MAGNETIC PROPERTIES OF SPUTTERED PERMALLOY/MOLIBDENUM MULTILAYERS

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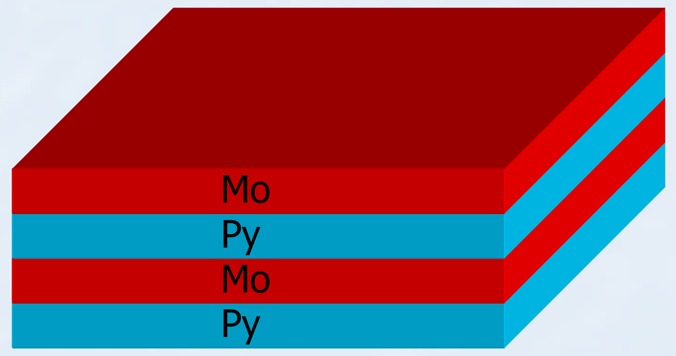
Abstract:
In this work we study the magnetic properties of Permalloy (Py: $Fe_{20}Ni_{80}$) films grown as multilayers with thin Molibdenum (Mo) spacers, in order to optimize it for sensor applications. Properties like permabillity or linearity of the loops can be controlled by growing Py as a multilayer with alternating perpendicular anisotropies [2]. However for thicknesses over 180 nm sputtered Py films develop perpendicular anisotropy (induced by the columnar morphology of the sputtered films) and the magnetic properties degrade notably [3]. Both coercive and saturating fields are nearly 10 times bigger than those measured for thinner films. Nevertheless, we found that it is possible to obtain low coercivity and high permability if thick Py films are grown as multilayers with a non-magnetic spacer between magnetic layers. In addition, we studied the effect of the layers thicknesses in the coercive field which is minimum for a Py thicknesses about 30 nm.

Samples characteristics

- The multilayers were grown by dc magnetron sputtering
- The anisotropy induced was controlled by the angle of incidence of the beam.
- The anisotropy was measured for a single Py layer (125 nm thick) obtaining an anisotropy constant of K=1200 J/m3 which corresponds to an exchange correlation length of 180 nm.



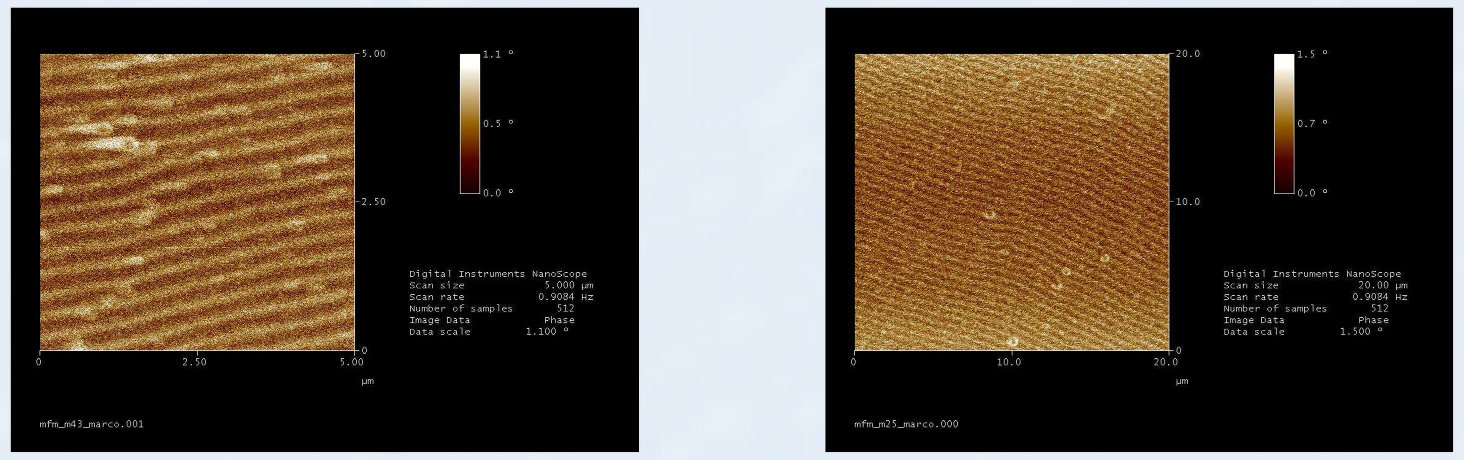


Fig 1: MFM measurements

Permeability and linearity control

- Permeability can be controled by the relative thickness between layers with different anisotropy direction.

