

Magnetic Properties of Nickel Layers Electrodeposited on Amorphous Carbon

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The electrodeposition of the initial several layers is well known to be different from the normal behavior at thicker ranges. We previously verified that the electrode potentials of cobalt and cobalt-nickel alloy are noticeably dependent on the layer thickness by using controlled pulsed current. The immersion potential (E_{imm}) for the substrate or the deposit reflects the nature of the electrode surface. E_{imm} can be measured as the electrode potential for the pulse-off (E_{off}). In the previous studies it was found that E_{imm} of the deposit at the initial stage is different from the steady value at about 50 ML. In the case of the Co-Ni alloy, the elemental composition was also found to vary up to 50 ML. On the other hand, by measuring the i - E curve for the electrodes before and after the deposition, it was clarified that the overpotential of cathodic deposition at the initial 50 ML stage is also different from the steady value. The shifts of the immersion potential and the overpotential can be ascribed to the changes of the film morphology and/or texture. However, the possibility of diffusion of the substrate element into the film layer cannot be excluded. In this work, we have investigated the structure and magnetic properties of nickel films electrodeposited on amorphous carbon. Carbon substrate was employed because it is not solved in the electrolytic solution or is not diffused into the film. The structure and magnetic properties may be influenced by the electrochemical behavior at the initial stage.

Figure 1 shows the potential curve during the deposition by the pulsed current ($I=25\text{mA/cm}^2$, $T_{on}=100\text{ms}$, and $T_{off}=1000\text{ms}$). E_{imm} at the initial stage up to 10-20 pulses was particularly different from that above 10-20 pulse region. This indicates that the E_{imm} change is characteristic of the deposit surface itself, without any diffusion of carbon. This electrochemical behavior may be related to the chemical condition of the deposits surface. Figure 2 shows the XPS of the Ni films of 1 to 50 ML. Ni metal and NiO phases were predominant for more than 10 ML films, while the oxide phase and another unclear one for less than 5 ML. The last phase might be the hydroxide, and the peak positions seem to be dependent on the film thickness.

Electrodeposited Ni films composed of several chemical phases exhibit different nanostructure depending on the film thickness. The MCXD experiment is useful to estimate separately the spin and orbital moments, and provides the magnetic properties of the nanostructure. Figure 3 shows the MCXD spectra of 1 to 50 ML Ni films. The MCXD intensity for the films thicker than 50 ML was similar to that of 50 ML, and for the film thickness of less than 10 ML, the MCXD intensity decreases as the film is thinner. These results are contradictory with those given by SQUID. This is because the thinner the Ni films are, the more non-ferromagnetic phase is present in the deposit, and the MCXD intensity originates only from the corresponding metallic nickel phase. Hence, we tried to modify the MCXD intensity by using a ratio of magnitude of only the metallic phase, which could be calculated from the XAS spectra. The modified MCXD intensity is consistent with the magnetization given by SQUID.

The present study did not give appreciable change of the spin and orbital moments, and the modification is difficult for less than 5 ML films because of the presence of unknown complicated phases. Our next step is to prepare the films without surface oxide layer by capping thin gold layer, and further more precise experiments must be done to verify the relation between

the magnetic moments and the nanostructure of deposits.

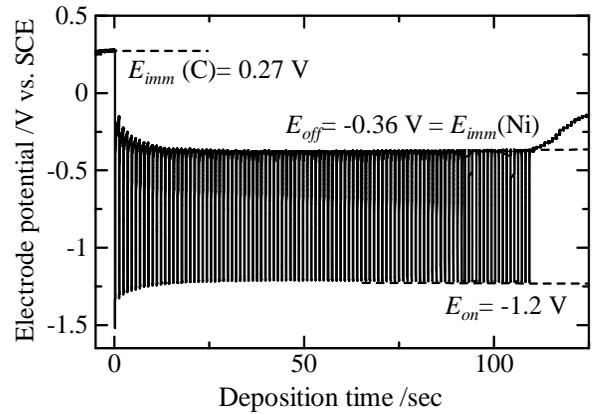


Fig. 1 Potential curve of the electrodeposition of nickel on carbon substrate, with the pulsed current. About 1 ML of nickel electrodeposits with 1 pulse of the current.

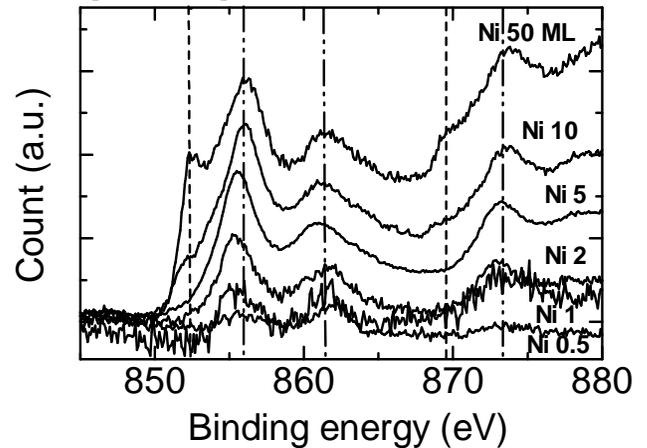


Fig. 2 XPS in the Ni2p region for 1 to 50 ML Ni films deposited on amorphous carbon. Dotted and broken lines denote the metallic Ni and NiO phases, respectively. For less than 5 ML, another phase exists, which can be ascribed to nickel hydroxide.

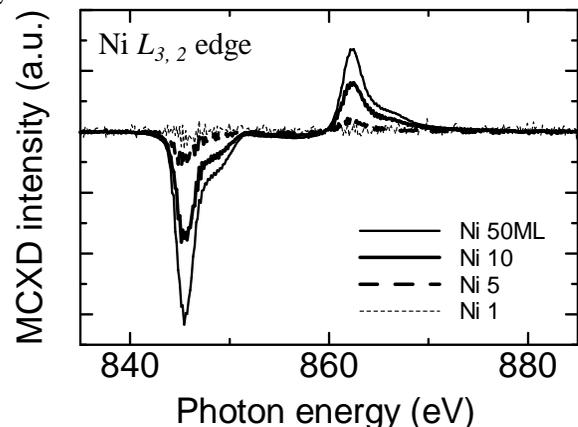


Fig. 3 MCXD spectra of nickel films, which were obtained by normalizing XAS in a conventional manner.