	Experiment title:	Experiment number:
ESRF	XMCD studies of magnetic moment in normal *d* metals (Ta, Nb) induced by heavy Yb ion irradiation	HC-3878
Beamline: ID12	**Date of experiment:** from: 31 Oct. 2018 at 08:00 to: 6 Nov. 2018 at 08:00	**Date of report:** 18 September 2019
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Report:

The aim of the performed experiment was to find a magnetovolume effect (MVE) in pure 4d and 5d metals, predicted by theory (see details in the priopsal) but not proved experimentally, so far. Because three-axial tensile strains are difficult to be realized, we assumed that heavy (at the level of 10^{16} ions/cm^2) and uniform in volume Yb ion irradiation of Nb and Ta films would destroy the lattice in the manner that partially resembles a strained lattice. Initial XRD measurements showed an expansion of crystal lattice after irradiation (results not shown in the report). Also SQUID measurements have shown a well-developed magnetic hysteresis loop in the irradiated samples, as expected for MVE (see Fig.1 in the proposal). The assumed magnetic moment per atom material of the film was expected to reach a level of 5e-3 μ_B. Because SQUID probes a total moment of the sample, we used an element-sensitive x-ray magnetic circular dichroism (XMCD) technique to check where the detected magnetic moment is located.

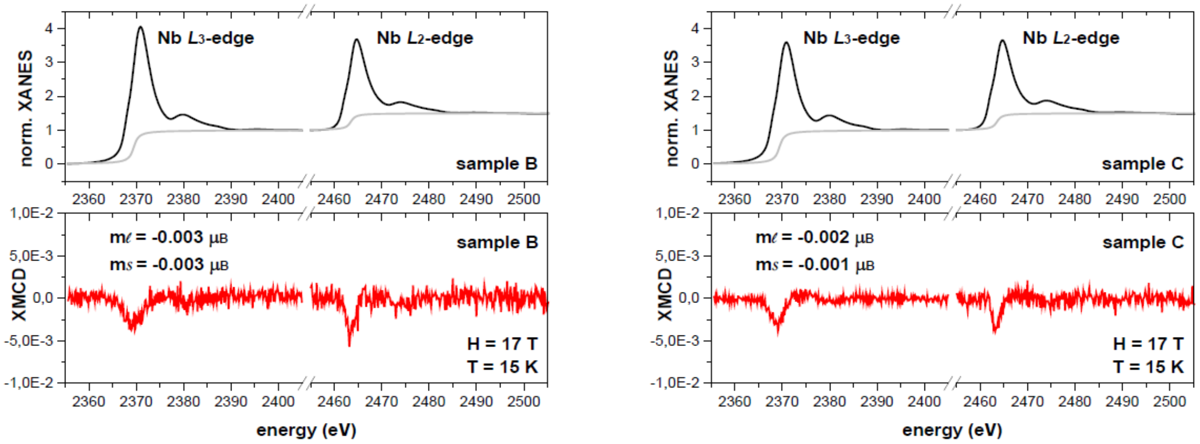

Fig. 1. Normalized Nb $L_{3,2}$ XANES and XMCD spectra recorded at 15 K and 17 T for Nb samples: B (left) and C (right).

Complete XMCD measurements were carried out for Nb films. Fig. 1 shows XANES and XMCD and XMCD spectra recorded at Nb $L_{3,2}$ edge. Both spectra for irradiated (B) and non-irradiated (C) samples suggest a low value for m_l and m_s , close to the sensitivity level of this technique. Because of a lack of any difference between these two spectra, we cannot conclude that magnetic moment is located at Nb atoms in the irradiated film. Similar results were obtained for Ta films (not shown in this report). A dependence of XMCD signal vs applied magnetic field (XMCD (H)), measured in the next step, reflected magnetization reversal of a specified element, similarly as a standard magnetic hysteresis loop recoded by magnetometry techniques. This dependence, registered for the samples B and C of Nb films at L_3 edge, shows similar flat negative slopes suggesting their diamagnetic behaviour (Fig. 2). On the contrary, the same dependence acquired for the Yb L_3 edge in Ta irradiated film displays a substantial positive slope (Fig. 3).