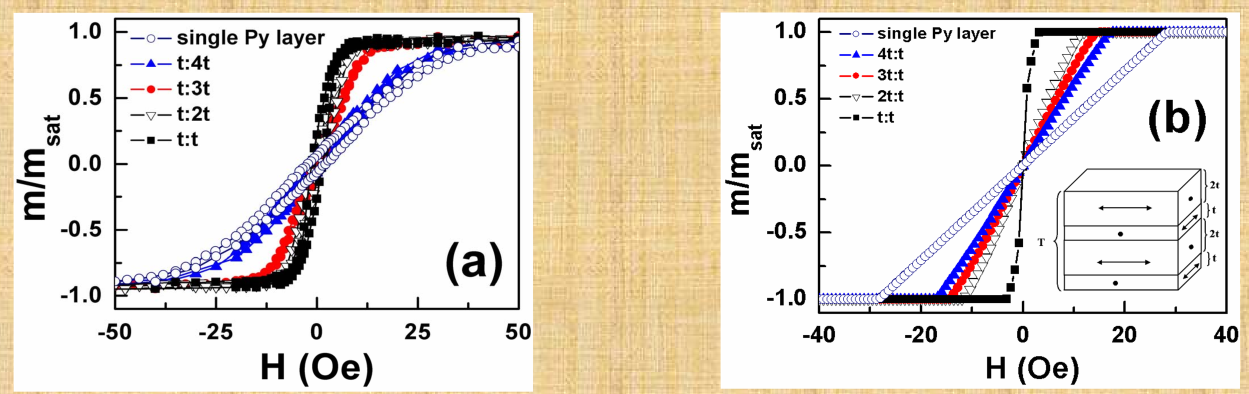


Figure 6. Hysteresis loops of Py multilayers with a total thickness of 150 nm and 4 layers with alternating perpendicular anisotropies and different relative thicknesses (t:t, t:2t, t:3t and t:4t), a) experimental and b) simulated.

- Linear hysteresis loops can be obtained by growing the sample with a large number of layers so the thickness of each single layer is much lower than the exchange correlation length.

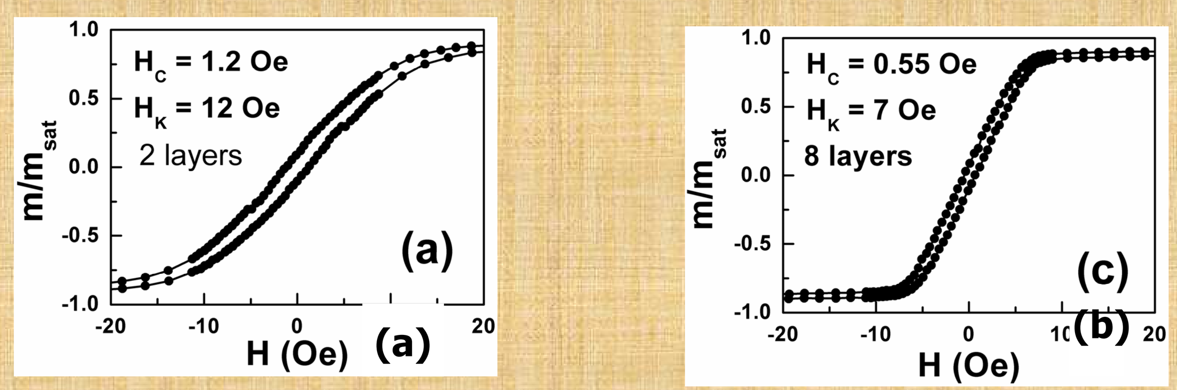


Figure 7. Hysteresis loops of Py samples with (a) 2 and (b) 8 layers with alternating perpendicular anisotropies and a t:2t thickness ratio. In both cases the total thickness is 150 nm.

