Precise Detection of Evaporation Boat Breakdown

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Abstract

Film evaporation boat sometimes breaks down in combination with poor electrodes. Denka succeeded in developing precise current monitoring system which can detect a short term current down. Frequent discontinuities of boat current were resultant signs of the breakdown of an evaporation boat. This was a powerful tool in developing a high performance boat against the thermal stress.

Introduction

High performance of film evaporation boats is desirable for metallizers. Low erosion rate and high evaporation rate with few spitting are required, however, the mechanical strength against the break down is more significant to present the boat performance. Some of boats are terminated in operation because of the cracking or the collapse. In this case, 'Crack' is recognized as a cleft opening from an edge. In this paper our attention is focused on 'Collapse' near the boat edge and the preliminary phenomenon are detected by a precise measurements.

Origin and growing of a crack

The causes of crack are clamping problem, boat strength, mismatch of boat length and underestimate of the resistivity. These problems are avoidable if an appropriate operation is applied on the optimized boats. Contact between a boat and an electrode is, on the other hand, a serious problem. The electrodes are being damaged after long time evaporation and overflowing aluminum sometimes erodes the surface of electrode (Figure 1). Cleaning electrodes sometimes may waste the surfaces of them worse.

Fig. 1 Electrodes eroded after long time evaporation

That is why the contact point can play important roll in generating a crack. A small crack is sometimes found at an edge (Figure 2). Some of cracks are possibly grow longer; on the other hand, several cracks may join and collapse the boat edge (Figure 3). The edge of boat is finally chipping or broken down (Figure 4) and the electric current is shut down.

Fig. 2 Small crack appeared at a boat edge

Fig. 3 Eroded boat edge by localized heating

We assumed micro cracks are beginnings of damages at boat edge and tried to observe micro cracks growing. The conventional technique to survey micro cracks is measuring acoustic emissions. In an evaporation chamber, however, it's difficult to detect any emission because of extremely noisy condition. Then we noticed a micro crack arising may influence the electric current for a moment. Precise detection of electric current was attempted.

Fig. 4 Eroded boat edge was finally chipping or broken down

Measuring system

A typical block diagram of power source in an evaporation machine is shown in Figure 6. Voltage and current meters on the panel are mostly indicating those of input (V_1, A_1) to the transformer. The current at this point is not corresponding to that through a boat and delicate ripple or jump of the boat current is not detectable here. This is why a direct monitor of the large current through a boat is significant to observe cracks growing in the boat. A current meter (A_2) was installed through the boat power line, and substituted by a sensor of a data logger afterward. The sampling time of this current monitor was 0.1 second. The data acquisition was continued throughout the evaporation.

