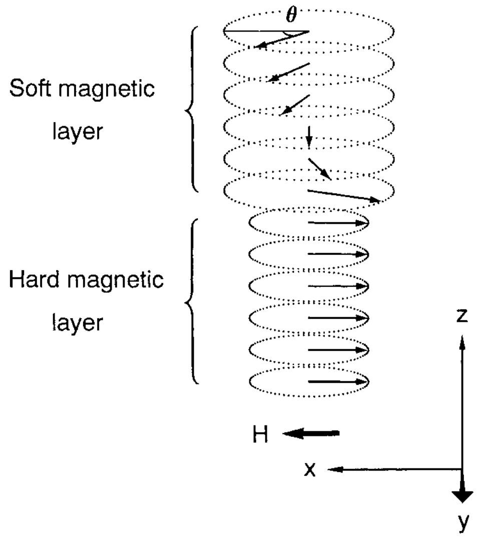

Figure 1. Illustration of an exchange-spring state in a soft-magnetic/hard-magnetic bilayer.

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Scope of research

By using vacuum deposition method, artificial multilayers have been prepared by combining various metallic elements. The recent major subject is an interplay of magnetism and electric transport phenomena such as the giant magnetoresistance effect. Fundamental magnetic properties of metallic multilayers have been studied by various techniques including Mössbauer spectroscopy using Fe-57, Sn-119, Eu-151 and Au-197 as microprobes, and neutron diffraction. Preparation of microstructured films is attempted and novel magnetic and transport properties are investigated.

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placement in the CoSm layer occurs at H_c. The magnetization curve reflects the magnetization process as shown for a NiFe(300Å)/CoSm(1000Å) bilayer in Figure 2. The magnetization process between H_b and H_c is completely reversible. The direction of the magnetic moments at each magnetic field during this reversible process is calculated from the condition that gives the minimum in the total magnetization energy. The reversible magnetization curve is also reproduced using the directions calculated for each magnetic field [1].

Magnetoresistance was measured with a magnetic field parallel to the axis of easy magnetization (the *x* direction) and with electric currents parallel (ρ_{xx}) and perpendicular (ρ_{yy}) to the magnetic field. The magnetoresistance in these configurations corresponds to the magnetoresistance due to electric currents along a Bloch wall. In NiFe/CoSm bilayers, the resistivity of the CoSm layer is about 100 times larger than that of the NiFe layer. Therefore, when the magnetoresistance is measured in current-in-plane geometries, the electric current mostly flows in the NiFe layer.

The magnetoresistance curves of the NiFe(300Å)/CoSm(1000Å) bilayer in the two geometries, ρ_{xx} and ρ_{yy}, at 5.0 K are shown in Figure 3 (a). A reversible change is observed in the magnetic field range where the reversible magnetization process takes place. The observed magnetoresistance shows a characteristic shape; the resistance changes drastically right above H_b, has an extremum, then recovers gradually. The curves measured in the two geometries appear to be a mirror image of each other relative to the average value. This fact implies that the effect is mainly due to anisotropic magnetoresistance (AMR), i.e. magnetoresistance dependent on the angle between the magnetization and the electric current. In the present system, each atomic layer has different direction of magnetic moment relative to the direction of electric current. If the phenomenological equation for AMR, which is valid for uniformly magnetized films, is applied to such a system, the local resistivity is distributed as a function of the depth from the interface. The AMR of the NiFe layer as a whole is estimated from the parallel circuit of the distributed local resistivity. The calculated resistivity reproduces the feature of the reversible parts in Figure 3 (a) well [1].

If the magnetoresistance due to the electric current flowing in a twisted magnetic structure is only from the AMR effect, the average of ρ_{xx} and ρ_{yy} should be almost constant, independent of the rotation angles. The experimental average (ρ_{av}) of ρ_{xx} and ρ_{yy} for NiFe(300Å)/CoSm(1000Å) shows a small positive effect as shown in Figure 3 (b). The result indicates that a positive magnetoresistance effect that cannot be explained with the

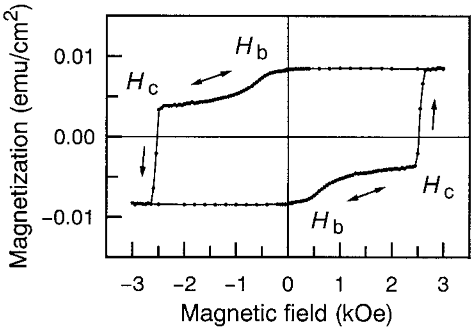

Figure 2. Magnetization curve of NiFe(300Å)/CoSm(1000Å) at 5.0 K.

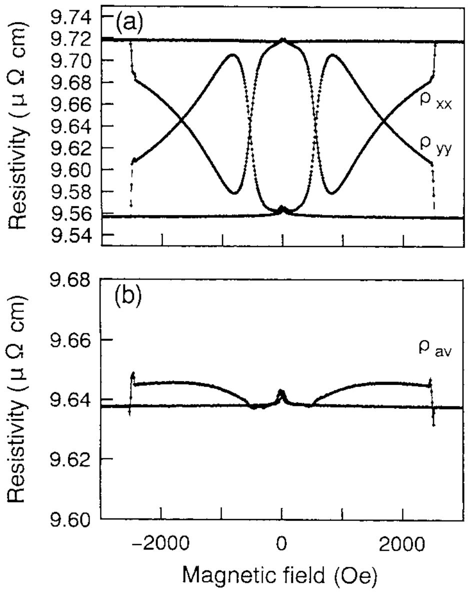

Figure 3. Magnetoresistance curves of NiFe(300Å)/CoSm(1000Å) at 5.0 K: (a) ρ_{xx} and ρ_{yy}, and (b) ρ_{av}.

AMR effect exists in ρ_{xx} and ρ_{yy}. The average resistance ρ_{av} increases as the relative angle between the magnetic moments in the NiFe layer increases. Therefore, the effect is thought to be due to a giant-magnetoresistance-(GMR)-type effect, i.e. magnetoresistance dependent on the relative configuration of magnetic moments [2].

In this way, magnetoresistance when an electric current flows in a twisted magnetic structure was studied using NiFe/CoSm exchange-spring bilayers. It was found that a GMR-type effect of less than 0.1 % coexists with an AMR-type effect of several %.

REFERENCES

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