Results

1. The effect of the sample thickness in the magnetic behaviour

The effect of the sample thickness can be seen in figure 2. These loops exhibit quite different behaviour changing from an in-plane anisotropy for the thinner to a clear perpendicular to the plane anisotropy for the others. MFM measurements on the thicker samples (Fig 1) show a stripe domain pattern that proves the existence of an anisotropy perpendicular to the sample plane.

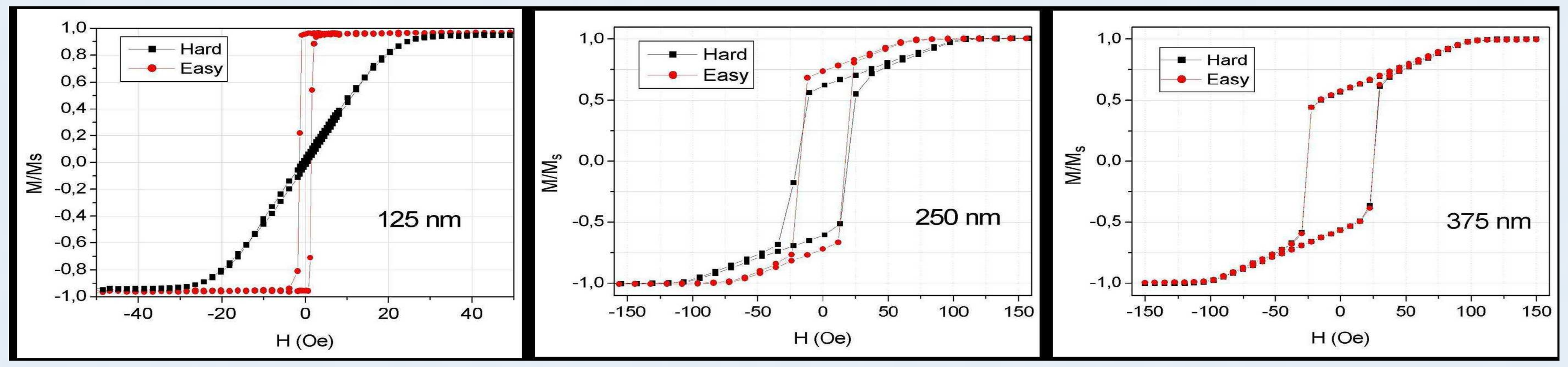


Fig 2: Py hysteresis loops for film thicknesses (a)125, (b)250 and (c)375 nm

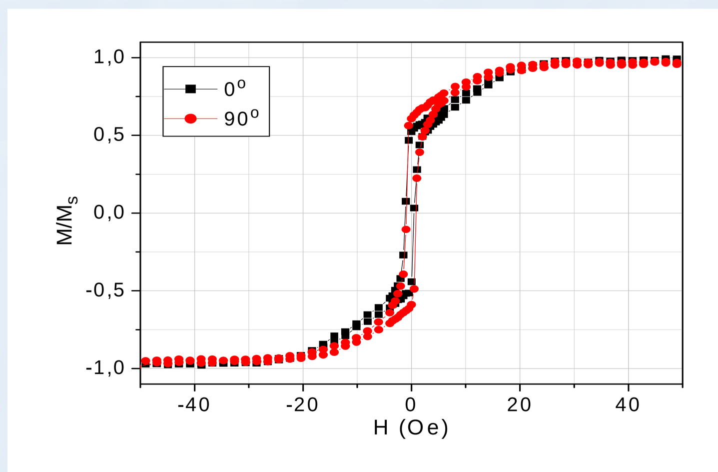


Fig 3: Py/Mo/Py hysteresis loop with perpendicular anisotropies.

