MICROSTRUCTURE OF SPIN-VALVE MR SANDWICHES

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Giant magnetoresistance (GMR) effects in magnetic multilayers with spin-valve structures are under intensive investigation.[1] The GMR effects in spin-valve structures originate from the change in the orientation of magnetization in the successive ferromagnetic layers. Of the various types of spin-valve multilayered structures reported, spin-valve sandwiches, in which one of the two ferromagnetic layers separated by a nonferromagnetic metal layer is constrained through exchange coupling to an adjacent antiferromagnetic layer, are most promising for applications in read heads for high density magnetic recording. This is due to their large MR and high sensitivity in low magnetic fields.[2] Study of the correlation between magnetic/magnetotransport properties and the microstructure of spin-valve sandwiches is crucial for a better understanding of the mechanism of the spin-valve effects and for future MR heads design. Here, we present the results of transmission electron microscopy (TEM) studies of the microstructure of a $Ni_{81}Fe_{19}$(47Å)\Cu(18Å)\$Ni_{81}Fe_{19}$(53Å)\FeMn(186Å) spin-valve sandwich. The two ferromagnetic $Ni_{81}Fe_{19}$ layers are decoupled by the 18 Å thick Cu layer and the 53 Å thick $Ni_{81}Fe_{19}$ layer is exchange coupled with the antiferromagnetic FeMn layer. This spin-valve sandwich was sputter deposited onto a Si(100)\$Si_3N_4$(1000Å) substrate using a RF diode sputtering system.

Figure 1a is the bright field plan-view TEM image of the sandwich at 0° tilt. The grain size of the film estimated from this micrograph is about 100 Å. The Moiré fringes in Fig. 1a are due to the grain overlapping of the different layers. Diffraction patterns of the plan-view sandwich at 0°, 30°, and 60° tilt around an axis **OT** in the film plane are shown in Figs. 1b, 1c, and 1d. Two fcc phases, which are believed to be NiFe/Cu/NiFe and FeMn, with slightly different lattice parameters can be clearly identified.[3] Figs. 1 b-d also show that part of the grains are (111) textured with an angular distribution of about 10° and part of the grains are randomly oriented in both the NiFe/Cu/NiFe and FeMn layers. This observation agrees with the diffraction pattern taken from a cross-section sample of the sandwich (Fig. 2b) which shows that the overlapped (111) diffraction arcs of the NiFe/Cu/NiFe/FeMn layers are parallel to that of the Si (200) diffraction spot. Figure 2a is the high resolution cross-section TEM image of the sandwich. A grain with $[1\bar{1}0]$ zone axis (labeled **A** in the image) shows the $(11\bar{1})$ lattice planes are continuous through the NiFe/Cu/NiFe layers. This indicates that the Cu layer is strain matched with the NiFe layers although Cu has a larger bulk lattice parameter (a= 3.61 Å) than that of NiFe (a= 3.55 Å). This is because the thickness of the Cu layer, 18Å, is below the critical thickness where misfit dislocations can be generated. The interface between the NiFe and FeMn layers is not perfectly smooth. The role of the NiFe/FeMn interface roughness is being studied through the comparison of samples with different $\Delta R/R$ and different exchange fields.

