	Experiment title: Atomic lattice distortion in Co@FePt nano-composite permanent magnet on MgO substrate from X-ray chemical local probe	**Experiment number**: HC3629
Beamline: BM30B	**Date of experiment**: from: 18 april 2018 to: 24 april 2018	**Date of report**:
Shifts: 18	**Local contact(s)**: Isabelle Kieffer (isabelle.kieffer@esrf.fr)	*Received at ESRF:*

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Report:

Scientific Background

The performance of permanent magnets, measured in energy product $(BH)_{max}$, has doubled every 12 years in the last century, but remained stagnant over the last 20 years as no new magnetic phases better than $Nd_2Fe_{14}B$ have been discovered. As controlling the structure is a key parameter to adjust magnetic performances, theoretical calculations[1] predicted that the energy product could be doubled by producing nanocomposite ferromagnetic materials that combines soft grains with high saturation dispersed in a hard magnetic matrix. Using the PLYRA platform of Institut Lumière Matière, we have prepared such nanocomposites from Co nanoclusters embedded in a FePt matrix, (named: Co@FePt) post-annealed at different temperatures but also equivalent nanofilms (alternative thin films stacking) (e.g. CoFePt) used as references.

Sample preparation and Characterization

The Co clusters were produced by Mass-Selected Low Energy Cluster Beam Deposition (MS-LECBD) into an UHV chamber where the metallic matrix and nanofilms can be deposited on the same substrate from successive electron beam evaporations. An annealing above 700°C is expected to allow the transition from alternative layers of Fe (resp. Co) and Pt up to the $L1_0$-FePt (resp. $L1_0$-CoPt) ordered alloy for equiatomic proportion[2]. While an annealing at lower temperatures only leads to chemically disordered alloy phases. Different samples were used to study the influence of the annealing temperature, of the nature and concentration of Co inclusions (layers or clusters with 6 nm in diameter) but to test also aging effects on the local structural order in the samples listed in Table 1.

Experimental results

[1] Kneller, Eckart F., and Reinhard Hawig. "The exchange-spring magnet: a new material principle for permanent magnets." *IEEE Transactions on Magnetics* 27.4 (1991): 3588-3560.
[2] Zeng, H., et al. "Orientation-controlled nonepitaxial L1 $_0$ CoPt and FePt films." *Applied physics letters* 80.13 (2002): 2350-2352.

During our allocated FAME beamtime, we have been able to systematically performed EXAFS measurements on all our as-prepared and annealed samples. First, they were all passed at the K-edges required by their composition (Fe, Co) at different angles (5, 45 and 85°) and at L_3-edge (Pt) when needed.

Sample name	Description	annealing	capping	Made in
TM17-29	30% Co cluster in FePt matrix	~600°C*	C	2017
TM17-53	10% Co cluster in FePt matrix	~600°C*	C	
TM18-04	FePt film (45% Fe)	700°C		2018
		600°C		
TM18-07	CoFePt film (20% Co)	700°C		
		600°C		
TM18-06	CoFePt film (10% Co)	700°C		
		600°C		
TM18-08	Fe_3Pt film (70% Fe)	~600°C*		
TM18-02	CoFePt film (30% Co)	700°C		
		600°C		
UHV17-66	FePt film (45% Fe)	700°C	C	2017
UHV17-67	Fe_3Pt film (70% Fe)	none	C	
		400°C		
UHV17-70	$FePt_3$ film	700°C	C	
UHV17-65	CoFePt film (30% Co)	700°C	C	
TM18-05	CoPt film (45% Co)	700°C		2018

* Annealed in situ (lower accuracy)

Table 1 - Summary of all the samples characterised during the run.

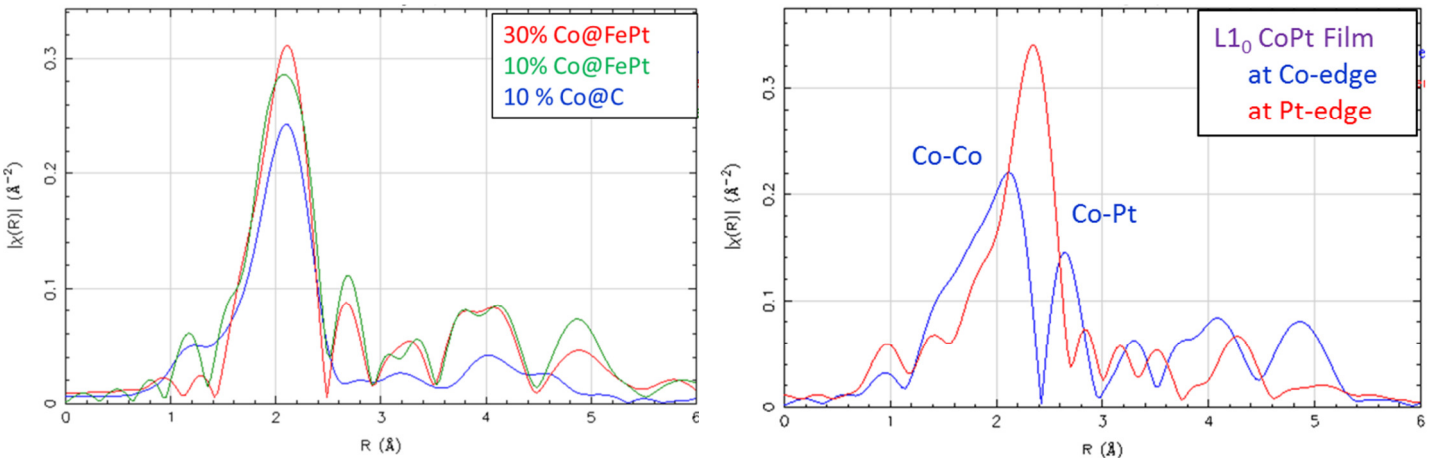

Fig. 1 - Radial distribution obtained on annealed samples of 10 and 30% Co clusters in FePt (compared to a previous Co@C sample) at the Co K-edge (left) and on $L1_0$-CoPt film at Co K-edge and Pt L_3-edge (right).

First of all, from a qualitative analysis of the non-corrected radial distribution of the samples at the Co K-edge, one can underline that the signatures are completely different between equivalent nanocomposites and nanofilms, even after annealing (see Figure 1). For the Fig. 1, on the left, we observe several peaks corresponding to different first-neighbours contributions, attesting to the good crystallinity of the annealed nanocomposites. But overall, the main peak around 2 Å as observed in 6 nm-Co@C samples, accounts to a majority of Co-Co bonds for annealed Co@FePt samples. The peak around 2.6 Å is coherent with Co-Pt bonds as confirmed by the analysis of the annealed $L1_0$-CoPt film (see Fig. 1, on the right) probably at the cluster interface. The fact that the Co-Co signal increases when the Co-Pt decreases with Co-concentration in Co@FePt samples can be attributed to coalescence effects upon annealing between clusters (which are closer for higher concentration). This observation can be attributed to a tendency to the formation of a Co-rich core surrounded by a limited $Co_xFe_yPt_z$ shell for Co@FePt samples upon annealing.
We are in the process of fitting the obtained data for more quantitative results.