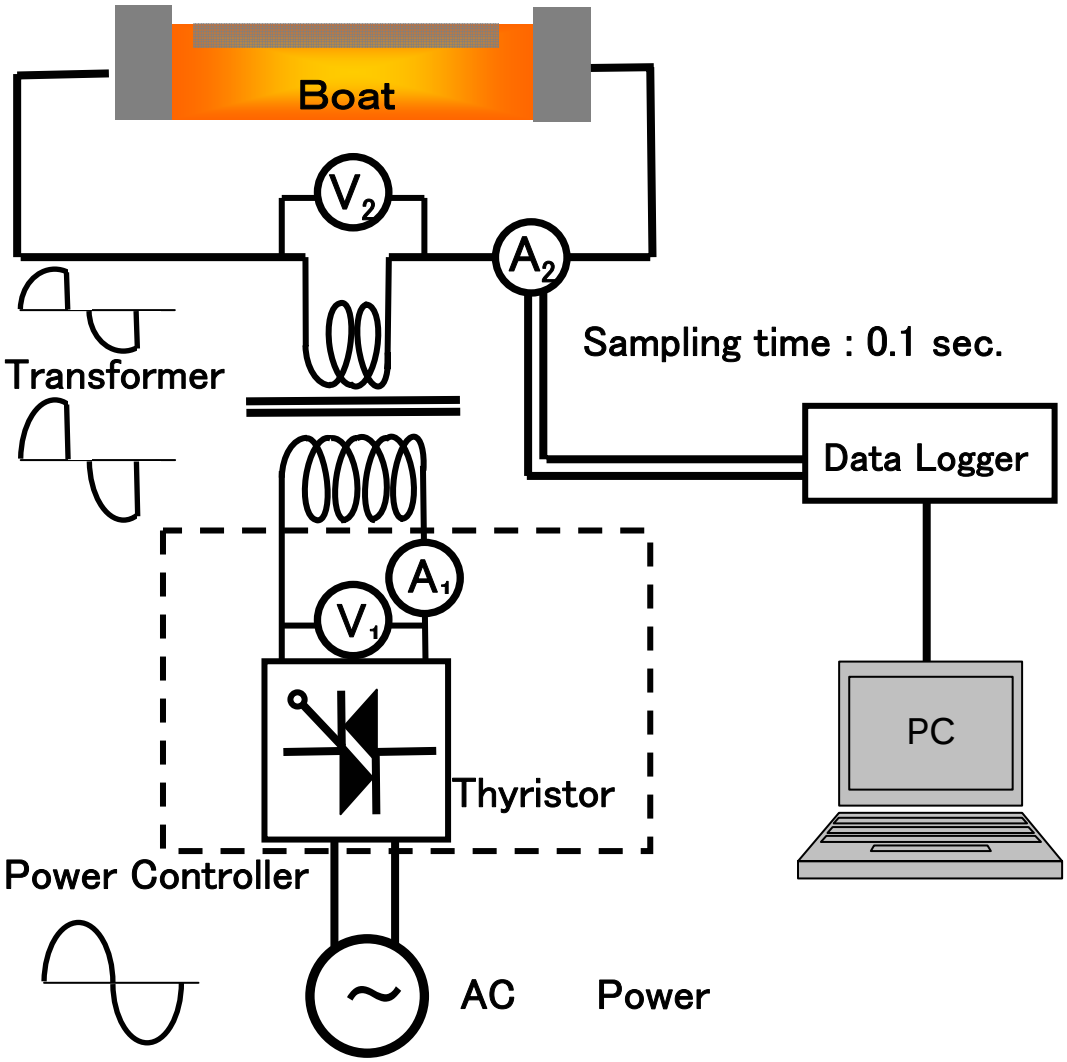


Fig. 5 Block diagram of a boat heater power circuit and data acquisition system of boat current. Current from commercial AC input is controlled by an electric device and transformed in advance of the boat circuit. The boat current is monitored directly.

Standardization of an electrode in the measurement

To evaluate the potential of a boat against the cracking in combination with bumpy electrodes, the surface of electrode is not negligible to obtain reliable data. A tilted electrode was adopted at the beginning of measurement as Fig. 6 (left), however, the

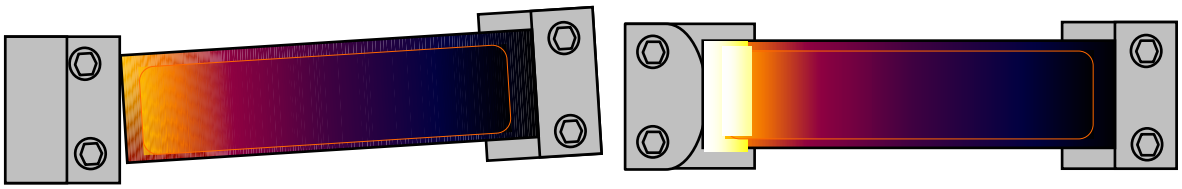


Fig. 6 Point contact trial with tilted boat (left) and the adopted electrode with curved surface (right).

contact between a boat edge and electrode is not so constant as to obtain the repeatable boat current. Then the electrode was improved with curved surface which guarantees constant contact in any time (right).

