Control of magnetic properties of FeCo thin films grown by sputtering

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Motivation

- $Fe_{50-70}Co_{50-30}$ are among the alloys with the highest flux densities (about 2.4 T).

These alloys have been widely used in the recording industry for many years and are continuously being investigated to improve their properties [1] - [4].

- They are currently being used in the development of new spintronic devices [5], [6] due to their high spin-polarization and also in biomedical applications like hyperthermia [7].
- Considering soft magnetic materials applications, although they have much larger flux densities than typical permalloy films, properties like coercivity, dispersion and low anisotropy should be improved.

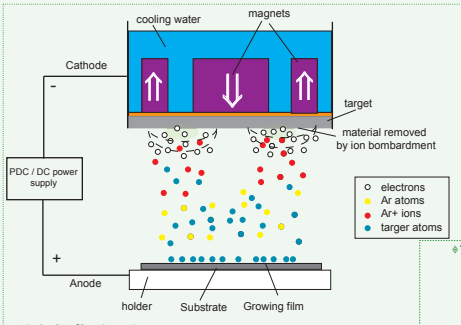
Typical coercivities for FeCo ranges from 50-100 Oe and exhibits a high positive magnetostriction [8].

- Magnetic properties of FeCo can be tailored during the fabrication process.

Properties of films synthesized by conventional sputtering techniques have proved to be strongly dependent on growing parameters like power and the inert gas flux [9], *pressure and substrate bias, underlayer materials* [10] *or the sputtering rate* [11].

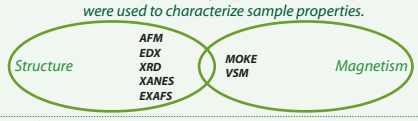
Experimental method

- Pulsed DC (PDC) magnetron sputtering have proved to produce better structural quality films than DC sources used in similar conditions [12].

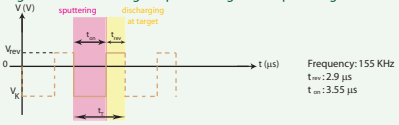


- **We compare the magnetic properties of FeCo films obtained using DC and PDC sputtering sources under the same growing conditions.**

Several complementary experimental techniques were used to characterize sample properties.



- Target voltage waveforms during the pulsed magnetron sputtering.

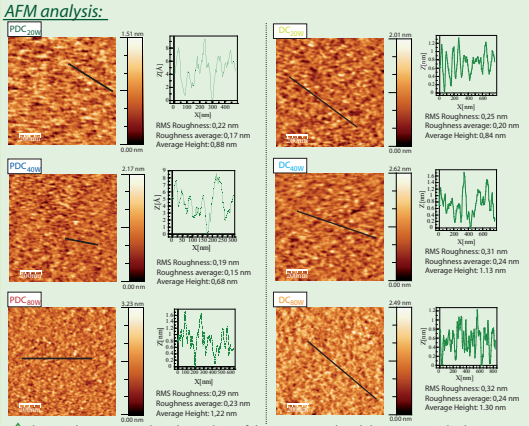


- FeCo thin films (20nm).
- Au(5nm) buffer [11] and capping layers.
- All layers were deposited sequentially without breaking vacuum at RT.
- No magnetic field was applied during the growing process.

Structure

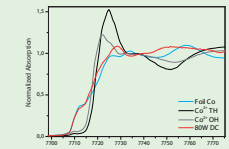
$P_{Ar} = 5$ mTorr

AFM analysis:

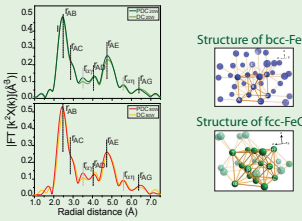


- The roughness is mostly independent of the source used and the power applied.
- These small roughness is expected to have a small influence on samples coercivity, as similar pinning for magnetic domain walls at the surface is expected for all samples.

XAS study:



- A XANES analysis rules out the presence of any Co oxide in the films being fcc-Co the only structure compatible with the XANES data.

