ELECTROREFINING OF ALUMINUM CONTAINING 1MASS% Fe USING A BIPOLAR ELECTRODE CELL

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ABSTRACT

To investigate the applicability of a vertically stacked bipolar electrode cell to electrorefining of Al from scrap Al, the cell composed of three units was made with anode 61%Al - 37.3%Cu alloy containing 1%Fe and 0.7% Mn (mass) in melt and electrolysis was carried out for six hours at 750 °C. As the electricity of 90 Ahr, which corresponded to Al deposition of 30.0g per cathode in 100% current efficiency, was applied, the total mass of electrodeposited Al was 87.5g. The amounts of Mn, Cu and Fe in deposited Al were under 0.003, 0.008 and 0.009 %, respectively; the purity of Al exceeded 99.98%. The concentration of Al components in the 3rd unit containing a terminal anode increased compared with the initial concentration, and that in the 1st unit containing a terminal cathode decreased. It was interpreted that the reaction current through bipolar electrodes became small due to bypass current, and the bipolar electrodes worked almost ideally. The vertically stacked bipolar electrode cell is, therefore, useful for electrorefining of Al from scrap Al, if some counterpane to dissolve the ununiformity of the concentration in the cell is laid down.

INTRODUCTION

There is a possibility to achieve high energy saving and high productivity in application of a bipolar electrode system to electrorefining of Al, but such attempt has not been carried out yet. To investigate the fundamental characteristics of the Al refining system,
first we have studied electrowinning of high-purity Al from Al alloys with similar compositions to scrap aluminum using a single electrode cell operating in three layers, and proposed a new electrolytic melt for the system and reported the electrical conductivity of the melt and the behavior of Fe, Si and Mg components in the anode Al-Cu alloy \(^{13}\).

In this report, a bipolar electrode system was applied to electrowinning of aluminum containing Fe and Mn and the mass balances among deposited Al, anode alloys and dissolved aluminum components in each unit of the cell were described together with the purity of the deposited Al.

**EXPERIMENTAL**

The apparatus employed is illustrated in Fig. 1. The test cell was a graphite crucible whose inner wall was covered with an alumina tube (80 mm in inner diameter) inserted into the crucible. The test cell was composed of a terminal anode, a terminal cathode and two bipolar electrodes arranged between the terminal electrodes; the cell was three unit cell. Each electrodes were separated at regular spacings of 15 mm by three alumina tubes (6 mm in outer diameter). The alloys (61%Al- 37.3%Cu-1%Fe-0.7%Mn) settled in the bottoms of the graphite crucible and bipolar electrodes worked as an anode. Ni pieces were embedded in each bottom to improve the electric contact. The terminal cathode and the downward graphite surfaces of the bipolar electrodes operated as a cathode.

The reverse-funnel shape electrodes, the terminal cathode and two bipolar electrodes, had small center holes (2 mm in diameter), which gas bubbles were able to pass through, whereas the particles of deposited Al were not, and it enabled us to measure separately the masses of Al deposited in each unit.

After melting a 55 mol% BaCl\(_2\)-NaCl salt in the crucible at 750 \(\degree\)C, a 40 mol% AlF\(_3\)-NaF double salt was added to it. Next, the bipolar electrodes and the terminal cathode were inserted into the melt. The upper terminal graphite electrode and the lower terminal alloy electrode were connected with the positive and negative pole of a power supply respectively, and the pre-treatment of the melts was carried out at 0.22 Acm\(^{-2}\) for about one hour. During this pre-treatment the melt was stirred by chlorine gas evolved on the graphite electrodes, and the concentration of Al components in the melt was prepared between 7.5 and 5 mol\%. After the pre-treatment both electric poles were oppositely connected, and electrolysis was carried out for six hours and 90 Ahr as a total electricity.
was applied. It was possible to apply the current up to 0.75 Acm$^{-2}$ to these terminal electrodes in the melt with the Al concentration of 5 mol% 4). After the electrolysis, small parts of the melt were sampled from each of the three units, and the Al metals electrodeposited in each unit and the anode alloys remained in each unit were collected and weighed. The collected sample melts and the deposited Al were dissolved in 6M HCl and analyzed with ICP emission spectroscopy.