Analysis of observed data

Figure 10 shows an example of boat current down observed for a boat which was destroyed at the edge in the beginning of the evaporation. In this run, the applied power was increased step by step and regulated at each step. The boat temperature is also monitored using an optical meter and added on the graph. When the temperature was increased from 600A to 650A, the first current down about -40% was observed. The consequent current jump was the result of a feedback function of the power source. The similar current down was also observed when the current was around 680A. Then the aluminum wire was fed into the boat and the current was increased further more (Time > 8 min). This current increase also brought rise of the temperature at the boat edge contacted at a point. (Fig.7) Frequent current downs were observed consequently and the boat current was finally shut down. Figure 9 is the edge of the salvaged boat. Discolored area is trace of the overheating caused by the point contact. The block clipping, which brought the current shut down, is observed. Microscopic observation revealed small cracking at 5mm depth from the edge surface. Frequent current downs were caused by generation and growth of cracks which can prevent the boat current.

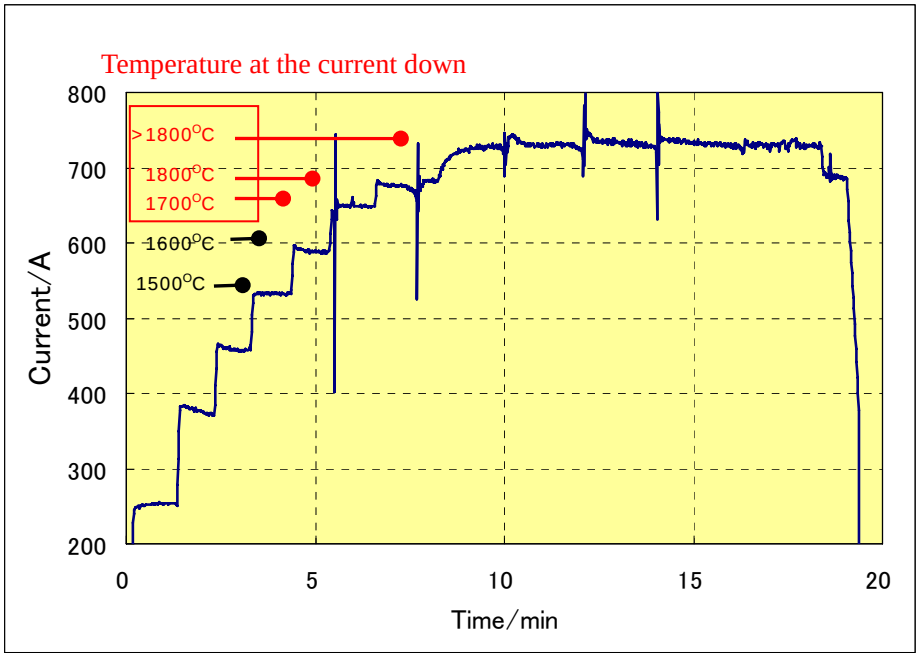


Fig. 7 Boat current in increasing temperature and observed current downs of a boat which was destroyed at the edge.

