Direct Observation of Cathode Surface†
– Gas-Tungsten-Arc Electrode (3) –

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Abstract

Direct observation of cathode tip during arc burning was carried out by using stereoscope. The important phenomena concerning the current density, morphorogical change near emission area as a function of arcing time and current in pure argon and pure helium shielding gases, and rim formation in Ar+0.2%O_2 and He+0.2%O_2 shielding gases were studied. La_2O_3-W electrodes are superior to ThO_2-W electrodes in these characteristics. Also, the effective work functions of these electrodes were estimated showing that the work function of La_2O_3-W electrode is lower than that of ThO_2-W electrode.

KEY WORDS: (Oxide Tungsten) (Work Function) (Direct Observation)

1. Introduction

From the previous studies[1] it was concluded that the La_2O_3-W electrode in GTAW has superior characteristics, namely, arc starting characteristics, arc pressure distribution, electrode consumption, and, etc. comparing with for that of ThO_2-W electrode.

This work was thus directed towards analysing the reasons why La_2O_3-W electrodes have superior characteristics than ThO_2-W electrodes. To clarify these reasons, it is necessary to observe the cathode surface during arc burning and investigate the surface phenomena-current density, arc root as a function in arcing time and the formation of rim in several shielding gases, namely, pure argon, pure helium, Ar+0.2%O_2 and He+0.2%O_2.

2. Experimental work

Various types of tungsten electrodes activated with La_2O_3, ThO_2 were produced by the conventional powder metallurgy process, with 3.2mm in diameter, centerless ground. **Table 1** shows the chemical composition of these electrodes. Direct current was applied in electrode negative polarity and copper cooled anode.

Fig. 1 shows schematic illustration of the experimental alignment used in this study for direct observation of electrode surface during arc burning. The intense light from Xe lamp was focused on the electrode tip by lens to overcome the effect of plasma. Then the electrode tip observed clearly by stereoscope.

Table 1 Electrode produced and its oxide content.

Electrode material		Oxide content (%)
Thorium oxide-Tungsten	(ThO_2-W)	2
Lanthanum oxide-Tungsten	(La_2O_3-W)	2

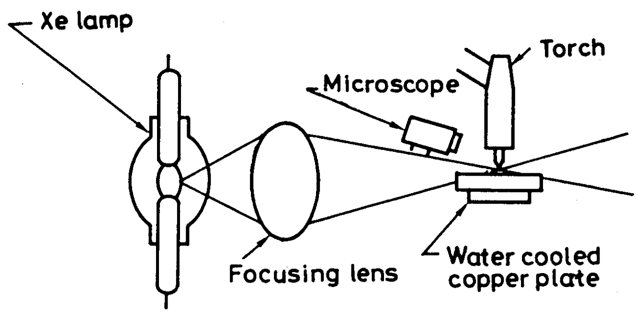

Fig. 1 Schematic illustration of direct observation alignment.

3. Results and Discussion

Fig. 2 shows the change of cathode surface after burning at various currents for 1 min in pure argon. It is

