Extended Abstract of PSA-19
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Fine structure of spectrum of secondary electron, 5: metals and their compounds

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The fine structures of secondary electron are considered using the electron spectra measured using the special CMA. The differential logarithmic spectrum and EELS revealed that the fine structure is closely related the electronic structure such as the plasmon and unoccupied state.

1. Introduction

Although the material contrast in the secondary electron image with ultra-low acceleration voltage has been observed, the interpretation for this contrast is limited. Werner et al. showed that the decay of the plasmon is essential for Al using the coincidence spectroscopy [1]. Willis showed that the electron excited at the unoccupied state gives the fine structure of the spectrum of the secondary electron for W [2]. Such attempts are only performed for the limited elements, and the universal idea of the emission of the secondary electron is not known.

Therefore, the fine structure of the spectrum of the secondary electron for elemental metals and their compounds, which are measured using the Cylindrical Mirror Analyzer (CMA) which is specially designed [4], is classified to consider the origin of emission of the secondary electron.

2. Formula for fine structure in energy distribution of secondary electron

The spectrum of the secondary electron, $N(E)$ is expressed as eq. (1) as is shown in the elsewhere [3].

$$N(E) = Cp \cdot E^{-\gamma} + Cex \cdot E^{-\gamma} \int_{E}^{Emax} \emptyset ex(E' - E_0) \cdot dE' \quad (1)$$

The energy distribution of the secondary electron in the cascade is expressed by the negative power law [4]. The first term is due to the secondary electron produced by the primary electron and the second term is due to that produced by the other excitation. The energy distribution of the other excitation is expressed as $\phi_{ex}(E-E_0)$. E_0 is the peak energy of the excitation and E_{max} is the maximum energy of the secondary electron that the excitation generates. Here, we assume that the probability, which the excitation generates the secondary electron, is independent to the energy of the excitation. The excitation is directly appeared in the differentiation of the logarithm of eq.(1) as eq.(2). This spectrum is called as the DLS spectrum here.

$$\frac{dLn(N(E))}{dLn(E)} = -\gamma - E \frac{\emptyset ex(E - E_0)}{1 + \frac{Cex}{Cp} \int_{E}^{Emax} \emptyset ex(E' - E_0) \cdot dE'} \quad (2)$$

3. Experimental

The spectrum for Li, Mg, Al, Al_2O_3, Si, Ti, Fe, Fe_2O_3, Ni, Cu, Zn, Ga, GaP, GaAs, Zr, Mo, Ag, Sn, W, Au, Pb and soot was measured with the acceleration voltage of 1000V using specially designed CMA[4]. The DLS spectrum of secondary electron is compared with the Electron Energy Loss Spectroscopy (EELS) spectrum with the acceleration voltage of 200 V having the similar energy resolution of this DLS.

4. Results and discussion

Figure 1 shows the spectra (N(E), DLS and EELS) of Al, Ga, Fe and W. Comparing DLS spectrum and EELS spectrum, the peak of DLS for Al (15 eV) and Ga (14 eV) is same as the free electron plasmon peak in

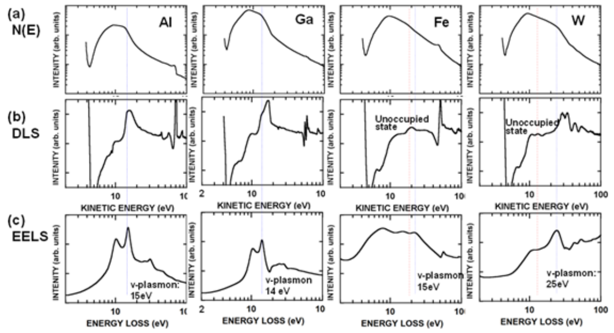

Fig.1 Energy distribution of secondary electron of A and Gal as NFE metal and Fe, W as transition metal, Ep=1000 eV for N(E) and DLS, Ep=200 eV for EELS. (a) N(E) spectrum, (b) deferential logarithmic N(E) spectrum, (c) EELS spectrum.

