ESRF	**Experiment title:** **Influence of an electric field on the magnetism of FePd ultrathin films**	**Experiment number**: MA-1963
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Report:

In this experiment, we measured the x-ray magnetic circular dichroism (MCD) of Pd in $L1_0$-ordered FePd thin films subjected to an external electric field. The perpendicular magnetic anisotropy of these films is highly sensitive to an applied voltage [1-3]. Spin-dependent capacitive charging is believed to be the origin of this effect [4,5], but the detailed microscopic mechanism has not been uncovered experimentally so far. The present experiments are the first attempt to measure variations of the magnetic moment under electrical excitation in a conventional feromagnet. We studied an MgO/Cr/Pt(100 nm)/FePd(3 nm)/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(3 nm)/Au(60 nm) electrodes were evaporated on top of polymide and electrically contacted, the bottom Pt/FePd electrode being grounded [2,3]. The beam incoming direction and applied magnetic field were both normal to the sample plane; the absorption detected by fluorescence yield. All experiments were done at room temperature. The applied voltage of ±200 V corresponds to an electric field of about 50 mV/nm at the FePd/MgO interface.

Figure 1 (a) and (b) show the influence of the electric field on polar Kerr magnetization loops and Pd L_3 MCD loops, respectively. In both cases, positive (negative) voltage results in a reproducible increase (decrease) of the coercivity of about 20%. This result shows the feasibility of MCD measurements under electrical excitation with our custom-made setup, in terms of beam positionning (the ~500 µm beam could address one single junction), stability of the dielectric (3 shifts to acquire data in Fig. 2(b)) and magnitude of the signal (8 burried atomic layers of Pd were probed).

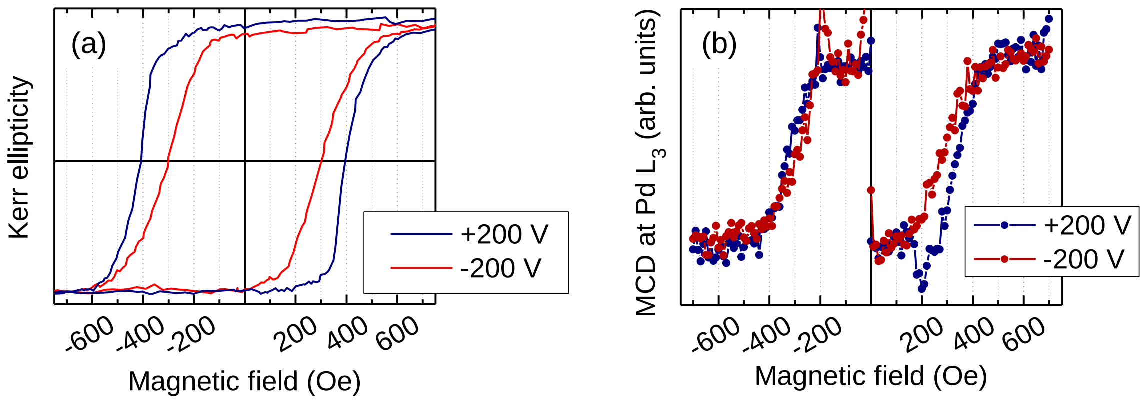

Fig. 1 (a) Polar Kerr magnetization loops of FePd under ±200 V (measured in Osaka University). (b) MCD loops of FePd at the Pd L_3 edge under ±200 V (same multilayer than Fig. 1(a), but different location on the surface). The coercivity change due to the applied electric field is observed in both experiments.

Figure 2 shows the averaged Pd $L_{2,3}$ MCD signal and the change in the MCD integrals under voltage application. The data were obtained at magnetic saturation (±0.5 T), so that the observed variations are due to changes in the magnitude of the magnetic moment, not in its orientation. This result was found to be reproducible when flipping three times the electric field direction, and it clearly shows that the magnetoelectricity of ultrathin FePd is related to Pd magnetism.

By application of the sum rules, the variation of the orbital and effective spin moments under ±200 V amounts to ±25% and ±3%, respectively. Measurable variations in the spin moment are actually unexpected and are possibly due to the influence of the electric field on the magnetic dipole term, which measures the asphericity of the spin density. Additional angular measurements are required to clarify this issue, and to measure the orbital moment anisotropy as well.

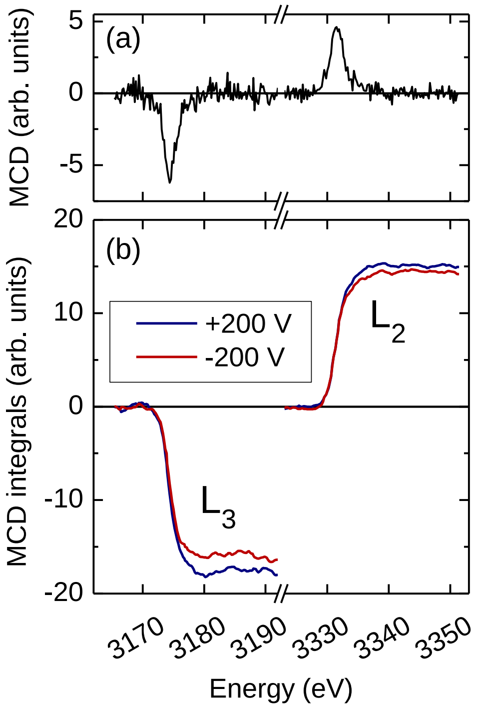

Fig. 2 (a) Averaged MCD spectrum at the Pd $L_{2,3}$ edges. (b) Integrals of the $L_{2,3}$ peaks measured under ±200 V, showing a clear dependence on the applied voltage, which indicates that the anisotropy variations are related to Pd magnetism.

For an accurate quantitative study of the magnetic moments magnitude and anisotropy under voltage application, further optimization of the samples and setup is planed. First, the absolute determination of the magnetic moments was hampered by a large background (in XANES, not in MCD) due to strong absorption at Au edges. Therefore, pure Cr electrodes should be prefered in future experiments. Improvement of the signal-to-noise can also be reached by increasing the applied voltage up to ±300 V. Indeed, we oberved dielectric breakdown around 350 V. Moreover, given the signal magnitude in the present experiments, it will be possible to study thinner FePd (down to 1.5 nm ≡ 4 Pd atomic layers), which shows a much larger magnetoelectric effect. At last, improvement of the sample holder will enable further reduction of the background by reducing the contribution of reflected photons in the total count.

References

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