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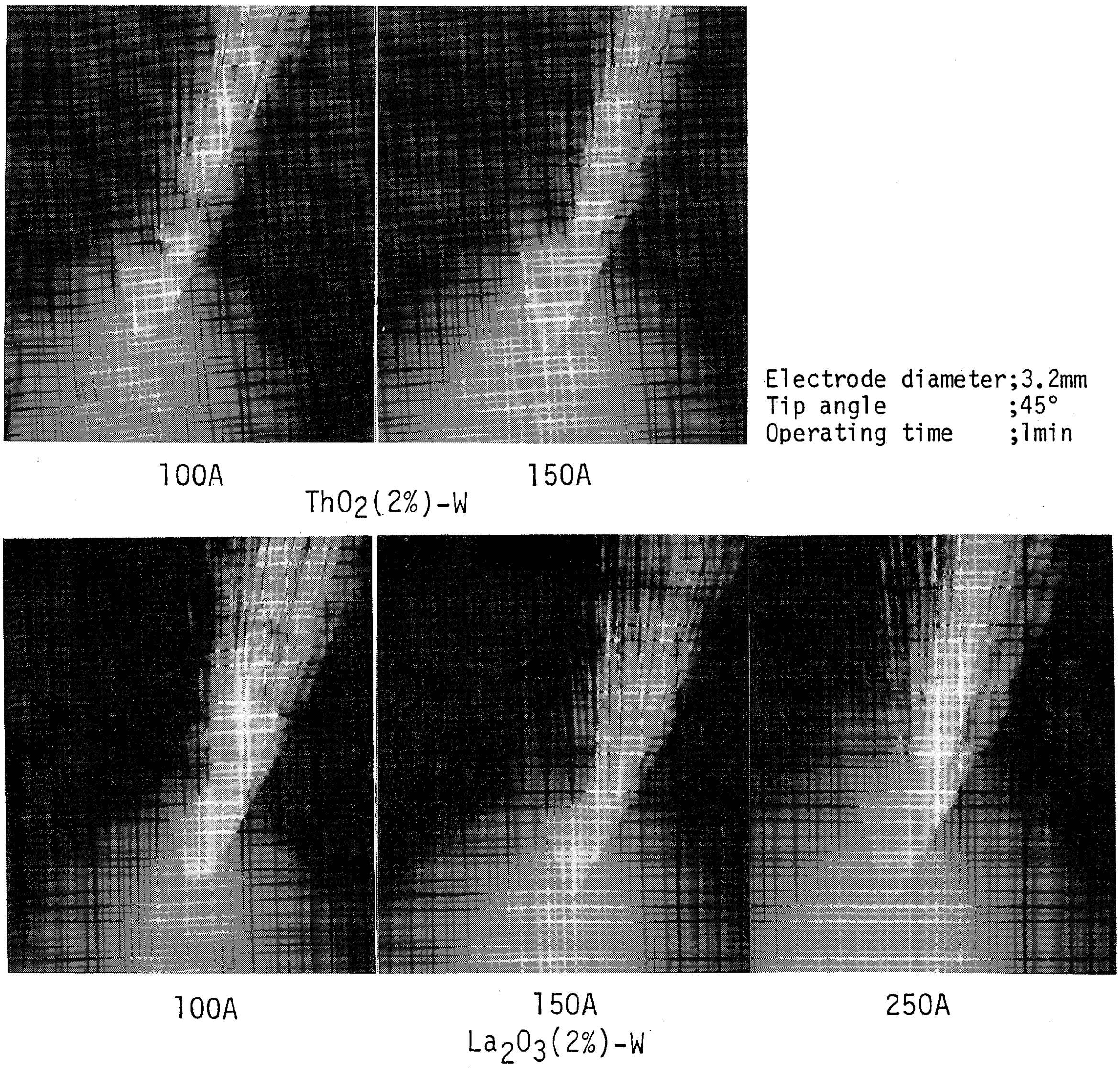

Fig. 2 Cathode surface during arc burning at various current in pure argon.

obvious, three characteristics zones at the tip for both La_2O_3-W electrode and ThO_2-W electrode. These characteristics zones which illustrated schematically in **Fig. 3** can be clarified as follows; the first zone is the emitting blue arc and concentrated emission area with brightness (A zone), the second zone has smooth surface (B zone), and the third zone has rough surface due to the deposition of tungsten (C zone). The size and location of these zones are depended on arcing current and time. Also, it was clearly observed that the ThO_2-W electrode is more luminous and its A zone area is little larger than La_2O_3-W electrode. Moreover, above 200A the tip of ThO_2-W electrode melted while the tip of La_2O_3-W electrode did not melt and kept continuously arcing with increasing of A zone area. On the assumption that electron emission is occurred at A zone, the current density at that zone was calculated. As a result, the current density of La_2O_3-W electrode is 2×10^8 (A/m^2) and for ThO_2-W is 1×10^8

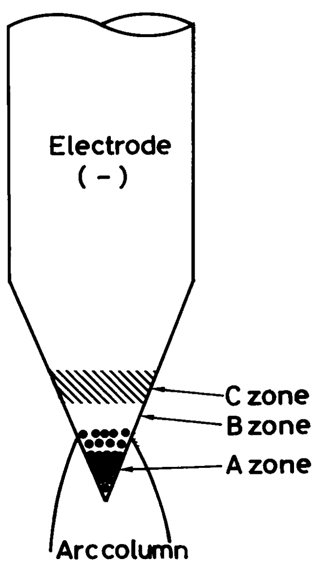

Fig. 3 Morphological change of electrode tip due to arcing.

(A/m^2).

The work function was calculated by using Richardson-Dashman equation knowing the temperature of La_2O_3-W electrode (3200K) and ThO_2-W electrode (3650K) from the previous study[2)].

$$Je = AT^2 exp(-e\Phi/kT)$$

Where

A = Constant
k = Boltzman Constant
T = Temperature
Φ = Work function

The effective work function of La_2O_3-W electrode is 2.8eV, and for ThO_2-W electrode is 3.5eV. It may say that the superiority of La_2O_3-W electrode than ThO_2-W electrode is a result for its high ability of electron emission, even the work function of La_2O_3 itself is higher than that of ThO_2 itself. The reason of this phenomena is not clearly understood, but it may be attributed to the reaction between tungsten and these oxides producing metallic La or Th, the diffusion or segregation rates of these metals to the electrode surface and vaporization rate from the surface

To study the effect of electrode tip angle on arcing behaviour, arcing in pure argon at 100A for 1 min, had been made and showed in **Fig. 4**. It is obvious that, with increasing the tip angle A zone area becomes wider. This is due to the change in energy balance at tip surface with changing the tip angle.