References

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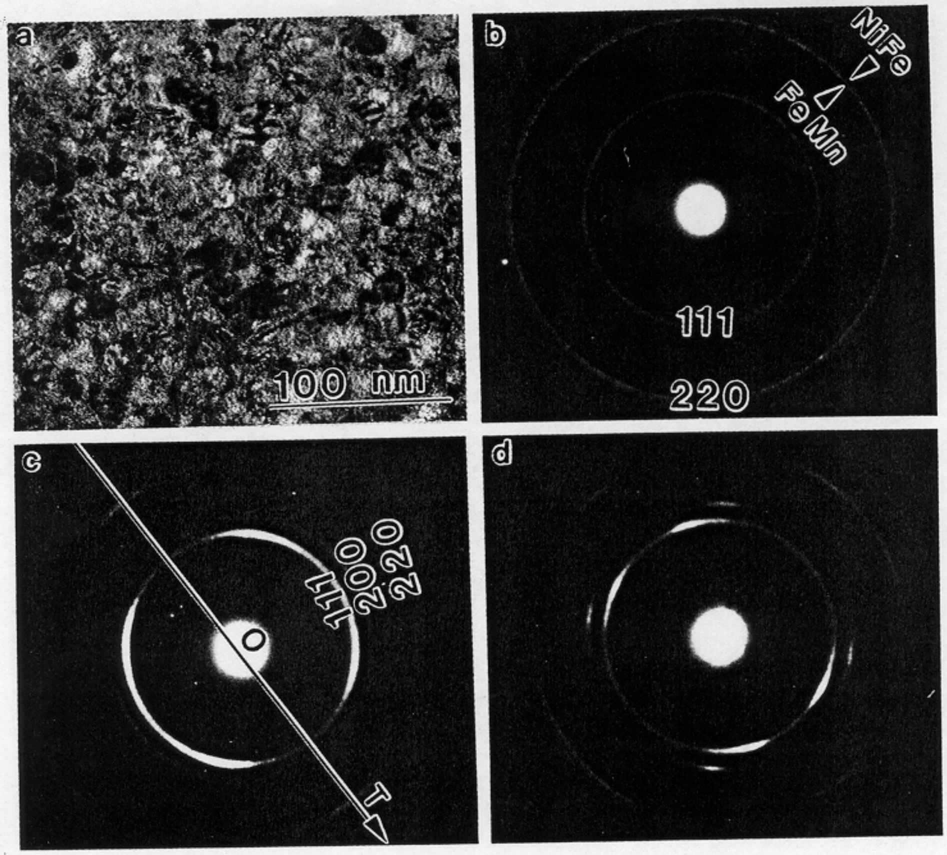

Fig. 1. Plan -view bright field image (a) and diffraction patterns at (b) 0°, (c) 30°, (d) 60° tilt of the spin-valve sandwich.

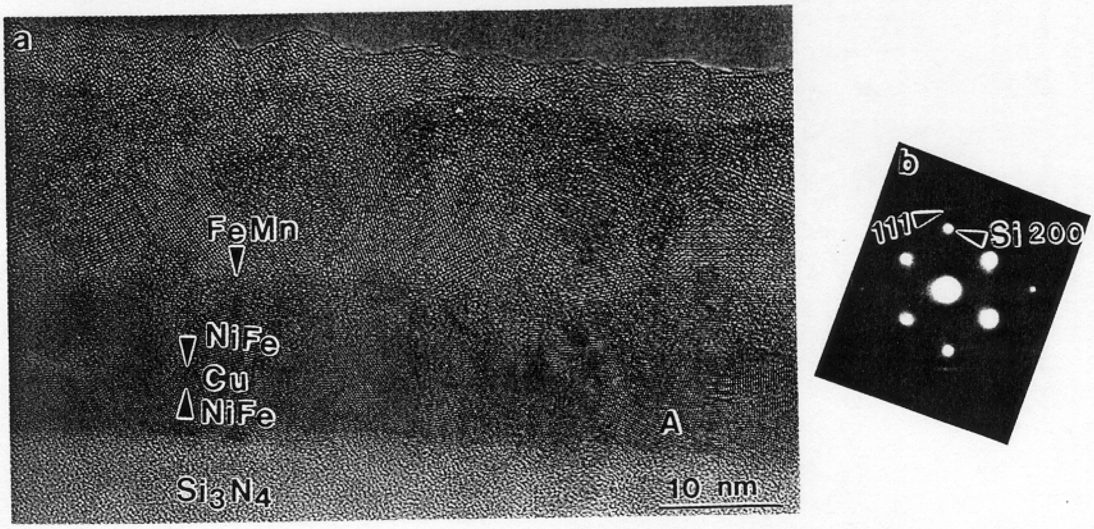

Fig. 2. Cross-section high resolution image (a) and diffraction pattern (b) of the spin-valve sandwich.