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Dependence of Magnetic Properties and Microstructure of $Ni_{81}Fe_{19}$ Film on Base Vacuum and Sputtering Pressure

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Abstract: The $Ni_{81}Fe_{19}$/ Ta films with different NiFe thickness were prepared at different base vacuums and sputtering pressures. The results of magnetic measurement and atomic force microscope (AFM) showed that the films prepared at higher base vacuum and lower sputtering pressure had larger $\Delta R/R$. The reason should be that higher base vacuum and lower sputtering pressure introduce larger grain-size and lower surface roughness, which will weaken the scattering of electrons, reduce the resistance R, and increase $\Delta R/R$.

Key words: NiFe film; anisotropic magnetoresistance; surface roughness; grain-size

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1 Introduction

Related with the detection of weak magnetic fields, the anisotropic magnetoresistance (AMR) effect is widely utilized in sensor applications [1]. NiFe is one of the most important materials used as AMR films for its desirable properties [2], such as low coercivity, low crystalline anisotropy, large magnetization and small magnetostriction. In the past years, many process factors have been reported to influence the magnetic properties and the microstructure of NiFe films. These factors include the thickness of NiFe film [3, 4], substrate temperature [4], annealing [5, 6], impurity effect [7, 8] and so on. However, little effort has been made to gain the understanding of the effect of base vacuum and sputtering pressure.

In this paper, the effect of base vacuum and sputtering pressure on the grain-size and the surface roughness of sputtered $Ni_{81}Fe_{19}$ films was reported, hence on the AMR.

2 Experimental

Two sets of $Ni_{81}Fe_{19}$(x nm) / Ta (9 nm) were prepared on glass substrates using rf (radio frequency) and dc magnetron sputtering: (I) the thickness of NiFe was 30 nm, the base vacuums were varied from 6.67×10^{-7} to 6.67×10^{-3} Pa, and the sputtering pressure was 0.27 Pa; (II)the thickness of NiFe was 100 nm, the base vacuum was 2.27×10^{-4} Pa, and the sputtering pressures were 0.27, 0.53, 0.80 and 1.07 Pa respectively. x is the thickness of $Ni_{81}Fe_{19}$ film. The sample with the base vacuum of 6.67×10^{-7} Pa was prepared by Ar+ gun and the sample table of a MICROLAB MK II X-ray photoelectron spectroscopy system. The principle is similar to magnetron sputtering. The deposition rates were roughly 0.03–0.1 nm/s. A permanent magnet which produced a magnetic field of 16 A/m along the substrate surface was present during the deposition process.

The anisotropic magnetoresistance was measured by a four-probe method in magnetic fields up to 8 A/m, where the magnetization was saturated for all the samples. The surface roughness and the grain-size were measured by a Dimension™ 3100 atomic force microscope produced by di Digital Instrument. All the measurements were completed in half an hour after the samples were taken out of the vacuum chamber.

3 Results and Discussions

3.1 Dependence of magnetic properties and microstructure on base vacuum

Figure 1 shows $\Delta R/R$ as a function of the base vacuum for samples of set I . $\Delta R/R$ of the sample prepared at 6.67×10^{-7} Pa reached 2.40%. Then $\Delta R/R$ decreased as the base vacuum fell, and reached 0.32% when the base vacuum was 6.67×10^{-3} Pa. Obviously, base vacuum influences the properties of the films dramatically. The films prepared at higher base vacuum have more superior properties.

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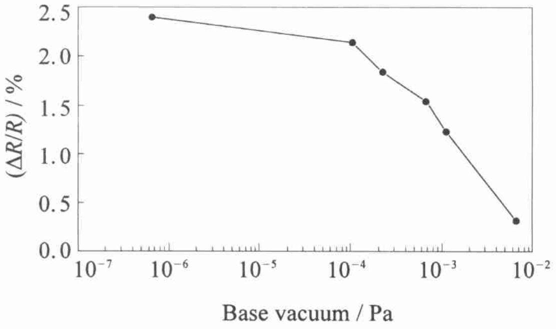

Figure 1 ΔR/R as a function of the base vacuum.

The AFM (atomic force microscope) images of samples prepared at 1.07×10^{-4} and 6.67×10^{-3} Pa were shown in **figure 2** (a) and (b). The rms (root-mean-square) roughness R_{rms} and the grain-size of the former were 0.445 nm and 104.7 nm respectively. Those of the later were 1.017 nm and 68.0 nm respectively. The results show that the surface roughness will decrease and the grain-size will increase dramatically with the base vacuum rising.