Fig. 5 shows the changes of cathode surface after arcing for 1 min at various arcing current in pure He. In this case, both La_2O_3-W and ThO_2-W electrodes have the three characteristics zones as in pure argon. Though the arc plasma can not be observed in the figure due to the very weak luminousity and the condition of photographing, the dence arc is actually emitted from the A zone and blue weak flare is emitted from the C zone. The electrodes behaviours are as same as in case of pure argon. Also, the work function of La_2O_3-W electrode is 2.7eV, and of ThO_2-W electrode is 3.1eV, that means, the work function is independent on the type of shielding gas.

The change of emitting area with time was investigated and showed in **Fig. 6**. It is obvious that, in case of ThO_2-W electrode the tip started to melt after 5 mins, at 80A and with prolonged time (30 mins) the electrode surface heavily eroded.

However, in case of La_2O_3-W electrode the emitting area is stable until 100A. But, at 200A arc root significantly changed and the A zone area decreased after 60 minutes arc burning. This behaviour may be related to the role of oxide stability and its vaporization mechanism with time during arc burning.

In case of arc burning in pure helium, quite differences were observed as shown in **Fig. 7**. Here the ThO_2-W

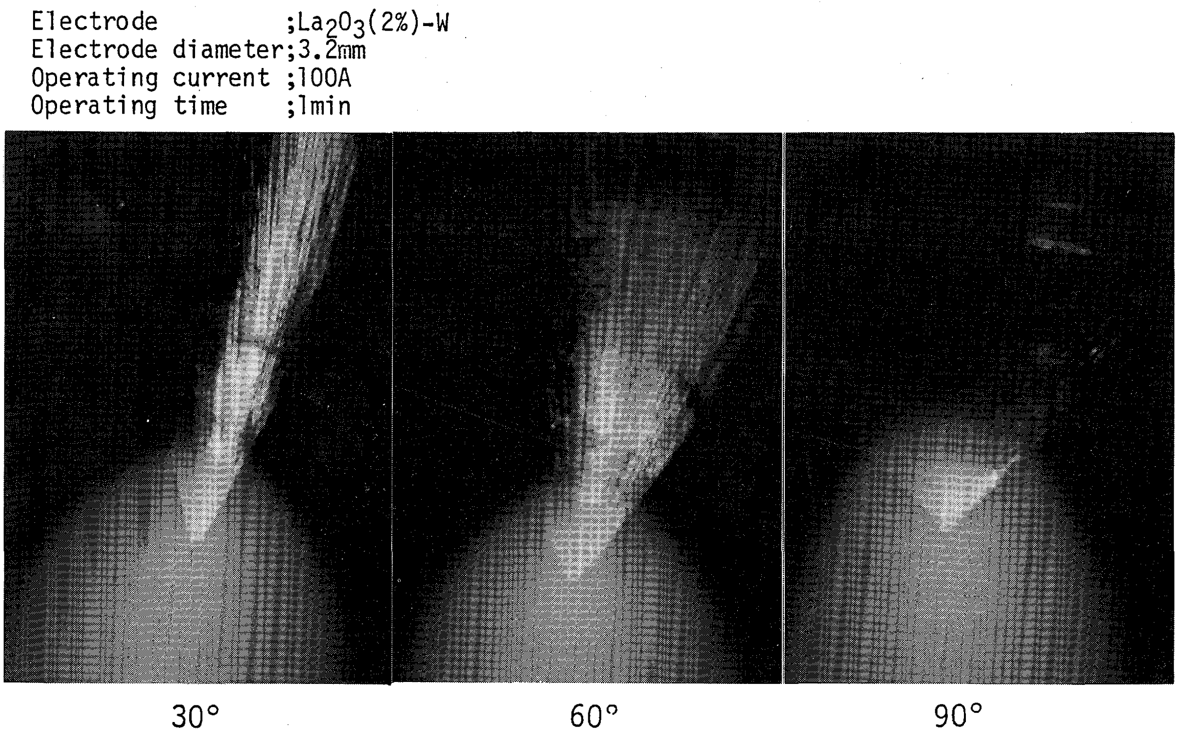

Fig. 4 Cathode surface during arc burning at various angle in pure argon.

