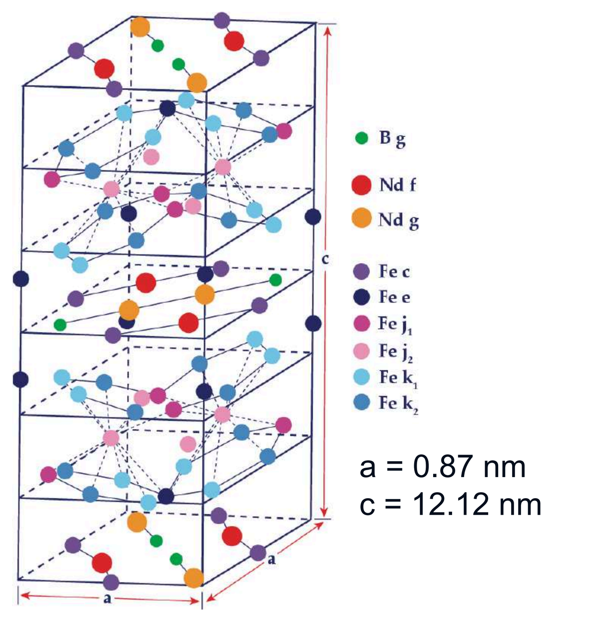
Epitaxial NdFeB films grown by molecular beam epitaxy with an Fe underlayer

J. Soler-Morala[1], C. Navío[1], L. Zha[2,3], J. Yang[2,3,4], A. Bollero[1]

[1] *Group of Permanent Magnets and Applications, IMDEA Nanoscience, 28049, Madrid, Spain*
[2] *Beijing Key Laboratory for Magnetoelectric Materials and Devices, Beijing, 100871, China*
[3] *State Key Laboratory for Mesoscopic Physics, School of Physics, Peking University, Beijing, 100871, China*
[4] *Collaborative Innovation Center of Quantum Matter, Beijing,100871, China*

Motivation



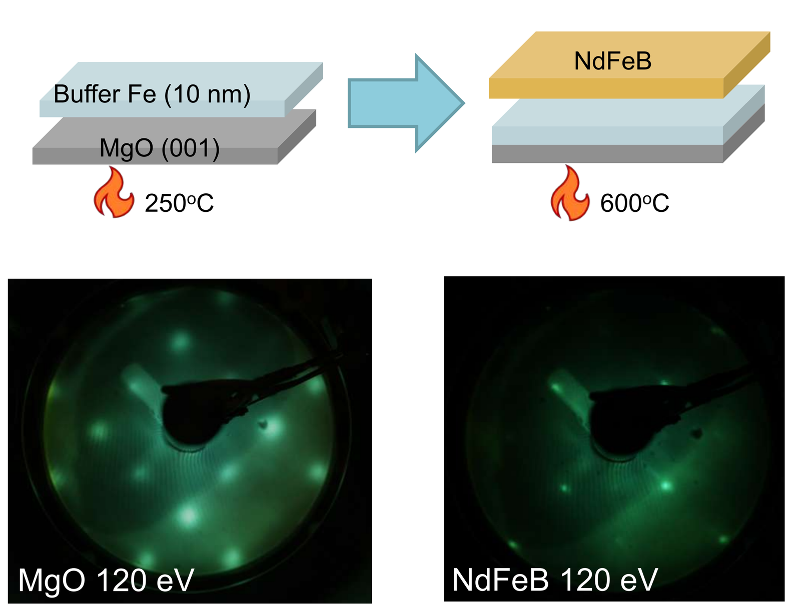
J.F. Herbst *et al.*, Phys. Rev. B 29, 4176(R) (1984)

Rare-earth transition metals thin films have attracted a lot of attention due to their high magnetic anisotropy that makes them great candidates for several applications including high density magnetic recording [1-2], microelectromechanical systems and actuators [3]. Rare-earth based thin films also allow the development of novel spintronic devices [4] and they are essential materials for energy-related technologies [5]. Furthermore, the study of certain elements in these rare-earth based systems such as interfaces, grain boundaries or interstitial additions can provide a wider knowledge of their coercivity and magnetization reversal mechanisms [5-7].

The aim of this study is to analyze the first stages of the growth of NdFeB thin and ultra thin films. For that purpose, NdFeB thin films have been grown on a MgO (001) substrate at 600ºC. An underlayer of 10 nm of Fe was previously grown in order to ensure epitaxiality. A 15 nm vanadium capping layer was deposited afterwards to prevent oxidation.

