SXPES of Single Crystal $Fe_{82}Ga_{18}$ by Different Surface Cleaning Methods

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Surface sensitive soft X-ray photoelectron spectroscopy (SXPES) requires a clean surface. In this research, we succeeded in creating a clean surface by cleavage in vacuum for SXPES of $Fe_{82}Ga_{18}$ single crystal, which is known as a magnetostrictive material, and compared the obtained results with those of on a clean surface created by a combination of polishing in Ar gas and Ar^+ ion sputtering.

1. Introduction

Fe-Ga alloys with a Ga concentration between 15 and 25 at% show ferromagnetic at room temperature, and magnetostriction of 200-300 ppm is obtained [1]. The crystal structure is bcc and since maximum magnetostriction is obtained in the <100> direction, the axis of easy magnetization, higher crystal orientation is needed for magnetostrictive materials. Fe-Ga alloys are expected to be applied to actuators, sensors, and vibration power generation devices because of their excellent mechanical properties. Understanding the electronic structure is important to elucidate the mechanisms of these physical properties. In this research, we planned SXPES with the single crystal $Fe_{82}Ga_{18}$ by different surface cleaning methods.

2. Experimental

Surface sensitive soft X-ray photoelectron spectroscopy (SXPES) measurements by Al Kα emission (1486.7 eV) was measured at SA-1 (ULVAC-PHI Quantes) of the SR Center. Fig. 1 (a) shows a sample polished in Ar gas and after that the surface was Ar^+ ion bombarded in-situ and Fig. 1 (b) shows a sample cleaved in a vacuum. In both cases, the observed surface is (100) plane.

In sputtering, a low acceleration voltage (500 V) was adopted to reduce the effects of preferential sputtering [2]. In cleavage, the sample was cleaved in the cleavage chamber of SA-1 (~10^{-6} Pa) and then moved to the measurement chamber (~10^{-8} Pa) while maintaining a vacuum.

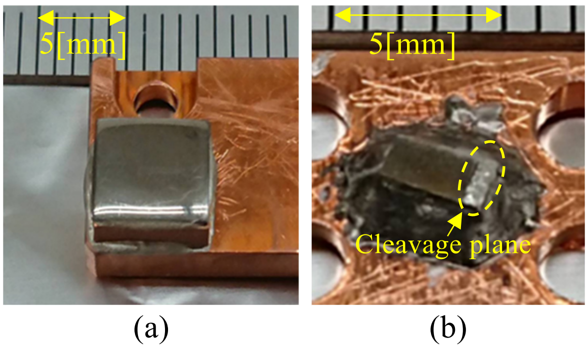

Fig. 1 Photographs of measured samples. Polished and spattered (a), Cleaved (b).

For comparison, the SXPES obtained from this experiment was normalized to the area of the spectrum after background removal using the Shirley method [3, 4].

3. Results and Discussion

Fig. 2 and Fig. 3 show Ga 2p SXPES and Fe 2p SXPES at cleaved surface, respectively and comparison between immediately after cleavage and after about 40 hours. Compared to Fe 2p SXPES, the change over time in Ga 2p SXPES is more remarkable. The shoulder structures found after about 40 hours seen around 1118eV and 1145eV in Ga 2p SXPES is thought to be mainly due to oxidation [5]. Although the measurement chamber is

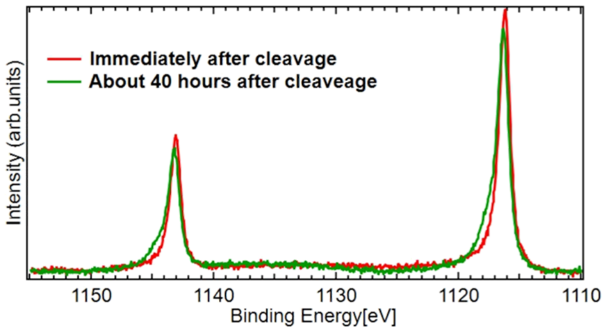

Fig. 2 Ga 2p SXPES comparison immediately after cleavage and after about 40 hours.

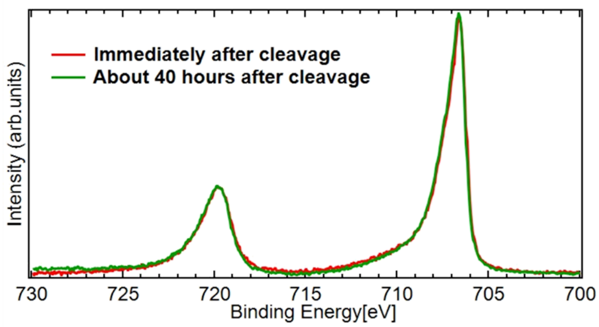

Fig. 3 Fe 2p SXPES comparison immediately after cleavage and after about 40 hours.

kept in ~10^{-8} Pa, the surface like oxidation over time cannot be avoided due to residual gas. This results also indicate that Ga could be more preferentially oxidized than Fe. For this reason, it is desirable to SXPES immediately after cleavage. In the following sections, we discuss the SXPES results immediately after cleavage for comparison.