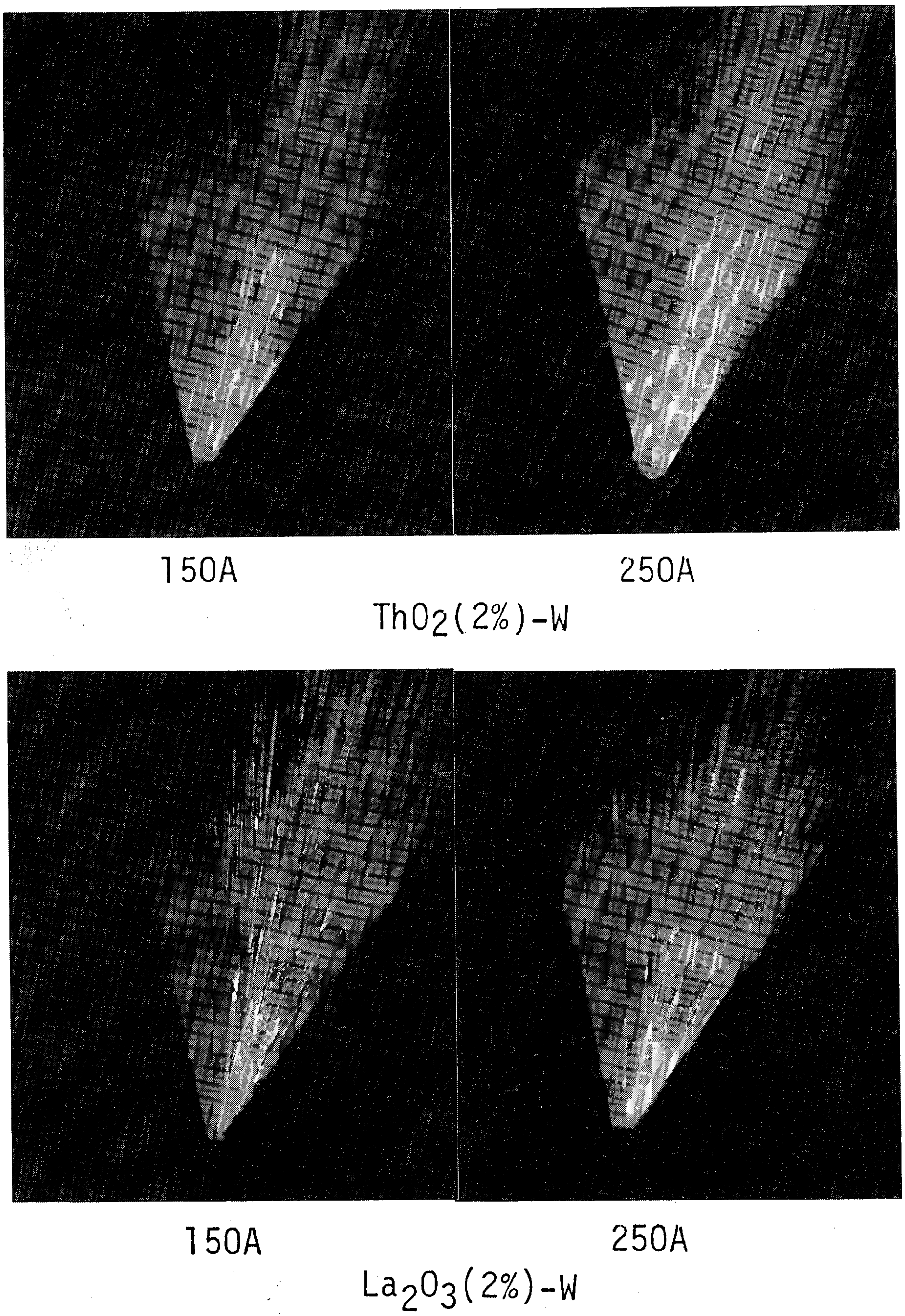

Fig. 5 Cathode surface during arc burning at various current in pure helium.

electrode started to melt at 100A after 30 mins arc burning. Also the A zone and B zone areas in case of La_2O_3-W electrode decreased with time due to the vaporization of La from the electrode surface.

In case of oxidizing shielding gases, direct observation for both electrodes after arc burning at several arcing current and time in Ar+0.2%O_2 and He+0.2%O_2 are shown in **Fig.** 8 and **Fig.** 9, respectively. Based on such data, the following statements become obviously;

(1) The rim formation zone is the C zone for both electrodes. But at higher current the rim zone expanded toward the electrode tip.

(2) Rim formation rate increases with increasing arcing current and time.

(3) The size and shape of rim in case of ThO_2-W electrodes are more luminous and bigger than that of La_2O_3-W electrodes for both types of shielding gases. However the rim formation rate in case He+0.2%O_2 is