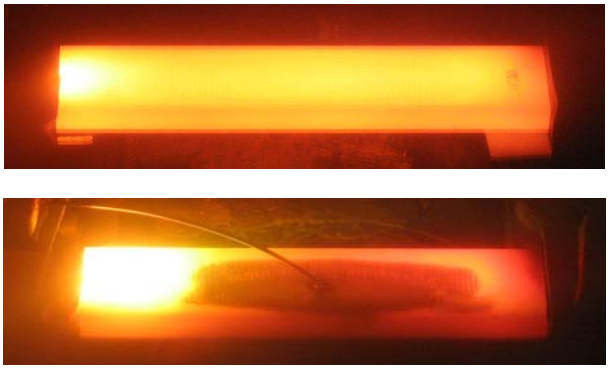
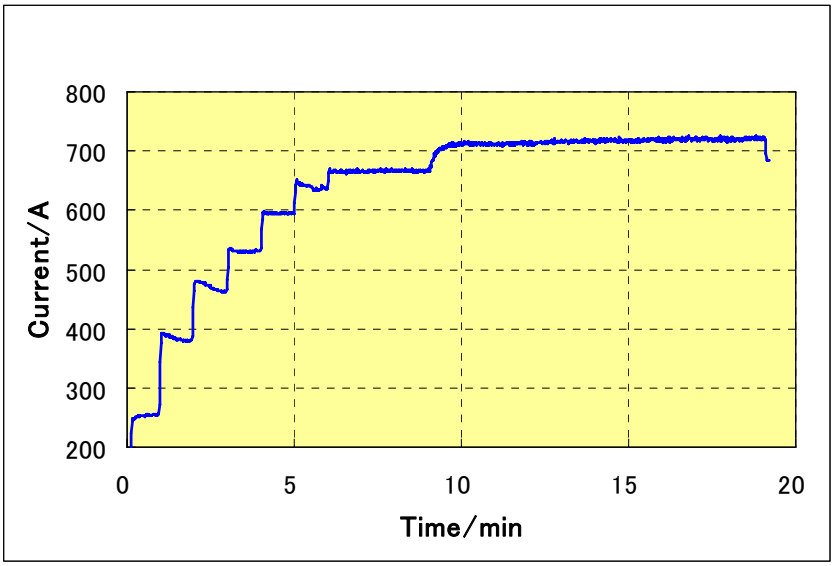


Fig.8 Thermal concentration at the point contact of electrode. Above: Before evaporation, Bellow: During evaporation.

Fig. 9 Damaged and clipped edge of the boat applied in the measurement of Fig10.

Observation of an edge intensified boat

The purpose of in-situ crack observation is actually to evaluate anti-crack boats developed. Figure 10 shows typical data and figure of the boat. This boat is an 'edge intensified boat' of which the edge is improved to reduce the thermal stress. No current down is observed at every step up of the applied power and the aluminum evaporation is started without any problem. Attached figure shows little damage at the boat edge.



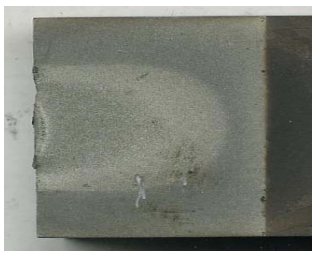


Fig.10 Boat current profile in increasing temperature of the edge intensified boat. Figure (right) shows damage at the edge is not severe in spite of the discoloration by overheat.

Long-term observation of boat current

Even if the evaporation is started without current down, new crack is possibly generated and growing during aluminum evaporation. Those cracks accumulate damages at the edge and edge block is sometimes clipped off in the middle of the evaporation. In the next step, the boat current monitor was continued during two hours approximately. Short time shut down was inevitable during the test to exchange the aluminum wire roll. Figure 11 shows the acquired data on the 'edge intensified boat'. Any remarkable current down was not observed during the evaporation. The photograph reveals damage at the boat edge was not so serious as to make boat current unstable.

