

Papers, etc.

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The two Al 2p peaks characteristic of metallic Al, peak-a and -b, were separated by 0.18 eV. To obtain information about the origin of these peaks, Al 2p spectra of the clean surface at different electron emission angles were measured. Peak-b at normal emission was stronger than at 30 degree take-off angle. Therefore, the origin of peak-b is located deeper below the surface and peak-a is attributed to a top surface component. Such chemical shifts between top surface and bulk atoms were observed also in NiAl(110), where the separation of the two peaks was 0.13 eV. Since peak-a disappeared at 512 L, the surface was completely covered by oxide at this dosage.

To obtain information about the origin of peak-c (73.63 eV) and -d (74.90 eV), Al 2p spectra were measured at normal emission and 30 degree take-off angle after 4000 L exposure, Fig. 3. Peak-d is more pronounced than peak-c for 30 degree take-off angle. Therefore, peak-d is located most towards the surface after oxidation. Since peak-b arises from the bulk, it is considered that peak-c originates at the interface between the substrate and outer layer (peak-d). The peak-d at 74.90 eV is attributed to Al in Al₂O₃ from the following two considerations: Al₂O₃ is the only oxide of aluminum in the phase diagram, and the Al 2p binding energy has been reported as approximately 75 eV, both for bulk oxide and alumina formed on Al foil.^{11,12} The binding energy of the interface layer, peak-c, 73.63 eV, falls between that of metallic Al and Al₂O₃. Such a chemical shift for an interface component is well-known for the SiC/Si interface.¹¹ An Al 2p chemical shift due to an interface component was reported for a well-ordered alumina layer formed on

NiAl(110)¹², where the interface was considered to be Al-terminated. It has been reported that in the case of an oxygen terminated interface made by the deposition of pure Cu on alpha-AlCu(O001), no Al 2p peak due to an interface Al component was observed.^{13,14} Therefore, it is believed that the interface is Al-terminated in our case.

The thickness of the interface layer and alumina layer was estimated using the method described in reference 15. With this method, the thickness of the interface layer (d_1) is estimated from eq. (1) and that of the alumina layer (d_2) from eq. (2).

$$d_1 = \lambda_{Al}^{2p} \times \sin^2 \theta \times \ln \left[\frac{I_{Al}^{2p}(30^\circ) \times N_{Cu}^{Al}}{I_{Al}^{2p}(0^\circ) \times N_{Cu}^{Al}} + 1 \right] \quad (1)$$

$$d_2 = \lambda_{Al}^{2p} \times \sin^2 \theta \times \ln \left[\frac{I_{Al}^{2p}(30^\circ) \times N_{Al}^{Al_2O_3}}{I_{Al}^{2p}(0^\circ) \times N_{Al}^{Al_2O_3}} + 1 \right] \quad (2)$$

where I_{Al}^{2p,Al_2O_3} , $I_{Al}^{2p,Al}$, and $I_{Al}^{2p,CuAl}$ are Al 2p intensity from alumina (peak-d), the interface (peak-c) and Cu-Al alloy (peak-b). The following values of the inelastic mean free path of the Al 2p photoelectron are used (kinetic energy of ca. 30 eV): alumina, $\lambda_{Al}^{2p,Al_2O_3}$, 1.24 nm; the interface layer, $\lambda_{Al}^{2p,Al}$, 1.24 nm; Cu-Al alloy, $\lambda_{Al}^{2p,CuAl}$, 0.60 nm.¹⁵ N_{Cu}^{Al} , N_{Al}^{Al} , and $N_{Al}^{Al_2O_3}$ are atomic densities of Al in the Cu-Al alloy, in the interface layer and in alumina. For the atomic density of Al in the interface layer, the average value between pure Al (6.02×10^{22} /cm³) and alumina (4.69×10^{22} /cm³) was used. The values used for N_{Cu}^{Al} , N_{Al}^{Al} and $N_{Al}^{Al_2O_3}$ are 7.50×10^{22} /cm³, 5.36×10^{22} /cm³ and 4.69×10^{22} /cm³, respectively. θ is the take-off angle of photoelectrons and is 90 degrees in this case. The estimated thickness of the interface layer reached around 0.25 nm and stayed almost constant for further oxygen exposure. This thickness, 0.25 nm, corresponds to the sum of one aluminum layer and one oxygen layer in the basic structure of the either possible growth orientation of the alumina film. The stacking of the aluminum and oxygen layers may be as in either the alpha-Al₂O₃ (0001) or the gamma-Al₂O₃ (111) plane.¹¹ The thickness of the alumina layer for 1024 L is approximately 1.3

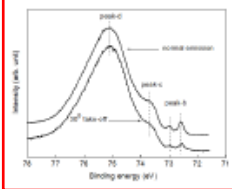
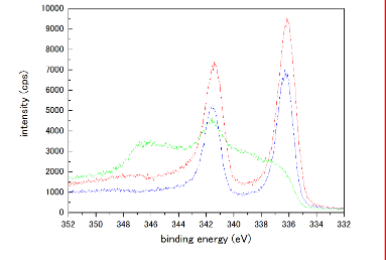
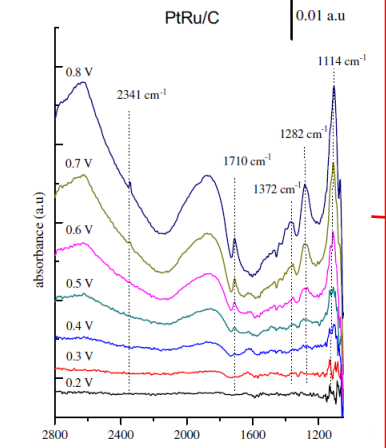
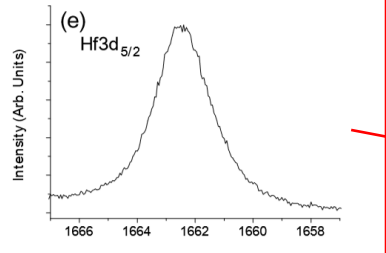
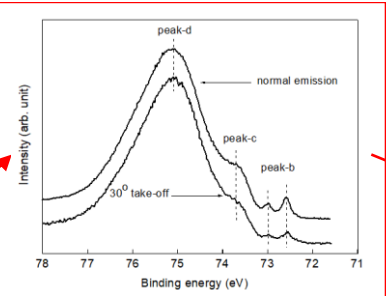


Fig. 3 The Al 2p photoelectron spectra obtained with 106 eV light at normal emission and 30 degree take-off angle after 4000 L exposure.



Numerical data in csv files

0.2304,0.2360,0.2465, ...,
0.7623,0.7521
0.3230,0.3232,0.3241, ...,
0.4425,0.4378

0.2639,0.2640,0.2677,0.2739,
0.2745, ..., 0.1093,0.1124

0.5094,0.5095,0.5098, ...,
0.5396,0.5345
0.4030,0.4032,0.4038, ...,
0.4393,0.4370
0.3350,0.3348,0.3343, ...,
0.3703,0.3688
... ..

0.2304,0.2360,0.2465, ...,
0.7623,0.7521
0.3230,0.3232, ...,
0.4425,0.4378

This program