3.2 Dependence of magnetic properties and microstructure on sputtering pressure

Figure 3 shows ΔR/R as a function of the sputtering pressure for samples of set Ⅱ. ΔR/R of the samples prepared at 0.27, 0.53, 0.80 and 1.07 Pa were 2.73%, 2.00%, 1.60% and 1.25% respectively. The AMR decreased as the sputtering pressure increased.

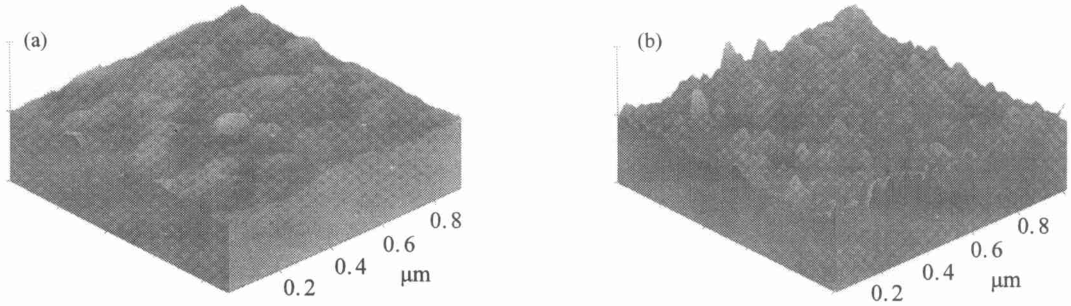

Figure 2 AFM images of the NiFe(30 nm)/Ta(9 nm) films prepared at different base vacuums, (a) 1.07×10^{-4} Pa; (b) 6.67×10^{-3} Pa.

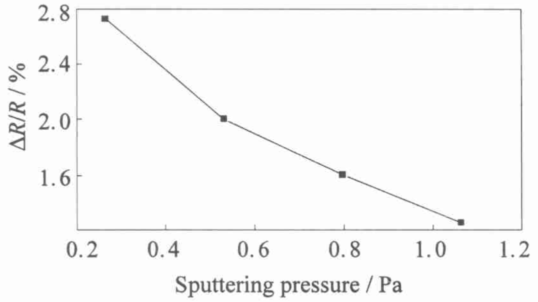

Figure 3 ΔR/R as a function of the sputtering pressure.

Figure 4 (a) and (b) show the AFM images of samples prepared at 0.27 and 1.07 Pa.The Rrms were 0.816 nm and 1.274 nm, and the grain-sizes were 115.0 nm and 80.5 nm. Higher sputtering pressure will introduce larger surface roughness and smaller grain-size.

3.3 Discussions

The above results show that the AMR of samples with larger grain-size and smaller surface roughness are better than that of samples with smaller grain-size and larger surface roughness. The reasons could be described as follows. First, the resistivity of NiFe films will decrease with increasing grain-size due to the reduction in the grain boundary scattering of conduction electrons [9]. Then ΔR/R increases due to the decrease in resistance R. Second, surface roughness can also influence the scattering of electrons. Smooth surface scatters electrons weakly. As will also decrease R and increaseΔR/R. Therefore, the samples with larger grain-size and smoother surface have larger AMR.

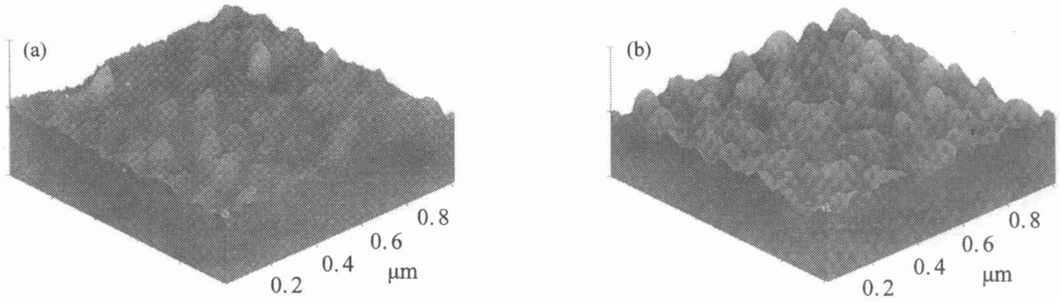

Figure 4 The AFM images of the NiFe(100 nm)/Ta(9 nm) films prepared at different sputtering pressures, (a) 0.27 Pa; (b) 1.07 Pa.

4 Conclusions

Base vacuum and sputtering pressure have great influence on the magnetic properties and the microstructure of $Ni_{81}Fe_{19}$ films. High base vacuum and low sputtering pressure are profitable to fabricate samples with higher $\Delta R/R$.

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