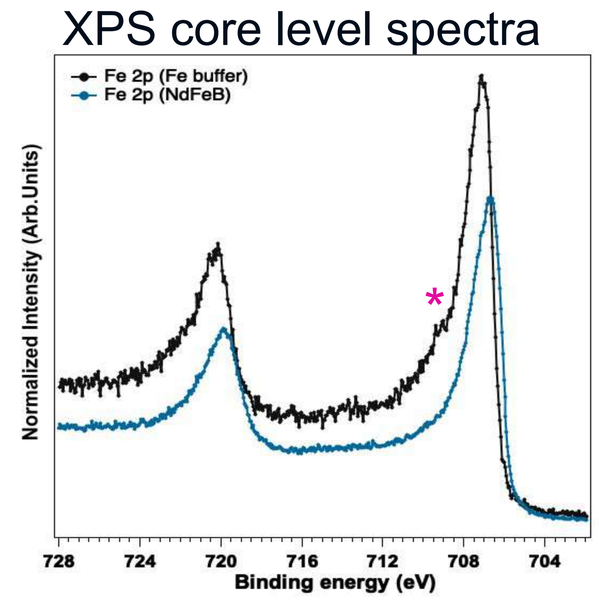
Growth and spectroscopy

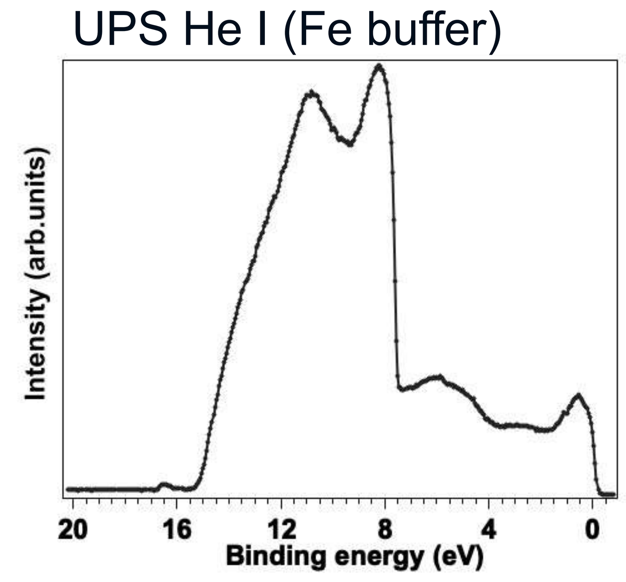
NdFeB films by MBE on MgO (001)



- Co-evaporation of Nd, Fe and B
- Epitaxial growth in the same direction of the substrate
- Fe underlayer and NdFeB rotated 45º with respect to the MgO substrate to decrease at the most the lattice mismatch