Fig. 4 shows a comparison of Ga 2p SXPES on clean surfaces obtained by Ar^+ ion bombarded for total 1, 5, 15, and 40 minutes at an acceleration energy of 500V after polishing in Ar gas and on clean surfaces immediately after cleavage. The characteristic spectrum structures around 1118 eV and 1145 eV indicate oxide peaks [5]. These peaks disappear with increasing total time of sputtering, and approach the results of immediately after cleavage.

Fig. 5 shows a similar comparison of Fe 2p SXPES between different surface cleaning conditions. Unlike Ga 2p SXPES, oxide peaks around 710eV and 723eV area [6] are mainly seen in the 1-minute sputtering and there is no significant difference in photoelectron spectra when sputtering for more than 15 minutes and these spectra are very

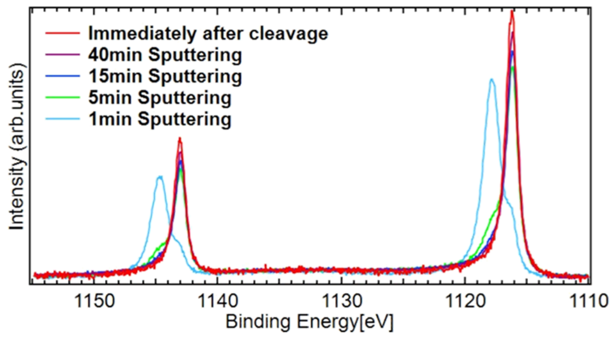

Fig. 4 Comparison of Ga 2p SXPES on clean surfaces obtained by Ar^+ ion bombarded for total 1, 5, 15, and 40 minutes at an acceleration energy of 500V after polishing in Ar gas and on clean surfaces immediately after cleavage.

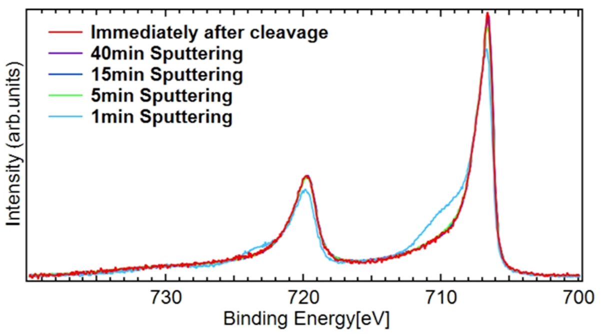

Fig. 5 Comparison of Fe 2p SXPES on clean surfaces obtained by Ar^+ ion bombarded for total 1, 5, 15, and 40 minutes at an acceleration energy of 500V after polishing in Ar gas and on clean surfaces immediately after cleavage.

similar to the spectrum of cleaved surface. These results mean that longer sputtering times are expected to yield results closer to the cleavage results.

Another reasons why the effect of oxidation is larger in Ga 2p SXPES than in Fe 2p SXPES is expected due to the difference in binding energy. Ga 2p orbital has a higher binding energy than Fe 2p orbital. Therefore, when a Fe-Ga alloy is irradiated with Al Kα emission, the photoelectron kinetic energy derived from Ga 2p orbital is smaller than that derived from Fe 2p orbital, and photoelectron's mean free path for Ga 2p electron is shorter than that for Fe 2p electron [7]. Therefore, Ga 2p is more surface sensitive than Fe 2p, and the effect of surface oxidation is considered to be more pronounced.

4. Conclusions

Compared to the clean surface immediately after cleavage, the clean surface obtained by Ar+ ion bombarded for total 15 minutes or less at an acceleration energy of 500V in situ after polishing in Ar gas was found to show significant effects of oxidation especially for Ga 2p SXPES. On the other hand, there were no significant differences in the shape of the spectrum for either Ga 2p SXPES or Fe 2p SXPES on the clean surface obtained by Ar^+ ion bombarded for total 40 minutes compared to the clean surface immediately after cleavage. Therefore, it is likely that differences in surface cleaning methods will not produce notable differences in experimental results, and it is desirable to select a more suitable cleaning method depending on the experimental environment and method.

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