EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:
https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Deadlines for submission of Experimental Reports

Experimental reports must be submitted within the period of 3 months after the end of the experiment.

Experiment Report supporting a new proposal ("relevant report")

If you are submitting a proposal for a new project, or to continue a project for which you have previously been allocated beam time, you must submit a report on each of your previous measurement(s):

- even on those carried out close to the proposal submission deadline (it can be a *"preliminary report"),*
- even for experiments whose scientific area is different form the scientific area of the new proposal,
- carried out on CRG beamlines.

You must then register the report(s) as "relevant report(s)" in the new application form for beam time.

Deadlines for submitting a report supporting a new proposal

- 1st March Proposal Round - **5th March**
- 10th September Proposal Round - **13th September**

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the experiment number to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Microscopic magnetic properties of novel magnetic nanolamellar structures (Mo2/3RE1/3)2AlC and Mo4RE4Al7C3 studied by XMCD	**Experiment number:** HC-3567
Beamline: ID12	**Date of experiment:** from: 20 June 2018 to: 25 June 2018	**Date of report:** 01/03/2020
Shifts: 15	**Local contact(s):** F. Wilhelm	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

During the allocated beamtime, we have successfully perfomed XMCD measurements at the RE (Ce, Nd, Gd) $L_{3,2}$-edges and Mo $L_{3,2}$-edges in $Mo_4Ce_4Al_7C_3$, $(Mo_{2/3}Nd_{2/3})_2AlC$ and $(Mo_{2/3}Gd_{2/3})_2AlC$ single crystals along the c-axis at 2K and under magnetic field. In the case of $MoCe_4Al_7C_3$, a new Rare-earth (RE) nanolaminates, X-ray absorption near-edge structure provided experimental evidence that Ce is in a mixed-valence state as (see Fig1.)

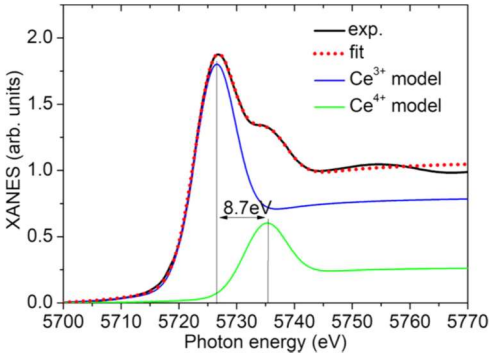

Figure 1: Deconvolution of the experimental Ce L3-edge XANES spectrum into a sum of model spectra for Ce3+ and Ce4+ atoms using a sum of an arctangent function describing transitions from the 2p core state into continuum and a Lorentzian function accounting for transitions into an unoccupied 5d band of Ce.

Further, we have also recorded XMCD spectra at the Ce $L_{3,2}$-edges at 2.1 K under a 1 T magnetic field. The existence of a finite XMCD signal at both L3 and L2 edges confirms that the Ce ions are carrying a magnetic moment. The spectral shape of the XMCD signals is characteristic of a $4f^1$ system. The magnetic field dependence of the maximum dichroic signal at the Ce L2 edge confirms ferromagnetic ordering of the Ce 4f

moments. It should be noted that there are two non-equivalent Ce sites. The Ce1 sites (2 Ce atoms) are closely bonded to Mo and C, and to a smaller extent to Ce2 ions, whereas the Ce2 sites (2 Ce atoms) are strongly hybridized with Al. It should be stressed that the observation of only one magnetic peak corresponding to the main $4f^1$ final state demonstrates that only this channel leads to ferromagnetism hence meaning that the Ce ions with a mixed valent state are not involved in the ferromagnetism. Using XMCD, we have provided strong arguments that the two nonequivalent Ce sites exhibit different electronic and magnetic properties. The Ce2 site features localized 4f 1 states with ferromagnetically ordered 4f moments of about 1.2μB, whereas the Ce1 site occupied by ions with strongly delocalized 4f electrons are not involved with the ferromagnetism. This is also supported by the fact that we did not observe within the detection level of our measurements, a distinguishable XMCD signal was observed at the Mo L3,2 edges (noisy horizontal red line in Fig. 2), confirming that the Ce in the Ce1 site is paramagnetic.

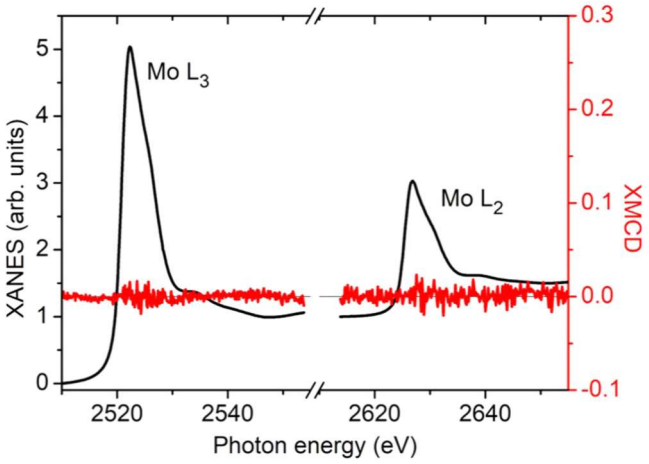

Figure 2: Normalized XANES (left axis) and XMCD (right axis) spectra measured at the Mo L3,2 edges in a Mo4Ce4Al7C3 crystal at T = 2.1 K and H = 1 T. Spectra have been corrected for selfabsorption effects and circular polarization rates.

The outcome of the measurments carried out for the Mo4Ce4Al7C3 at the beamline ID12 have been published the same year by Q. Tao, T. Ouisse, D. Pinek, O. Chaix-Pluchery, F. Wilhelm, A. Rogalev, C. Opagiste, L. Jouffret, A. Champagne, J.-C. Charlier, J. Lu, L. Hultman, M. W. Barsoum, and J. Rosen in Physical Review Materials **2**, 114401 (2018), paper entitled “Rare-earth (RE) nanolaminates Mo4RE4Al7C3 featuring ferromagnetism and mixed-valence states”.