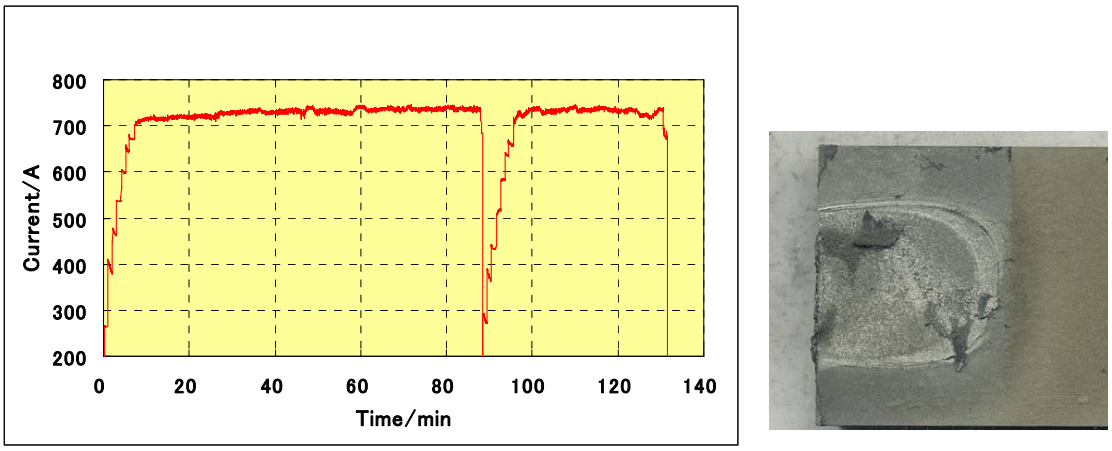


Fig.11 Boat current profile throughout the evaporation up to two hours. Data were acquired on the 'edge intensified boat'.
Figure (right) shows damage at the boat edge was not so serious

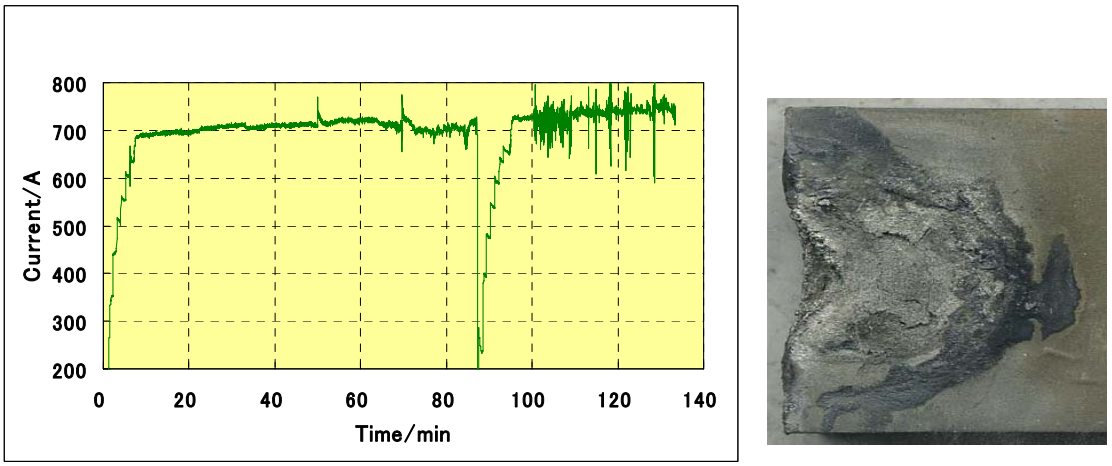


Fig.12 Boat current profile throughout the evaporation up to two hours. Data were acquired on a boat of other brands.
Figure (right) shows a clip of damaged block.

Figure 12 shows data acquired on a boat of other brands. Several current downs were, on the contrary, observed before the aluminum wire roll change. The current was changed to be unstable after the aluminum wire roll change and finally shut down after frequent current downs. The figure of the boat edge showed a clip of damaged block.

Summary

1. Electrodes with eroded surface may cause damage at the boat edge and new electrode with curved surface was adopted to evaluate the boat strength against cracks.
2. High speed current monitor on evaporation boats was attempted to detect micro cracks arising and growing in the advance of the fatal damage.
3. Frequent current downs were apparently observed as the symptom before the shut-down caused by edge damage.

References

1) K. Ikarashi, A. Miyai, S. Watanabe, J. Susaki and K. Iwamoto. WO 2005 049881 A1 (Denki Kagaku Kogyo KK), Prior. 2003-11-20