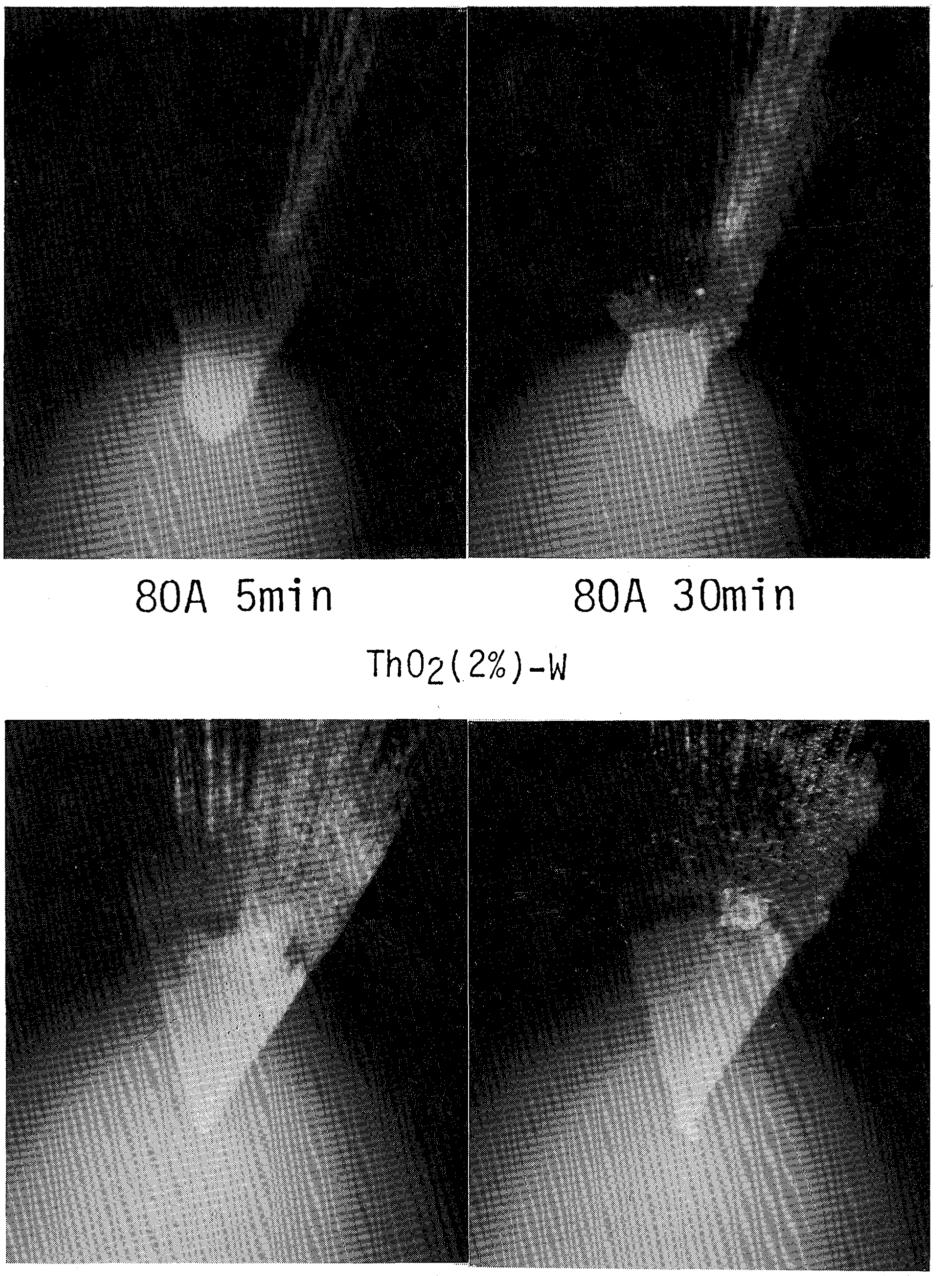

Fig. 6 Change of arc root in pure argon.

higher than that of Ar+0.2%O_2.

All of these observation illustrated above may be attributed to the effect of shielding gas type, arcing current and time on the temperature distribution at the electrode surface which affect the stability of rare earth metal oxides and the oxidation, vaporization and deposition rate of tungsten electrodes.

Furthermore, the presence of oxidizing elements significantly changes the electrode emission as shown in **Fig. 10**. This was clearly observed from the decreasing of A zone area with time for La_2O_3-W electrodes after arc burning at 100A in Ar+0.2%O_2.