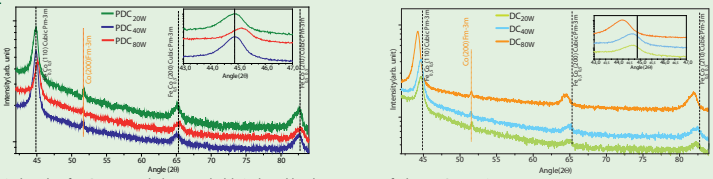


Structure of bcc-FeCo

Structure of fcc-FeCo

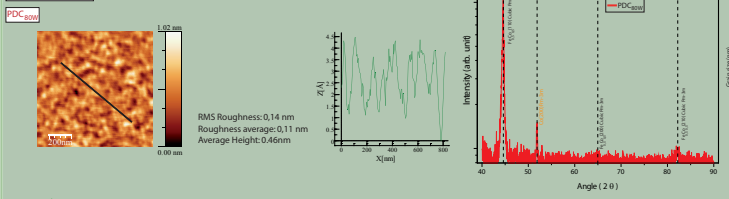
- Deviations from ideal structural distances are observed.
- The percent of deviation from ideal values indicates that the FeCo matrix is quite distorted, which most likely produce stress in the structure.

XRD patterns:



- Co peak can be indexed as fcc-Co, a crystal phase probably induced by the presence of a bcc-FeCo matrix.
- Reported values for high moment FeCo exchange length are between 20-30 nm [13]. We have estimated the grain size from the XRD data, finding very similar data for all samples (12-14 nm for DC films and 12-20 nm for PDC films), below the exchange lengnt.

$P_{Ar} = 40$ mTorr

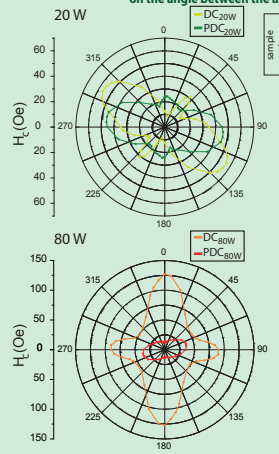


- Similar roughness, crystalline structure and grain size are present this thin films growing at high pressure.

Magnetism

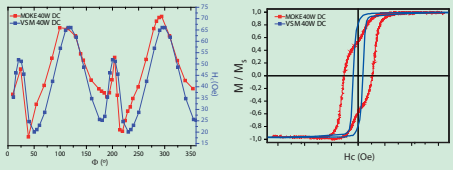
MOKE study:

We present the coercivity of the four samples and their dependence on the angle between the applied magnetic field and the long axis of the sample.

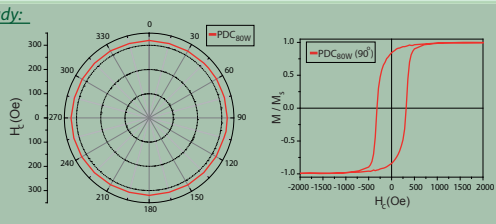


- All samples present magnetic anisotropy.
- Coercivities in PDC samples are smaller than their corresponding DC samples and these differences are more remarkable for higher growing power .
- PDC_{80W} sample has a coercivity more than 3 times smaller than it DC counterpart. Samples are anisotropic and strongly dependent on the growing power as other authors report on DC samples..
- The large difference is found in the case of the samples grown with the higher power (80 W).

Differences between VSM and MOKE measurement:



VSM study:



- All samples growing at this pressure don't present magnetic anisotropy.

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Conclusions

- We demonstrate that, we can tune the magnetic properties of the samples using differnt power sources, as the local structure strongly depends whether the power is DC or PDC.
- The case of a PDC source can reduce coercivity notably in films when compared to DC films grown in similar conditions.
- The increment of the bcc-FeCo atomic distances is in direct correlations with the magnetic properties as coercivity doubles when the stress is larger.
- Although the relationship between stress and magnetic properties is well known, the small changes induced in the structure by changing the growth conditions are large enough to produce changes in both, coercivity and direction of the easy axis, leading us to easily tune these properties by simple choosing the power source.