Title	Magnetization reversal in submicron magnetic wire studied by using giant magnetoresistance effect (SOLID STATE CHEMISTRY-Artificial Lattice Alloys)
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Magnetization reversal in submicron magnetic wire studied by using giant magnetoresistance effect

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The magnetization reversal phenomenon in a submicron magnetic wire with a trilayer structure consisting of NiFe(20nm)/Cu(10nm)/NiFe(5nm) was investigated by measuring the electric resistance in an external magnetic field. A giant magnetoresistance (GMR) effect of about 0.8 % was observed when the magnetizations in two NiFe layers are oriented antiparallel. It is demonstrated that magnetization reversal phenomena can be very sensitively investigated by utilizing the GMR effect.

Keywords: magnetization reversal/ submicron magnetic wire/ magnetic domain wall/ giant magnetoresistance

In very narrow ferromagnetic wires, due to the magnetic shape anisotropy, the magnetization is restricted to be directed either parallel or antiparallel to the wire axis. Normally, it is considered that magnetization reversal takes place by nucleation and propagation of a magnetic domain wall which lies in a plane perpendicular to the wire axis. The process of magnetization reversal attracts interests especially at low temperatures where a quantum tunneling process may be dominant. The magnetization measurement of magnetic wires, however, is difficult in general because the volume is very small.

We present magnetoresistance measurements of a single submicron magnetic wire based on a non-coupled type GMR effect. The GMR is the electrical resistance change caused by the change of the magnetic structure in multilaryers. This means, in turn, the magnetic structure of the system can be detected by resistivity measurements. Especially in the wire case, where the direction of the magnetization is restricted to be parallel or antiparallel along the wire axis, the GMR change is directly proportional to the magnitude of the switching layer magnetization. Here, we applied this method to a single NiFe(20nm)/Cu(10nm)/NiFe(5nm) trilayer wire. In magnetoresistance measurements the magnetic field was applied along the axis of the wires. The resistivity was determined using a four-point DC technique. As seen in

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Scope of research

By using vaccum deposition method, artificial multiilayers 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 diffration. Preparation of microstructured films is attempted and novel magnetic and transport properties are investigted.

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Figure 1, the samples have four current-voltage terminals, where the voltage is probed over a distance of 20 μm. Furthermore, the samples have an artificial neck (0.35 μm width) introduced at 1/3 distance from one voltage probe in order to control the magnetic domain wall propagation.

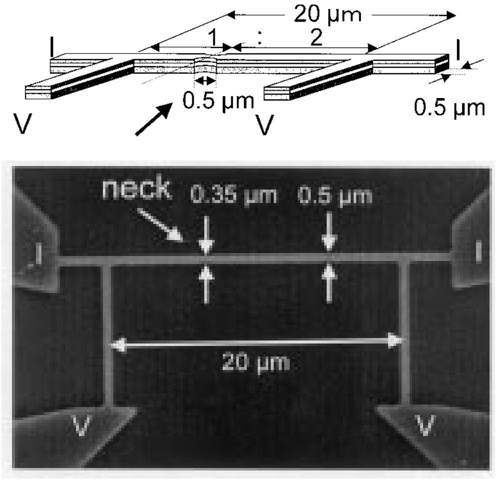

Figure 1. Schematic illustration and SEM image of the sample.

Figure 2 shows the resistance of our trilayer system as a function of the applied external field at 300 K. Prior to the measurement, a magnetic field of 100 Oe was applied in order to achieve magnetization alignment in one direction. Then the resistance was measured in steps of 1 Oe as the field was swept towards the counter direction. The result of our magnetoresistance measurement essentially displays four very sharp leaps. The first and second leap correspond to the magnetization reversal of the thin NiFe layer whereas the third and fourth leap correspond to the magnetization reversal of the thick NiFe layer. There is clear evidence resulting from a preliminary study on NiFe wire arrays deposited onto V-groove substrates that for the thickness range to be considered, the thicker NiFe layer has a larger coercive force than the thinner one. Here we discuss how the magnetization reversal takes place in the sample. As long as the counterfield is smaller than a critical field, the magnetizations of both thin and thick NiFe layers align parallel and the resistance shows the lowest value. As the applied magnetic field exceeds 5 Oe, the resistance abruptly jumps and is kept constant value up to 10 Oe. Then, exceeding 10 Oe, the resistance abruptly jumps again and maintains the largest value up to 22 Oe. The result indicates that the antiparallel magnetization alignment is realized at an external field between 11 and 22 Oe, where the resistance shows the largest value. The ratio of the resistance changes at the first and second leap is 1:2. This means that one third of the total magnetization of the thin NiFe layer changes its direction at the first leap in Fig. 2, since the GMR change is directly proportional to the switching layer magnetization. The ratio of one third corresponds to the ratio of length between the left voltage probe and the neck to the overall length of the wire between the voltage probes. Therfore, in this case, a magnetic domain wall nucleates in the shorter part of the wire and propagates to the neck, where it is pinned up to 10 Oe. The second leap when exceeding 10 Oe corresponds either to depinning of the magnetic domain wall from the neck or to nucleation and propagation of another magnetic domain wall on the other side of the neck. These two possibilities cannot be distinguished from the result shown in Fig. 2. The magnetization reversal of the thick NiFe layer takes place in the same manner as in the thin NiFe layer described above.

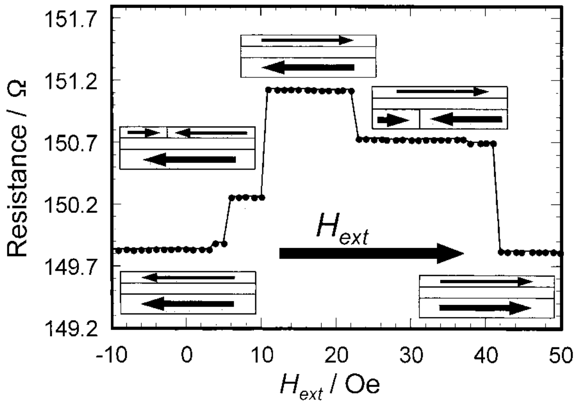

Figure 2. Resistance as a functon of the external field at 300 K.

So far, we reported on magnetoresistance measurements of submicron magnetic wire based on GMR effect and found that magnetic domain wall propagation is controlled by the neck artificially introduced into the wire. It should be noted that the method reported here corresponds to a very high sensitive magnetization measurement. For the sample reported above, the sensitivity is as high as 10^{-13} emu (10^{7} spins). The method, in principle, can be applied to smaller samples as far as the resistance of the samples can be measured and the relative sensitivity increases with decreasing sample volume.

REFERENCES

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