4. Conclusions

(1) Both La_2O_3-W electrodes and ThO_2-W electrodes

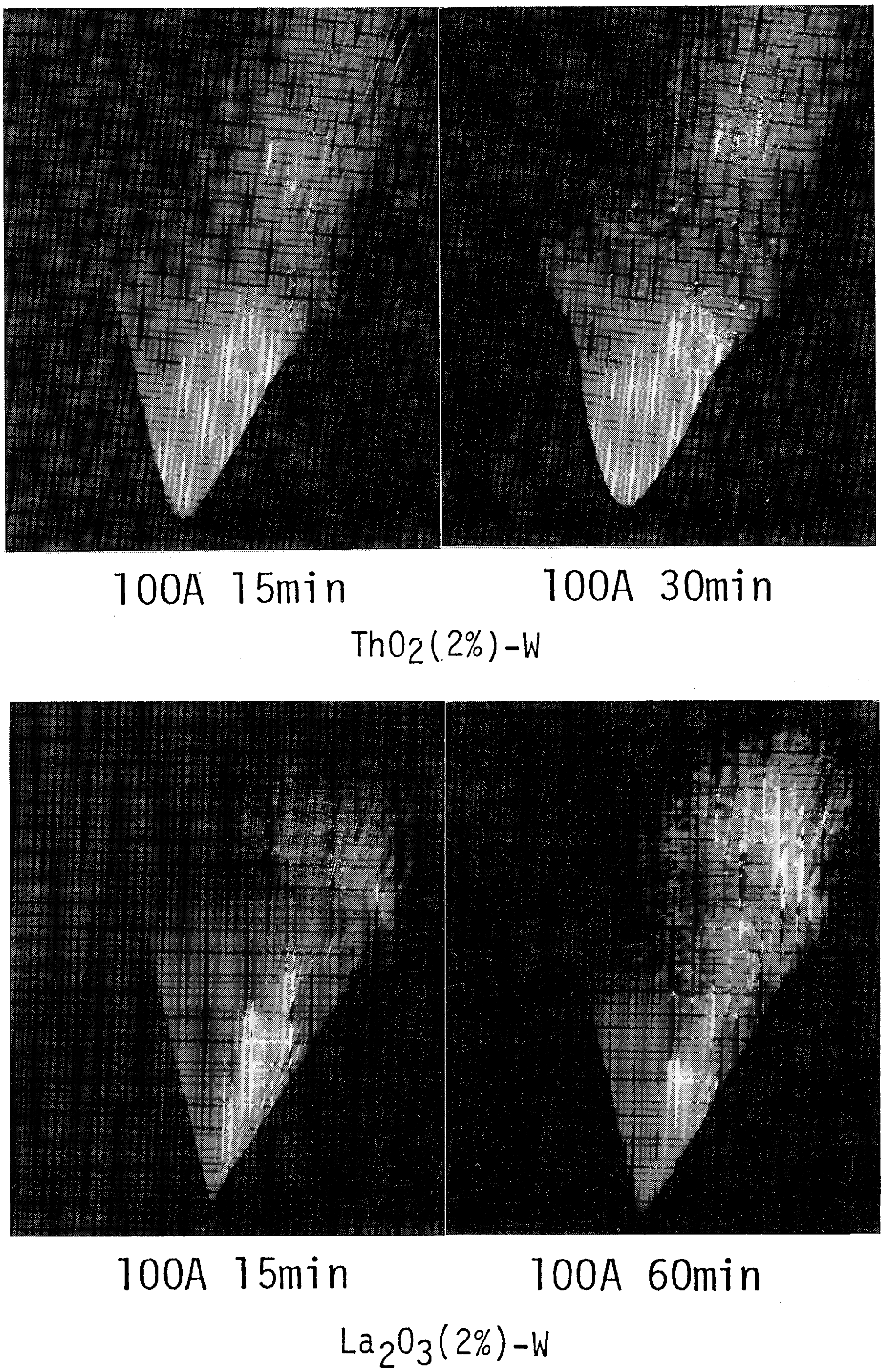

Fig. 7 Change of arc root in pure helium.

have three characteristics zones during arc burning. The size and locations of these zones are dependent on arcing current and time.

(2) The effective work function of La_2O_3-W electrode is 2.8eV and that of ThO_2-W electrode is 3.5eV. Also the work function is independent on the type of shielding gas.

(3) With increasing the tip angle the emitting area becomes wider.

(4) The electrode surface conditions for La_2O_3-W electrodes are more stable than that for ThO_2-W electrodes in inert gases.

(5) The presence of oxidizing element in shielding gases promotes the rim formation. The rim formation rate,

