

Stress measurements on magnetic multilayers

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Abstract

We present stress measurements on $\text{Co}_{50}\text{Ni}_{50}/\text{Pt}$ multilayers which have been sputtered at several argon and base pressures and the stack composition of which has been changed.

1. Introduction

Magnetic multilayers should in general exhibit a perpendicular magnetic anisotropy to be suitable for MO recording. One of the origins of this perpendicular magnetic anisotropy in thin films is caused by stress and magnetostriction. This effect seems to be especially pronounced in multilayered films like $\text{Co}_{50}\text{Ni}_{50}/\text{Pt}$ multilayers [1]. Other authors have found considerable contributions of stress induced anisotropy in the order of 35% in e.g. Co/Pd [2]. Therefore it is interesting to further investigate the internal average film stress of such multilayers.

2. Principle of stress measurement

The internal average film stress can be measured by using the fact that due to the stress that is build in the thin film during deposition, the shape of the sample is changed. To measure this change in shape, a standard Michelson interferometer was used, extended with a phase sensitive method to enhance the accuracy of the system.

The difference in shape can then be characterised by the radii of curvature as depicted in Fig. 1. After Röll [3] the following formula is used to relate the change in shape to the average film stress:

$$\langle \sigma_{ik}^{(2)} \rangle = \frac{E_1 H_1^2}{6(1+m_1)H_2} \left[\frac{\partial^2 W}{\partial x_i \partial x_k} + \frac{m_1}{1-m_1} \left(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial y^2} \right) \delta_{ik} \right], \quad (1)$$

with $\langle \sigma_{ik}^{(2)} \rangle$ in Pa, the average internal film-stress tensor with $(i, k) = (x, y)$. To ensure isotropical elastic properties of the substrate, we used silicon $\langle 111 \rangle$ [4] with Young

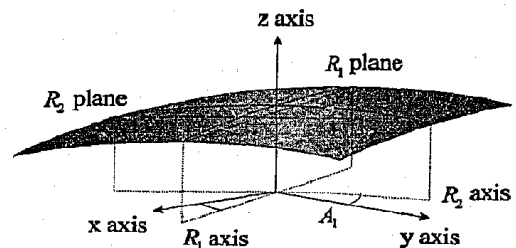


Fig. 1. Definition of the quantities R_1 , R_2 and A_1 .

modulus $E_1 = 168.9$ GPa, Poisson's constant $m_1 = 0.262$ and thickness $H_1 = 250$ μm . Furthermore H_2 is the thickness of the film, $W(x, y)$ the difference in shape before and after deposition, $\partial^2 W / \partial x^2 = 1/R_1$ and $\partial^2 W / \partial y^2 = 1/R_2$ the inverse radii of curvature in the x and y direction and δ_{ik} the Kronecker delta. Note that $\langle \sigma_{ik}^{(2)} \rangle$ is measured on the principle axis, i.e. $\langle \sigma_{xy}^{(2)} \rangle = 0$. Note also that for $R_1 = R_2$ Eq. (1) reduces to the well known equation given by Stony [5].

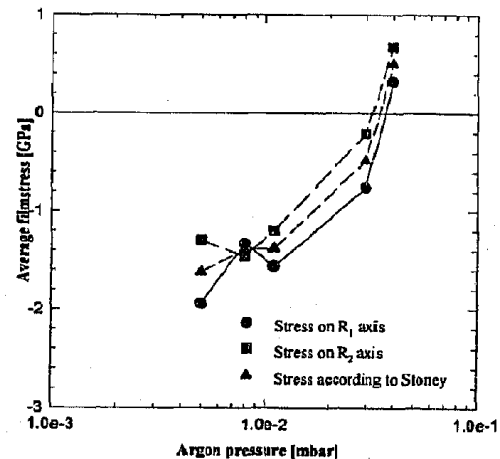


Fig. 2. Average internal film stress as a function of the argon pressure.

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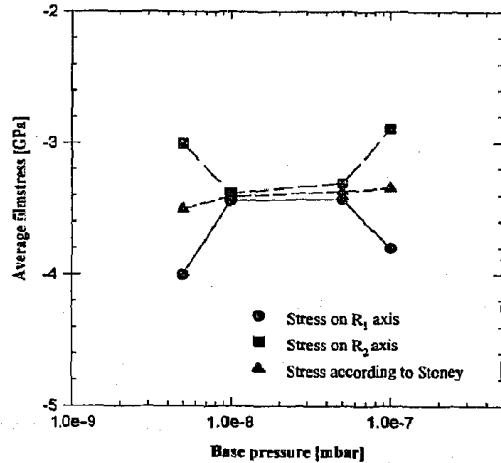


Fig. 3. Film stress as a function of the base pressure.

