Magnetoresistance of Multilayers on Microstructured Substrates

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A new class of multilayers is fabricated on microstructured substrates. The GMR effect in a new geometry, (CAP, with current at an angle to the plane) was studied using multilayers prepared on micron-scale V-shaped groove structures. The measured CAP-MR is greater than the CIP-MR.

Keywords: Giant magnetoresistance / CPP-MR / Metallic multilayer / Microstructured substrate

Thin films are usually prepared on substrates with flat surfaces. Generally speaking, the sample quality can be high only if the surface is flat enough. On the other hand, a method to prepare thin films with new types of structural modifications is to use substrates with microstructured surfaces [1]. Multilayers deposited on microfabricated substrates may exhibit novel physical properties.

Since the discovery of giant magnetoresistance (GMR) in Fe/Cr multilayers, the interplay of magnetism and transport properties has attracted great attention [2]. The usual geometry of MR measurements for magnetic thin films and multilayers is with a current in the plane, which is abbreviated as CIP. In contrast, MR measurements with current perpendicular to the plane are called CPP. Generally, the MR ratio is expected to be larger in CPP geometry than in CIP, because conduction electrons meet more boundaries between magnetic and non-magnetic layers within their mean free paths. However, due to experimental difficulties, there are only a few reports on CPP-MR studies [3-5].

The microfabrication technique for preparing a V-groove structure on a (100) Si surface using the anisotropic etching method has been well established [6]. A (100) oriented Si wafer, covered with a 1500 Å SiO_2 layer, was masked by photoresist and then a stripe pattern, 0.1 μm width and 1 μm separation, was printed by using electron beam lithography. By wet etching with KOH solution, V-shaped grooves were formed due to the different etching rates of (100) and (111) planes. Finally grooves are formed by the stable (111) planes and therefore the apex is the intersection of (111) planes, having the angle of 54.7°. The formation of microgrooves was confirmed by SEM.

On the V-groove microstructured substrates, a non-coupled type Co/Cu/NiFe/Cu multilayer was deposited. Due to the difference of coercive forces, the magnetizations of two components, Co and NiFe, are oriented antiparallel in the process of field sweeping and then the resistivity is greatly enhanced. As was

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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 the giant magnetoresistance (MR) in magnetic / non-magnetic multilayers. Non-coupled type MR multilayers including two magnetic components are found to have high sensitivities in low fields. Fundamental magnetic properties of large MR multilayers have been studied by applying Mösbauer spectroscopy, using Fe-57, Sn-119, Eu-151 and Au-197 as microprobes and by neutron diffraction. Novel magnetic and MR properties of multilayers prepared on microstructured substrate have been investigated

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reported already, such non-coupled multilayers have several definite merits for the study of GMR. A fairly large MR change can be induced by a small magnetic field, which is advantageous also for technical applications. Moreover, antiparallel magnetic alignment is realized at any spacer thickness as far as the interlayer coupling is negligible and therefore the spacer layer thickness dependence of MR is easily studied.

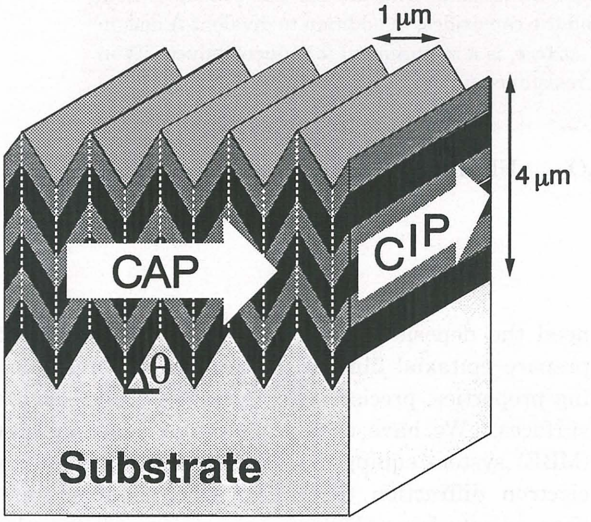

Figure 1. Schematic illustration of a multilayer prepared on a microstructured substarate. Current direction is indicated by arrow.

By depositing in the normal direction to the original (100) plane, multilayers with the structure as Figure 1 were prepared. The total thickness of deposited multilayers was 4 μm. When the width of groove is 1 μm, the height of groove should be 0.7 μm, which is much smaller than the total multilayer thickness. Therefore, in the argument of transport phenomena, wrinkled parts of multilayers with triangular shape may be essentially neglected. If we measure the resistance with current perpendicular to the grooves in the plane of original (100) Si, the average current direction has an angle of 54.7° to the multilayer planes, and MR in a geometry with an angle to the plane (CAP) is studied. On the other hand, we can measure CIP-MR with the current parallel to the grooves. Figure 2 shows the results of magnetoresistance measurements at room temperature for the sample [Co(12Å)/Cu(116Å)/NiFe(12Å)/Cu(116Å)]$_{167}$. The result with the current parallel to the grooves and with the current perpendicular to the grooves is indicated by squares and circles, respectively. Magnetic field was applied parallel to the grooves in multilayer plane. The measured CAP-MR was greater than the CIP-MR. Moreover we can estimate the CPP-MR value from observed CIP-MR and CAP-MR values by using the relation between CIP, CPP and CAP geometry which has been proposed by Levy et al [7].

Microstructured substrates are also useful to fabricate microwires. By depositing magnetic substance from a tilted direction onto a surface with 0.5 μm groove, magnetic wires with 0.3 μm width were obtained. These wires were afforded an uniaxial anisotropy due to the wire shape and the magnetic domain motions were studied from resistance measurements. Magnetic behaviors of multilayer wires are under invetigation.

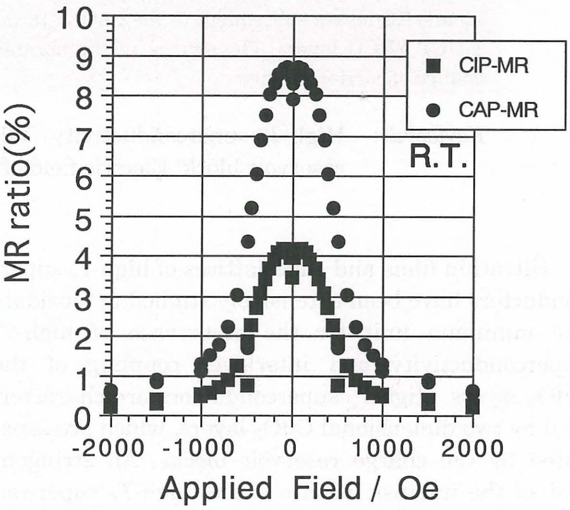

Figure 2. MR curves at R.T. with the current parallel to the grooves (square) and with the current perpendicular to the grooves (circle). Magnetic field was applied parallel to the grooves in multilayer planes.

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