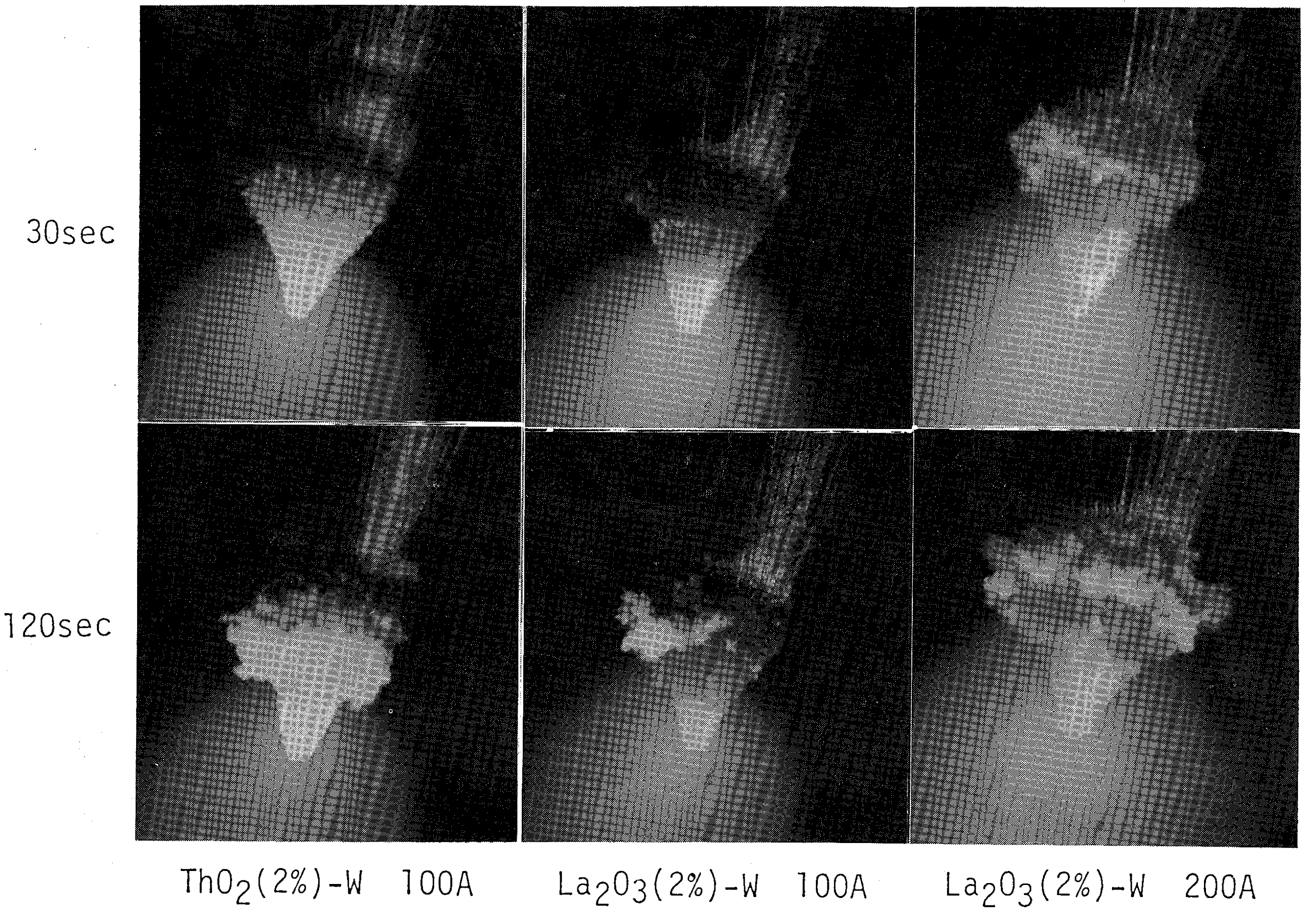

Fig. 8 Development of rim formation (Ar+0.2%O_2).

and its size and shape are dependent on arcing time, arc current and type of shielding gas.

(6) The size and shape of rim in case of ThO_2-W electrode is bigger than that of La_2O_3-W electrode.

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References

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2) F. Matsuda, M. Ushio and H. Fujii, Trans. of JWRI, (1987), Vol.15, No.2.