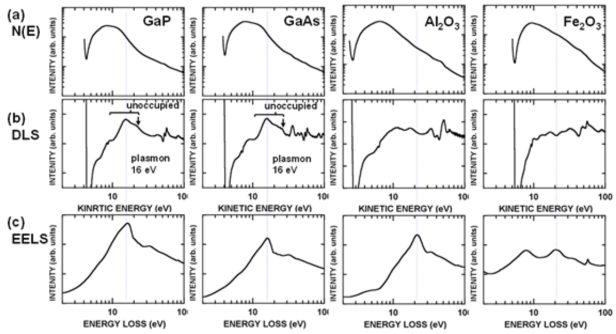

Fig.2 Energy distribution of secondary electron of GaP, GaAs, Al_2O_3 and Fe_2O_3. Ep=1000 eV for N(E) and DLS, Ep=200 eV for EELS. (a) N(E) spectrum, (b) deferential logarithmic N(E) spectrum, (c) EELS spectrum.

EELS. This result suggests that the plasmon produced by the incident electron decays, the electrons in the plasmon are emitted into the material, these electrons form the cascade and that the secondary electrons are finally produced.

The peaks except the plasmon are seen in the DLS spectrum of Fe and W. The peak of Fe (15 eV) and W (13 eV) is close to the component of the unoccupied state [2,6]. The results suggest that the electrons excited to the unoccupied state by the interband transition also cause the cascade and produce the secondary electrons.

The DLS spectra of the metals are summarized in Fig.3. The spectra shows that the decay of the plasmon cause the fine structure of the secondary electron for NFE metals and other metals transition metals and noble metal. The electron which is excited to the unoccupied state becomes another reason of the fine structure for the transition metal and noble metal.

Fig. 2 shows the spectrum of GaP, GaAs, Al_2O_3 and Fe_2O_3. For the DLS spectrum of GaP and GaAs, the energy of a peak is same that of the plasmon and the other components are close to the DOS of the unoccupied state [7].

The component by the plasmon is not significant in the DLS of Al_2O_3 and Fe_2O_3. Some peaks are close to those of the DOSs of the unoccupied states [8]. These results suggest that the main contribution to the fine structure is due to the electrons which are excited to the unoccupied state.

5. Summary

The fine structures of secondary electron are measured using the specially designed CMA. The differential logarithmic spectrum and EELS revealed that the fine structure is closely related the electronic structure such as the plasmon and the unoccupied state.

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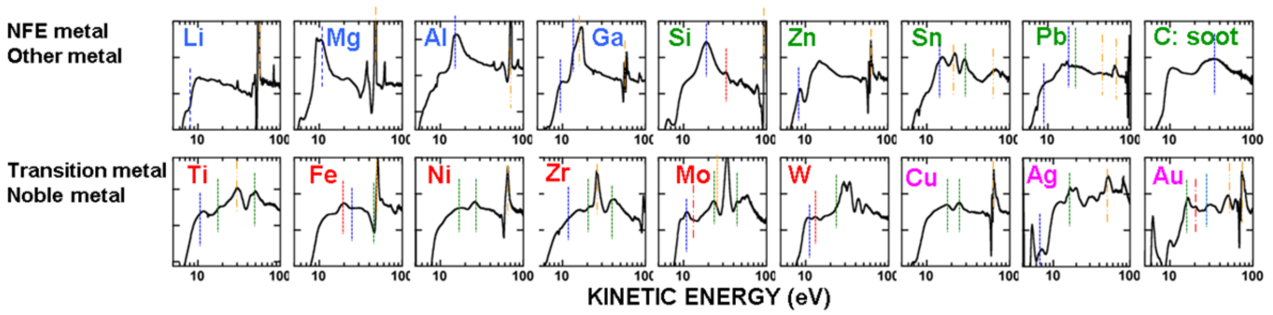

Fig.3 DLS spectrum of NFE metals (Li, Mg, Al, Ga), other metals(Si, Zn, Sn, Pb, soot), transition metals (Ti, Fe, Ni, Zr, Mo, W) and noble metal (Cu, Ag, Au). Ep=1000 eV. Broken line: plasmon, chain lines: unoccupied state, chain double-dashed lines: peaks Auger electron.