**RESULTS AND DISCUSSION**

The masses of the electrodeposited Al and cathodic current efficiency in each unit are presented in Table 1, and the decreases in mass of the anode alloys and anodic current efficiency in each unit are presented in Table 2. The table shows that the mass of Al electrodeposited in the first unit surpasses those in the other two units and almost corresponds to 100% current efficiency. Table 3 shows that the amount of dissolved Al in the third unit exceeds the others and the current efficiency shows about 100%. From these results it can be easily expected that Al concentration in the first unit decreases and that of the third unit increases, and it happened as presented in Table 3, where the concentrations of Al components in each unit are presented. The concentration of Al components of the first unit was decreased and that in the third unit increased, whereas the concentration in the second unit stayed at the initial concentration before electrolysis. The results suggest that both bipolar electrodes operated equally and the reaction current on both bipolar electrodes was smaller than that on both terminal electrodes due to bypass current.

The relation between bath voltage and applied current measured in the test cell is presented in Fig.2. The figure shows that there was a linear relation between applied current and bath voltage, and this suggests that the bath voltage was mostly attributed to ohmic potential drops in the electrolyte. The intercept of the curve to the ordinate shows almost 0.1V and it is probably due to the potential shifts for the surface layer formed on the anode alloys and the low activity of Al in the anode alloys, but the deviation is not large. This well explains the results from electrolysis as the bipolar system worked almost ideally except for the existence of small bypass current, and also it shows that some counterplan for dissolution of ununiformity of the concentration in the cell is required.

The amounts of Mn, Cu and Fe in deposited Al were under 0.003, 0.008 and 0.009
mass%, respectively; the purity of Al exceeded 99.98%. It suggests that the elements added to Al were satisfactorily removed by the bipolar electrode system similarly to a single cell.

CONCLUSIONS

The bipolar cell with three units was prepared and electrolysis was carried out focusing on reaction current, concentration of Al components and purity of electrodeposited Al in each unit. Both masses of Al electrodeposited or dissolved in terminal electrodes almost corresponded to 100% current efficiency of applied electricity, but the reaction currents on bipolar electrodes were smaller than the applied current for the bypass current. Al contents in the melts containing the terminal electrodes, therefore, changed from the initial content. But the bipolar electrodes worked almost ideally, and if some counterplan to laid down, the vertically stacked bipolar electrode cell is useful for electrorefining of pure Al from scrap Al.

Fe and Mn contents in the alloys were satisfactorily lowered, the purity of 99.98 mass% for electrodeposited Al was achieved.

REFERENCES

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### Table 1  Quantity of electrodeposited Al and Cathodic current efficiency in each unit.

| Unit  | Electrodeposited Al | Cathodic Current Efficiency |
|-------|---------------------|-----------------------------|
| 1st Unit | 30.07 (g)          | 100 (%)                     |
| 2nd Unit | 28.96              | 96.5                        |
| 3rd Unit | 28.52              | 95.1                        |

### Table 2  Quantity of dissolved Al and anodic current efficiency in each unit.

| Unit  | Dissolved Al | Anodic Current Efficiency |
|-------|--------------|----------------------------|
| 1st Unit | 27.96 (g)    | 93.2 (%)                  |
| 2nd Unit | 28.36        | 94.5                      |
| 3rd Unit | 30.10        | 100                       |

### Table 3  Concentration of Al in the melt in each unit.

| Unit  | Al Concentration |
|-------|------------------|
| 1st Unit | 4.6 (mol%)      |
| 2nd Unit | 4.8              |
| 3rd Unit | 5.1              |
Fig. 1 Schematic diagram of cell assembly.
Fig. 2 Relation between bath voltage and applied current.