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Secondary Ion Characteristics of Al-Ni Intermetallic Compounds Sputtered by Ar Ion

Nobuya IWAMOTO*, Yoshiaki TSUNAWAKI ** and Toshiaki TAKEUCHI***

The ion microanalyzer (IMA) has two faculties — to sputter secondary ions from a surface of the solid material and to analyze these through a mass spectrometer. It has been already mentioned by several investigators\(^1\)\(^–\)\(^3\) that IMA has characteristics as follows; high sensitivity to detect light elements, an ability of analysis of sputtered ions from extremely thin solid surface and excellent depth profiling capability of elements in solid material in spite of the lack of a sufficiently quantitative technique.

From a viewpoint of depth profiling, it is in progress using IMA in our laboratory to elucidate the oxidation process of some alloys\(^4\) and the origin of the joint defect in diffusion welding.\(^5\) This note reports the secondary ion characteristics of Al-Ni intermetallic compounds formed in diffusion welding of mild steel — nickel interlayer — aluminum.

When the nickel interlayer is used in diffusion welding between mild steel and aluminum, two kinds of intermetallic layers in the weld are formed which are identified to be \(\text{Al}_3\text{Ni}_2\) and \(\text{Al}_3\text{Ni}\) by X-ray diffraction measurement.\(^6\) The fracture of the welded joint occurs often in \(\text{Al}_3\text{Ni}_2\) layer.

Figure 1 shows the yields of the various secondary ions on the fracture of mild steel and aluminum sides, respectively. The experimental conditions of IMA are as follows;

- primary ion source: \(\text{Ar}^+\)
- primary ion beam diameter: 1mm
- accelerating voltage: 10KV
- sample current: 2\(\mu\)A

It is observed that iron and aluminum diffuse into the opposite sides through the nickel layer. Nickel also

![Graph](image)

**Fig. 1** Relative secondary ion yield of various elements on fracture surface vs. sputtering time.

\(\dagger\) Received on Jan. 8, 1976
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distributes into aluminum but has a plateau in vicinity of the fracture. The molecular ion of AlNi+ has maximum yield at the fracture. In the aluminum sides, multiply charged ion of \( \text{Al}^{2+} \) shows the plateaus both in the outer and inner sides. The yield in the former is about one third as large as that in the latter. The inner and outer sides would probably correspond to \( \text{Al}_3\text{Ni} \) and \( \text{Al}_3\text{Ni}_2 \) intermetallic layers, respectively.

It is difficult to interpret theoretically above mentioned features of various ions. It will be, therefore, important to investigate the standard specimens of \( \text{Al}_3\text{Ni}_2 \) and \( \text{Al}_3\text{Ni} \) intermetallic compounds. Their specimens were prepared as follows. Analytical grade powder reagents of aluminum and nickel were weighed and mixed to be ratio of stoichiometry. After they were pressed to disks (14mmφ x 2mmt), they were sintered at 600°C for 3 days in argon atmosphere. They were checked to be \( \text{Al}_3\text{Ni}_2 \) and \( \text{Al}_3\text{Ni} \) intermetallic compounds with X-ray diffraction means.

Relative secondary ion yields of \( \text{Al}_3\text{Ni}_2 \) and \( \text{Al}_3\text{Ni} \) versus to the energy of primary argon ion are shown in Fig. 2. The secondary ion species observed are \( \text{Al}^{2+} \), \( \text{Al}^+ \), \( \text{Al}_2^+ \) and \( \text{AlNi}^+ \). The ordinate shows the ratio of intensities between each secondary ion and \( \text{Al}^+ \) ion. Solid and broken lines correspond to the results of \( \text{Al}_3\text{Ni}_2 \) and \( \text{Al}_3\text{Ni} \), respectively. All ion yields increased monochinarily with the voltage of primary ion such as in the case of oxide materials.6) The gradients in \( \text{Al}_3\text{Ni}_2 \) were almost as large as those in \( \text{Al}_3\text{Ni} \). The tendency was remarkable for \( \text{Al}^2^+ \). The \( \text{Al}^{2+} \) ion yield of \( \text{Al}_3\text{Ni}_2 \) is one third as that of \( \text{Al}_3\text{Ni} \). It is very interesting that this value is same as that in Fig. 1.

It is considered that these phenomena would be probably due to the bonding force between the atoms in the specimens and also suggest possibility of the state analysis of various materials. If it is so, it is necessary to investigate not only single charged matrix ions but also complex ions such as multiply charged and molecular ions. However, it remains difficulty to discuss the details of the relation between the all of the secondary ion yields and the bonding force because of the occurrence of complex ionization process.

Further studies using IMA on the secondary ion yield of various elements are in progress.

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