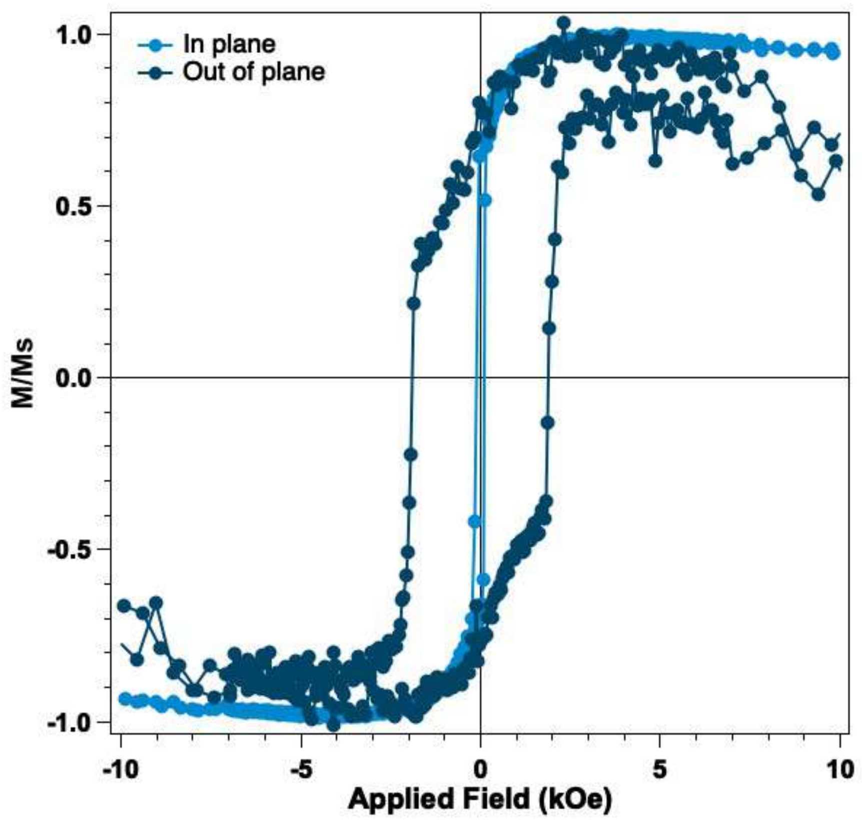
Photoemission spectroscopy

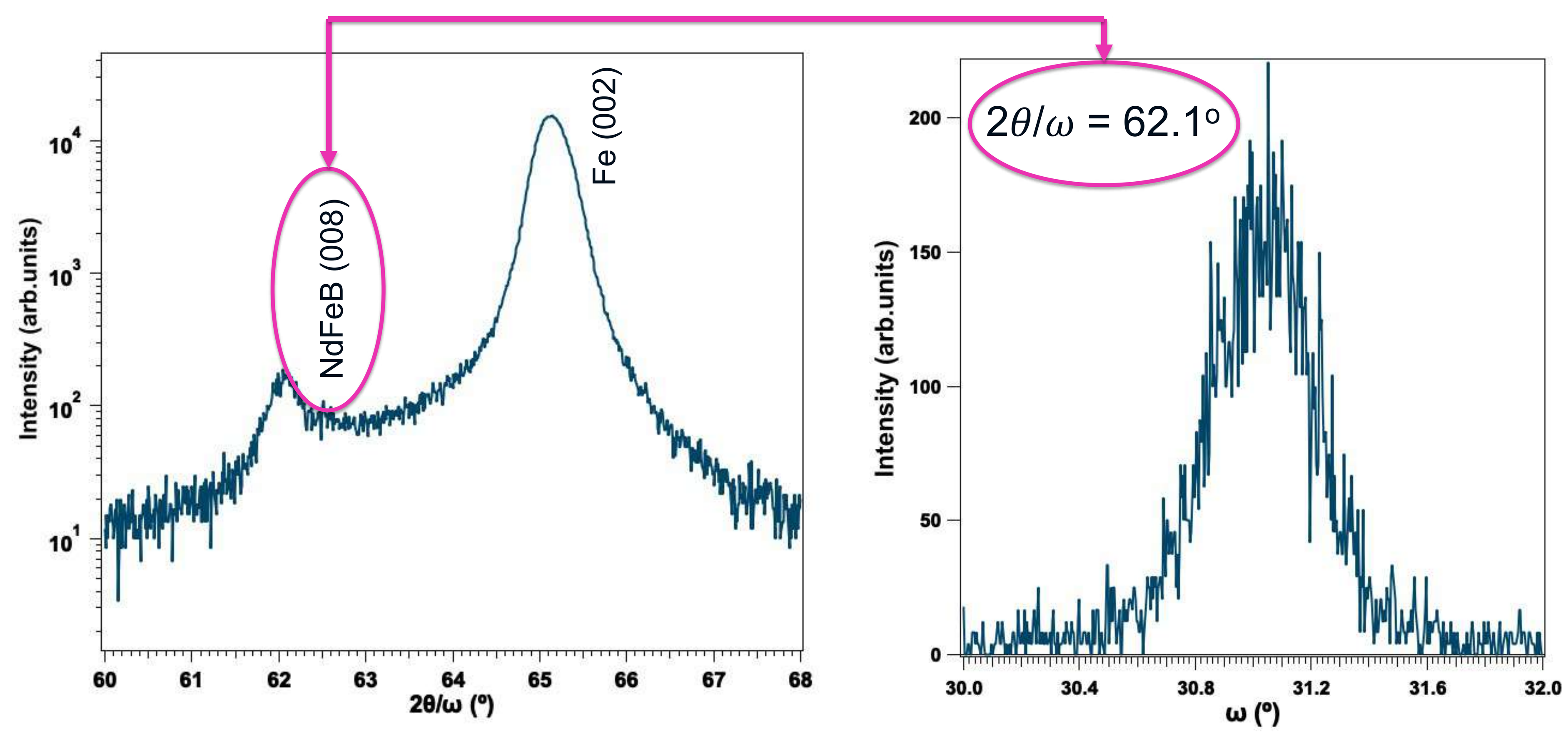




- Changes in the Fe 2p spectra: higher asymmetry in the Feº from the buffer (pure metallic Fe) than in the Fe linked to other elements
- Low Nd composition extracted from the survey (4%)

Magnetic and structural characterization





- H_c (oop) = 2 kOe. Strong magnetic anisotropy in accordance with the epitaxial growth
- Two magnetic phases are present in the hysteresis loop → Fe (002) and NdFeB (008) diffraction peaks are found in the XRD pattern
- Rocking curve measurement of NdFeB (008) shows high crystallinity ($\Delta\omega$ = 0.40°)

Conclusions

- **Epitaxial NdFeB films** have been obtained by co-deposition of each individual element by molecular beam epitaxy.
- Good crystallinity is obtained thanks to the high deposition temperature and the epitaxiallity of the buffer layer.
- Two magnetic phases are present: a soft one coming from the Fe buffer layer and a harder one from the NdFeB layer.

Acknowledgements

Authors acknowledge financial support from EU through the H2020 FET Open *UWIPOM2* project (Ref. 857654). J.S.-M. acknowledges also financial support from the Regional Government of Madrid (Ref. PEJD-2019-PRE/IND-17045).

References

[1] A. Morisako *et al.*, *J. Magn. Magn. Matter*. 304, 46-50 (2003)
[2] X. Liu *et al.*, *J. Appl. Phys.* 97, 10K301 (2005)
[3] T.-S. Chin, *J. Magn. Magn. Matter.* 209, 75-79 (2000)
[4] A. Bollero *et al.*, *Nanoscale*, 12, 1155-1163 (2020)
[5] O. Gutfleisch *et al.*, *Adv. Mater.* 23, 821–842 (2011)
[6] L. Zha *et al.*, *J. Magn. Magn. Matter.* 514, 167128 (2020)
[7] S. Bance *et al.*, *Appl. Phys. Lett.* 104, 182408 (2014)