ESRF	**Experiment title:** **Influence of an electric field on the magnetism of FePd ultrathin films**	**Experiment number**: MA-2327
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Names and affiliations of applicants (* indicates experimentalists):

F. Bonell[1,2,3*], S. Miwa[1,2*], K. Matsuda[1,2*], K. Tanaka[1,2], T. Nozaki[2,3], S. Yuasa[2,4], Y. Suzuki[1,2]

[1] Graduate School of Engineering Science, Osaka University, Japan

[2] CREST, Japan Science Technology Agency

[3] Institut Catala de Nanociencia I Nanotecnologia, Bellaterra, Barcelona

[4] Spintronics Research Center, AIST, Tsukuba, Japan

Report:

We measured the x-ray magnetic circular dichroism (MCD) of Pd in $L1_0$-ordered FePd thin films subjected to an external electric field (EF). The perpendicular magnetic anisotropy of these films is highly sensitive to an applied voltage as was checked in our laboratory prior to our venue (Fig. 1). The present experiments are an attempt to measure variations of the magnetic moment under electrical excitation in a conventional feromagnet. We studied an MgO/Cr/Pt(100 nm)/FePd/MgO(10 nm) multilayer grown by molecular beam epitaxy, on which an additional 1.5 µm-thick polyimide film was spin-coated. 1 mm in diameter Cr(20 nm) electrodes were evaporated on top of polymide and electrically contacted, the bottom Pt/FePd electrode being grounded. The beam incoming direction and applied magnetic field were parallel and slightly off-normal to the sample plane in order to avoid diffraction peaks near the Pd $L_{2,3}$ edges. The absorption was measured with total fluorescence yield. All experiments were done at room temperature. The applied voltage of ±200 V corresponds to an EF of about 50 mV/nm at the FePd/MgO interface. It was flipped several times in order to be able to rule out any drift in the signals.

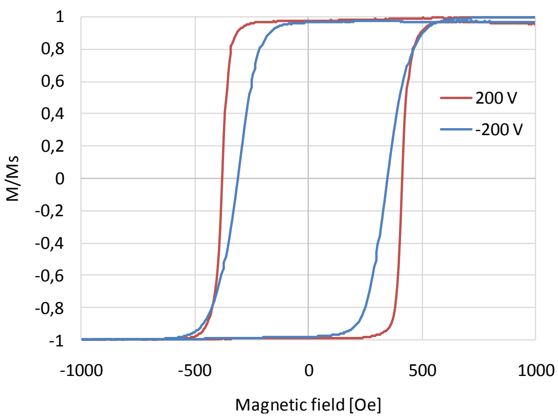

Fig. 1 – Polar Kerr magnetic loops of $(FePd)_4$ under ±200 V, showing the sensitivity of the perpendicular magnetic anisotropy to the electric field.

The preliminary results obtained during MA/1963 beam time showed variations of the Pd orbital moment (~20%) under ±200 V, whereas virtually no change was observed in the spin moment and in the white lines. However, the XANES baseline was somehow unstable and the presence of Au M edges (we used Cr/Au contacts) was responsible for a strong background preventing us to determine the absolute values of the EF-induced orbital moment.

The objective of MA/2327 was twofold: (i) improving the signal-to-noise ratio in order to clearly demonstrate the influence of the EF on the magnetic moments, and (ii) determining quantitatively the Pd magnetic moment and its variations. To this end:

- The contact electrodes were made of pure Cr instead of Cr/Au, which led to a clear improvement of the XANES baseline and the possibility to determine the magnetic moment accurately.
- Thinner $(FePd)_n$ films were studied, with n=4 as compared to n=8 during MA/1963. The Pd MCD was clear, demonstrating the ability of the beamline to measure such a small amount of material. However, the junctions with n=4 broke down due to the combination of electrical stress and interaction of the dielectric layer with x-rays. During the remaining beam time, we focused on an additional sample with n=8.
- The voltage was increased up to ±300 V (instead of ±200 V during MA/1963). Although the electrical stability under ±300 V was checked in our laboratory, the junctions systematically suffered dielectric breakdown after ~3 hours. A large photocurrent was also measured, which suggests that x-ray exposure induces an additional stress on the junctions. This issue was not noticed during MA/1963, most probably because of the lower beam current (16 bunch mode for MA/1963, 7/8+1 mode for MA/2327). The junctions investigated subsequently were subjected to a voltage of ±200 V and remained stable during several days.
- The new ID12 detector for partial fluorescence yield was tested successfully on our samples. However, the integration time could not be optimized beacause of the strong fluorescence from phosphorus present in the polyimide film, which led to saturation of the detector. A better signal-to-noise ratio was achieved with total fluorescence yield, which was therefore used for subsequent measurements.

