Pt 5d Magnetic States in Ordered Fe-Pt alloy under High Pressure Probed by the Pt L_{2,3}-edges XMCD

N. Ishimatsu,¹ M. Yamaeda,¹ H. Maruyama,¹ N. Kawamura,² M. Suzuki²

¹Department of Physical Science, Graduate School of Science, Hiroshima University, Higashi-Hiroshima, Japan.
²Japan Synchrotron Radiation Research Institute/SPring-8, Sayo, Japan.

Introduction
Fe-Pt alloy shows a wide variety of magnetic properties and crystal structures depending on the chemical composition. Although ordered Fe₃Pt (O-Fe₃Pt) and ordered FePt₁ take the cubic L₁₂-type crystal structure, they stabilize different magnetic states, i.e., the ferromagnetic state and the antiferromagnetic state, respectively. On the other hand, ordered Fe₅Pt (O-Fe₅Pt) takes the tetragonal L₁₀-type crystal structure and shows a hard magnetic property due to a large uniaxial magnetic anisotropy.¹ The unit cell of the ferromagnetic O-Fe₅Pt (a=3.85 Å, c=3.72 Å) has larger volume than that of the ferromagnetic O-Fe₅Pt (a=3.73 Å) at ambient condition.

To understand the relationship between the magnetic property and the crystal structure of the Fe-Pt alloys, pressure dependence of the magnetic state is one of the most fundamental issues. Since the Fe 3d- and Pt 5d-electronic states are strongly correlated with the nearest neighboring atoms, the applied pressure effectively affects their electronic states and may result in a modification of the magnetic state in the system. In this study, we compare the pressure variation of the Pt 5d electronic states in the ferromagnetic O-Fe₅Pt and O-FePt alloys by means of Pt L_{2,3}-edges X-ray magnetic circular dichroism (XMCD). The Pt L_{2,3}-edges XMCD is a useful technique for probing the ferromagnetic state under pressure because of small X-ray absorption by a pressure cell.

Experimental Procedure
X-ray absorption spectroscopy (XAS) and XMCD experiments under high pressure were carried out using the helicity-reversal method on the beamline 39XU at SPring-8. A diamond phase retarder was employed to produce the circularly polarized beam. Diamond anvil cells (DAC) were used for applying pressure. In order to magnetically saturate the sample, the high magnetic field of ±10T was applied to the O-FePt powder. For this measurement, a tiny DAC, 23.8 mm φ × 47 mm in length, was inserted into a superconducting electromagnet. The magnetic field of ±0.6 T was applied to the O-FePt powder sample. All the measurement was done at room temperature.

Result and Discussion
Figure 1(a) shows the pressure variation of the Pt L₃-edge XMCD spectrum of O-Fe₅Pt. In the compression process, the negative XMCD amplitude abruptly decreases from 0.8 GPa and disappears at pressures above P_c=3.5 GPa. Hence, the Pt 5d magnetic moment of O-Fe₅Pt is easily suppressed with increasing pressure. As the applied pressure is released, a reversible pressure variation of the XMCD spectrum is observed; O-Fe₅Pt transforms from the ferromagnetic state to a paramagnetic state due to a pressure-induced 2nd order transition. It is noted that the ferromagnetic state of O-Fe₅Pt disappears at much lower pressure than P_c=20 GPa of disordered Fe₇₁Pt₂₉ reported by Odin et al.²,³

On the other hand, the pressure variation of the Pt L₃-edge XMCD in O-FePt is different from that in O-Fe₅Pt. As shown in Fig. 1(b), the XMCD of O-FePt exhibiting intense amplitude of about -0.13 indicates the presence of a large Pt 5d magnetic moment. Furthermore, the intense XMCD amplitude remains even though the applied pressure reaches up to 20 GPa. Therefore, the Pt 5d magnetic moment is almost maintained at the maximum pressure, and no pressure-induced magnetic transition is recognized. This result evidences a highly stabilized ferromagnetic state of O-FePt under pressure.

Conclusion
We have successfully measured the pressure variation of the Pt L_{2,3}-edges XMCD spectrum indicating an obvious difference in the Pt 5d magnetic states of O-Fe₅Pt and O-FePt under pressure. This result gives an evidence that the ferromagnetic state strongly depends on the crystal structure of the Fe-Pt alloy. It is considered that the high stability of the ferromagnetic state of O-FePt may be attributed to the large volume of the unit cell compared with that of O-FePt. Since the spin-polarized Pt 5d electronic states are induced by the Fe 3d magnetic states, the obtained results are strongly related to pressure dependence of Fe 3d magnetic states in O-FePt and O-FePt alloys.

References

![Figure 1(a): O-Fe₅Pt XMCD spectrum with pressure dependence. M. Yamaeda et al., J. Appl. Phys. 110, 063915 (2011).](image)

![Figure 1(b): O-FePt XMCD spectrum with pressure dependence. M. Yamaeda et al., J. Appl. Phys. 110, 063915 (2011).](image)