3. Sample preparation

All samples were deposited in an UHV sputtering system which makes use of sputter guns. The target to substrate distance was 10 cm, the initial substrate temperature 27°C and the argon flow 35 ml/min. The platinum was dc sputtered and the $\text{Co}_{50}\text{Ni}_{50}$ rf sputtered both at 50 W. Furthermore all the individual layer thicknesses are shutter controlled. All multilayer films consist of a seed-layer of platinum, followed by $n\text{Co}_{50}\text{Ni}_{50}/\text{Pt}$ bilayers.

To investigate the average film stress we prepared three film series, as listed in Table 1. With these series we investigated the influence of sputter-gas pressure, background pressure and stack composition on the average internal film stress.

Film thickness measurements were performed by measuring the deposition rate on single layers with DEKTAK and Low Angle XRD (LAXRD). The bilayer thickness of the deposited samples was also measured with LAXRD. From this the individual layer thicknesses were calculated as shown in the table.

4. Results, discussion and conclusion

Before the measurements are presented, it should be mentioned that the total error in the measured radii of

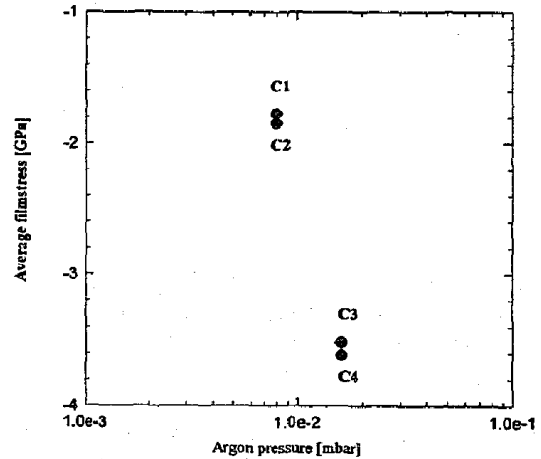


Fig. 4. Film stress according to Stoney as a function of the number of interfaces. The data points correspond with the table.

curvature is about 10%. This results in an error in the internal average film stress of around 20%.

In Fig. 2 the internal average film stress is plotted as a function of the applied argon pressure (series A). The stress changes sign (from compressive to tensile) at about 3.7×10^{-2} mbar. The shape of the curve is in accordance with other results reported in literature [e.g. 6], however a physical explanation is still hardly known. Also some High Angle XRD measurements were performed on these samples. This data was found to be in agreement with the interferometrical results as presented here; the position of the multilayer peak follows the same trend from compressive to tensile.

In series B (see Fig. 3), film stress was studied as a function of the base pressure. From this we hardly see any dependence on the base pressure in the range from 5×10^{-9} to 1×10^{-7} mbar.

In series C the dependence of the composition of the stack was investigated. Here two films were sputtered at the same argon pressure but with twice the number of bilayers. Each time the total and the seed-layer thicknesses were kept constant. This experiment was done at two different argon pressures, as listed in Table 1. Note that the absolute value of the film stress is different since the total

Table 1
Different deposition parameters of film series A, B and C

Series	P_{Ar} [mbar]	P_{base} [mbar]	n	t_{seed} [Å]	t_{CoNi} [Å]	t_{Pt} [Å]
A	5×10^{-3} – 4×10^{-2}	$< 5 \times 10^{-8}$	17	235	6.5	14.7
B	1.6×10^{-2}	5×10^{-9} – 1×10^{-7}	17	235	6.5	14.7
C #1	8×10^{-3}	$< 5 \times 10^{-8}$	17	180	13	10
#2	8×10^{-3}	$< 5 \times 10^{-8}$	34	180	6.5	5
#3	1.6×10^{-2}	$< 5 \times 10^{-8}$	17	235	13	29.4
#4	1.6×10^{-2}	$< 5 \times 10^{-8}$	34	235	6.5	14.7

thickness with each argon pressure is different. The results are plotted in Fig. 4 and the striking fact is that the film stress has hardly any dependence on the chosen multilayer stack, i.e. the number of interfaces.

In conclusion we can say that the internal average film stress of the multilayers reported upon here show an expected behaviour as a function of the argon pressure but seems hardly dependent on either the base pressure or the number of interfaces of the multilayer stack.

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