INVESTIGATION OF PERMEABILITY ON ELECTROPLATED AND SPUTTERED PERMALLOY

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Introduction

Softmagnetic materials are utilized for a multitude of applications in thin film technology such as microsensors and microactuators [1]. The most commonly used softmagnetic material is permalloy (NiFe in a range compositions). For NiFe81/19, the coefficient of magnetostriction λ has a zero crossing, changing from positive to negative, for NiFe45/55 it has a maximum. For NiFe45/55, the saturation flux density B_s is also at a maximum, reaching 1.6 T, compared to 1.1 T for NiFe81/19. Both materials lend themselves to being deposited either by PVD processes like sputtering or ion beam deposition, or by electroplating. This flexibility in fabrication processes makes them ideal candidates for soft magnetic MEMS applications [1], [2]. This paper investigates what relative permeability μ_r may be achieved as a function of the fabrication process, the material composition, and the film thickness.

Requirements on Magnetic Materials

For sensor applications, low tension films with a great permeability μ_r are desirable. For sensors, sputtering is the most common deposition technology. On the other hand, for actuator applications the goal is to achieve a high saturation flux density while sensor applications require a high magnetic permeability and a small coercivity [3]. Electroplating is a fabrication process, which is very common in microfabrication. Electroplating allows a metal deposition in microforms of photoresist. Usually the magnetic flux guides and magnetic poles of actuators and sensors are fabricated by electroplated permalloy. With the aid of galvanic deposition it is possible to achieve a layer thickness of a few tens of micron, which is very suitable for actor applications.
The sputtered permalloy is more suitable for deposition of seed layers and the sensors' functional layers. In comparison to electroplating, a sputtering process is easier to regulate and its deposited layer obtains a uniform thickness. During sputtering usually a temperature of 350°C arises and causes residual stress in the deposited layer, which influences the magnetic property of the deposited material. After sputtering an annealing process is desirable to reduce the residual stress and to improve the magnetic properties of the deposited film.

NiFe-Electroplating and Sputtering Test Setup

Test structures were manufactured by utilizing electroplating and sputtering processes. The electroplating took place in a galvanic cell with bath agitation [4]. The layer's properties depend on the current density, the bath temperature, and the velocity of the bath agitation [5].
Figure 1 depicts two *B-H* loops for electroplated Fe81/19 for two different thicknesses. While the saturation flux density B_s is the same (1.18 T), a film thickness of 12 µm results in a relative permeability of 310, whereas a thickness of 35µm shows a permeability of 105. The decrease in relative permeability is caused by growing tensions.

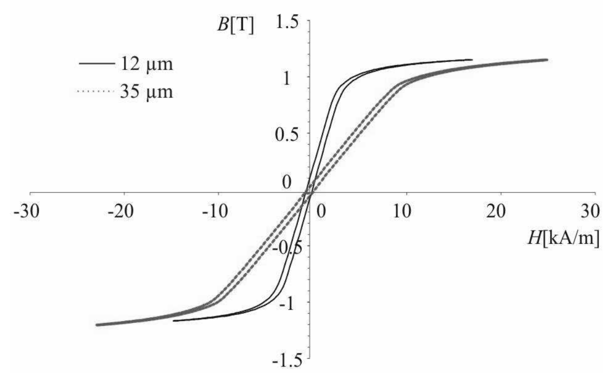

Fig. 1: *BH*-loops of 12µm and 35µm electroplated NiFe 81/19 layer

Investigations of deposition conditions of permalloy films fabricated by electroplating as well as sputtering lead to an improvement of physical properties due to an increase of the saturation flux density and permeability.
Figure 2 reveals the correlation of the layer thickness d and the relative permeability μ_r of NiFe 81/19 as a function of the film thickness. An increase in film thickness decreases the film's relative permeability μ_r.

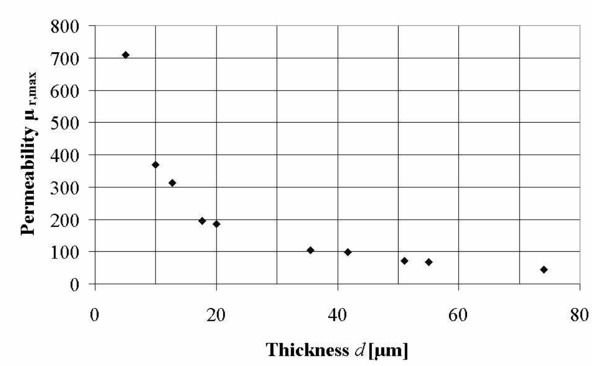

Fig. 2: Relative permeability $\mu_{r,max}$ of NiFe 81/19 dependent on layer thickness *d*

Conclusion

For permalloy films, an increase in film thickness does not influence the saturation flux density B_s (which was to be expected) but it does affect the relative permeability μ_r. Due to a growth of film tensions, an increasing film thickness decreases the permeability.

References

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