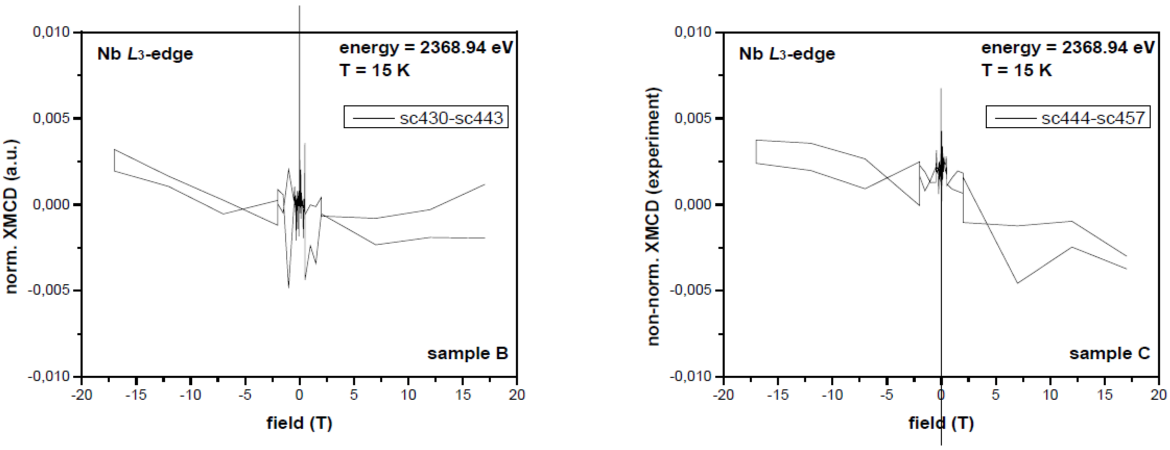

Fig. 2 The element selective Nb L_3 XMCD(H) magnetization loops recorded for Nb samples B (left) and C (right).

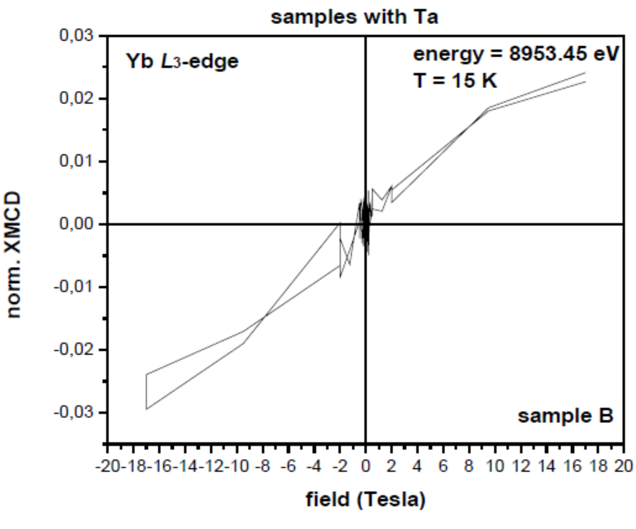

Fig. 3 The element selective XMCD(H) magnetization loop for Yb L_3-edge in the irradiated Ta film.

In conclusion, Yb ion irradiation with a fluence of 10^{16} ions/cm^2 of 4d (Nb) and 5d (Ta) metals does not induce at their atoms a magnetic moment (due crystal lattice deformation) as expected for MVE. Instead, detected magnetic moments are located most probably at the implanted Yb atoms, with a concentration of 2% in the irradiated sample. If it is located only there, a mean value should reach a value of 0.2 μ_B per atom. It is difficult to judge unequivocally whether ordering adopts the ferromagnetic or spin-glass character. Most probably, due to low concentration, it is the latter case with freezing temperature higher than that for SQUID measurements (15K) showing evident magnetic hysteresis loop in Yb-irradiated films.