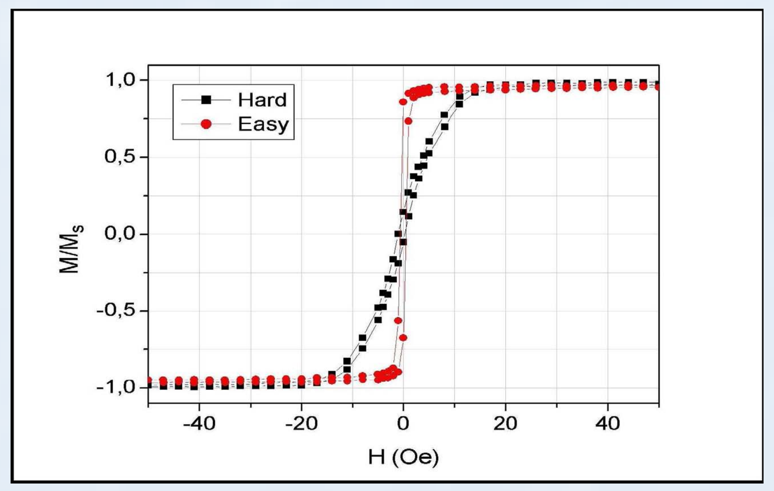


Fig 4: Hysteresis loop of a multilayer consisting in 4 Py layers separated by 10 nm Mo spacers. The total Py thickness is 250 nm.

2. The effect of the Molibdenum spacer

Figure 3 shows that a thin Mo spacer of 10 nm results enough to break the magnetic coupling between the Py layers and the columnar morphology, maintaining the anisotropy in the plane. Hysteresis loops in Figure 4 shows coercive and saturating fields much lower than those obtained in a Py monolayer with the same thickness (Figure 2b).

3. The effect of the thickness in the coercive field of Py/Mo multilayers

Figure 5 shows the effect of the thickness in the coercive field of Py/Mo multilayers. A minimum in the coercivity was found for Py layer thicknesses corresponding to 30 nm. This minimum coincides with the transition thickness of a single film where Bloch domain walls change to Néel domain walls. The width of Bloch domain walls increases as the Py thickness increases and the width of the Néel walls core increases as the Py thickness decreases. This fact makes the coercivity have the same behavior (increase) when the Py layer is thicker or thinner than 30 nm.

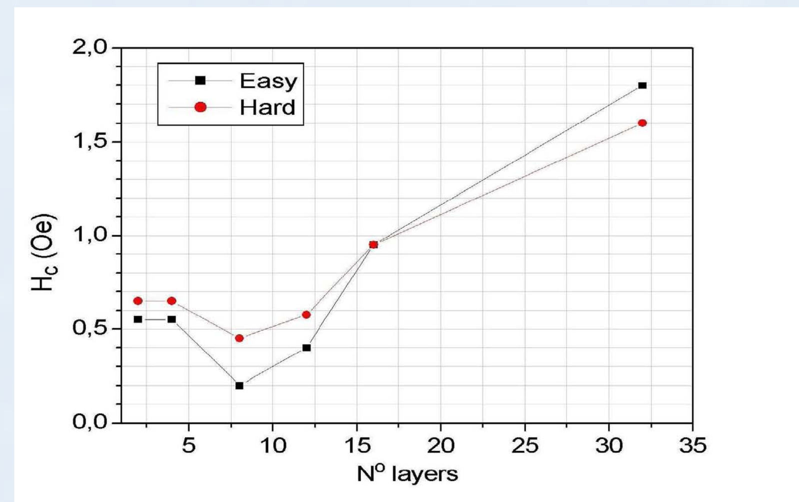


Fig 5: Coercive fields of a Py/Mo multilayer with a total thickness of 250 nm as a function of the number of Py layers

Conclusions:

It is observed how the soft magnetic properties of sputtered Py films can be maintained for thicknesses over 180 nm by growing samples as multilayers with thin Mo spacers. The coercivity can be minimized for particular Py thicknesses about 30nm.

References:
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