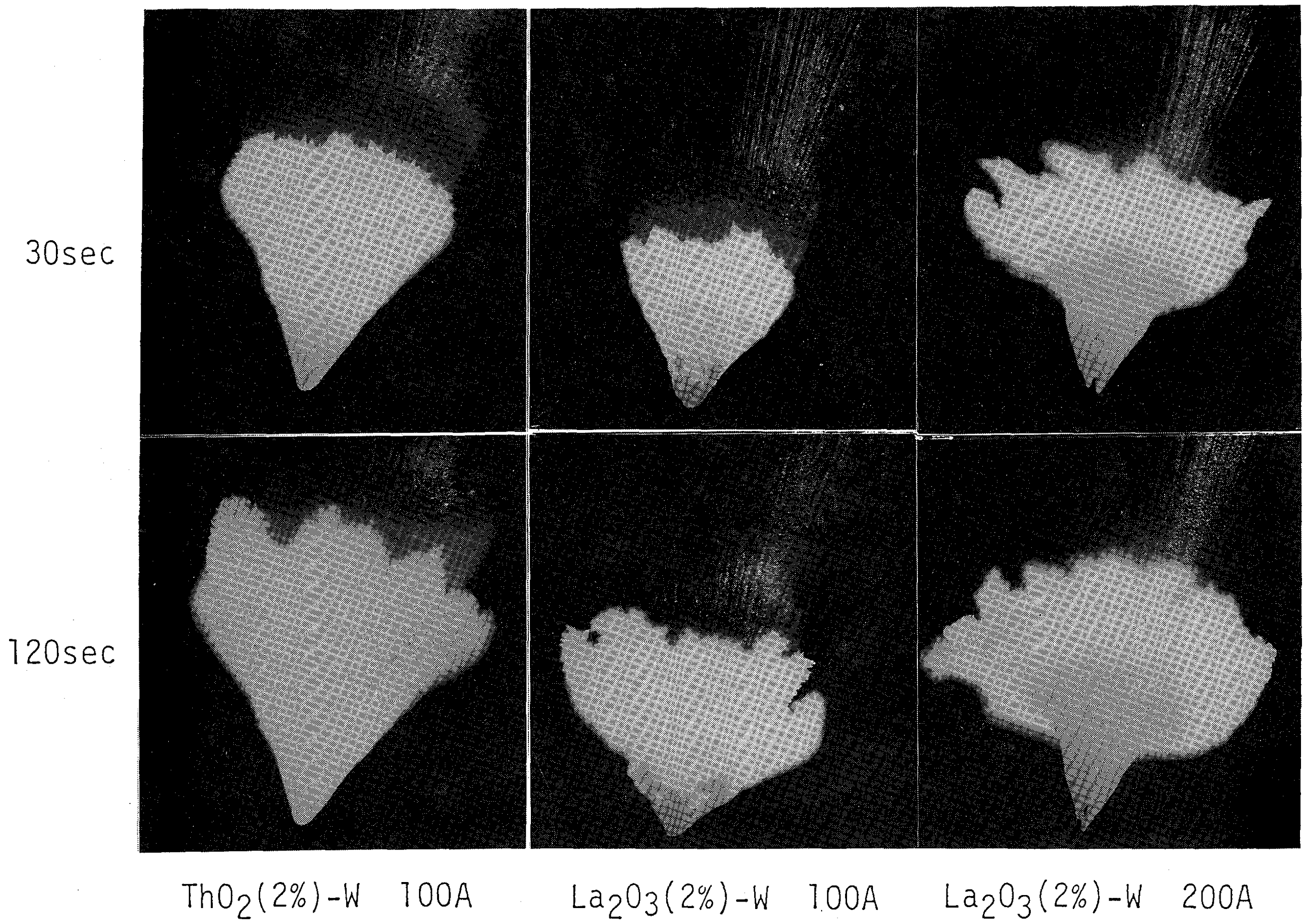

Fig. 9 Development of rim formation (He+0.2%O_2).

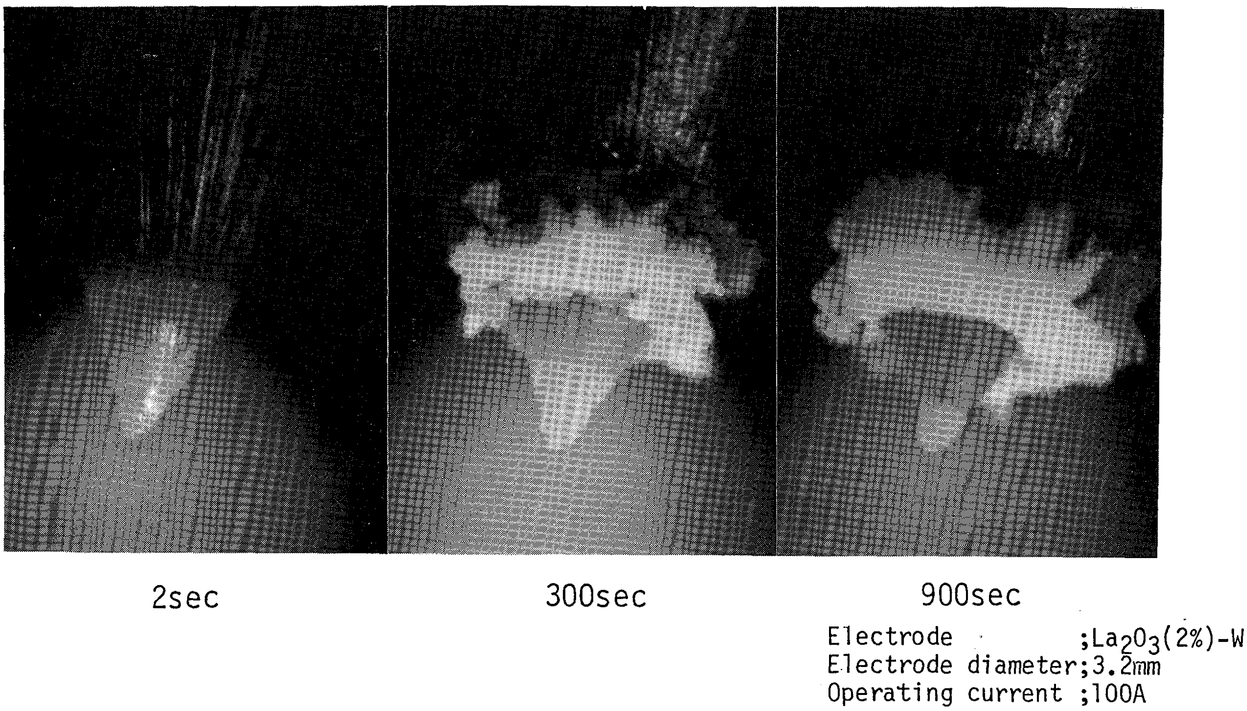

Fig. 10 Change of cathode surface (Ar+0.2%O_2).