The beam time remaining after these tests was dedicated to the measurement of a junction with thick FePd. Because of the large FePd thickness, the effect of the EF on Pd MCD could not be evidenced. However, better stability of the beam together with improvement in the XANES background allowed us to evidence systematic variations of the absorption under voltage (Fig. 2). The most prominent variations were visible in the XANES. They are hysteretic and originate from trapped charges in polyimide and at the MgO/polyimide interface. Notably, the time constant for stabilizing the junction (1-2 hours) was much larger than required during Kerr measurements (< 1 hour), which may be related to the x-ray photocurrent. It is however possible to obtain a stable electrical state under ±200 V. Concerning the signal-to-noise ratio (S/N), we found that the larger photon flux in 7/8+1 mode compensated the loss in statistics due to the dead time required after changing the voltage. As in MA/1963, we achieved S/N≈10, but with a more reliable signal.

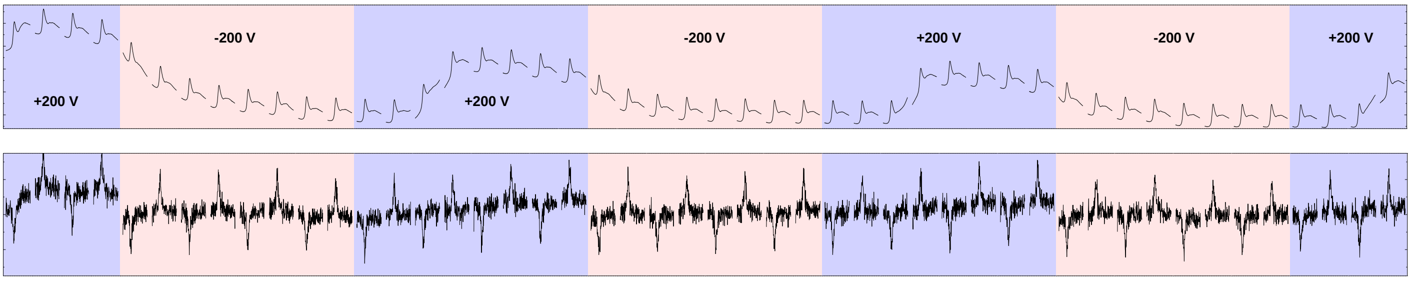

Fig. 2 – Pd L_3 XANES (top) and MCD (bottom) as a function of time. The helicity is flipped between each spectrum. The voltage is flipped between +200V (blue background) and -200V (red background).

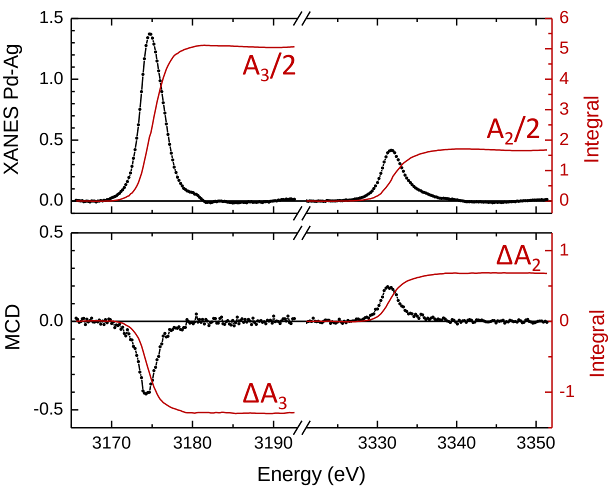

Fig. 3 – Pd XANES and MCD together with the integrals entering the sum rules. A reference background (rescaled Ag XANES measured on ID12) has been subtracted from the Pd XANES, following the standard analysis.

Applying the sum rules (Fig. 3), the Pd orbital and effective spin moments in our films were found equal to m_S=0.20±0.09 μ_B and m_L=0.06±0.01 μ_B. Although the variations of the magnetic moments under an EF could not be measured, MA/2327 beam time allowed us to confirm the relevance of the optimized sample structure and to determine the measurement conditions which guarantee a stable and maximized signal.