

# The Observations of the Behavior of Cathode Spot at Breaking Arc of Contact

Kagehiro ITOYAMA

*(Technology Laboratory, Faculty of Education, Nagasaki University, Nagasaki-shi, 852 Japan)*

(Received October 31, 1975)

## Abstract

A behavior of cathode spot which is an important factor for a consideration on a contact erosion was observed with a lapse of time by using a high-speed camera.

The differences of behavior caused by the contact materials were cleared and the violence of shift of cathode spot was found to be the order of Au>Ag>Cu>Ni.

Furthermore, the contact erosion for each material is referred from these behavior.

## 1. Introduction

An arc phenomenon of electric contact has a great influence upon a contact erosion or a transfer of contact, and many reports which are described about these relations have already presented.

The contact erosion is caused by a evaporation of electrode material from a cathode spot and an anode spot which are kept at a high temperature in the arc discharge of contact. Therefore, it is an important factor for a consideration on the contact erosion to know a behavior of cathode spot on the cathode surface.

The present author is studying about the arc phenomena of contact by using a high-speed camera. This report is described about the observation of a behavior of cathode spot from the arcing series photographed by the high-speed camera. A change of a shift of cathode spot was observed with a lapse of time, and a shift speed of it was calculated.

These experiments were done for Au, Ag, Cu and Ni contacts under the various conditions, and the differences of behavior caused by the contact materials were discussed by the formation of oxide film of each materials on the cathode spot.

## 2. Experimental Procedure

The experimental circuit and the way of photograph are the same thing what had already presented.<sup>1)</sup>

The contact materials used in this experiment are Au, Ag, Cu and Ni, and these are the material of the field emission type. The contact has 5mm in diameter and about 5mm in length, whose surface is flat in the cathode and spherical in the anode. One of the cathode is fixed, and the other of the anode is able to move.

The surface of the test contact was polished at an emery paper of No. 3000. The testcontact was operated about 500 times without the current, and the shape of arc was photographed after about 1000 times of switching in the condition with the current.

The experiments were done under the condition of DC 50V, 60V and 72V at the voltage between electrodes, 2A, 3A, and 5A at the current through the electrodes in the present work.

The schematic shape of contact arc photographed is shown in Fig. 1. A shift length is obtained by measuring  $x$  in Fig. 1. This measurement was done in every frame photographed. As a lapse of time is caught from a time-marker (1 msec. interval) which appears in a film, the behavior of cathode spot which changes with a lapse of time can be obtained. And a shift speed of the cathode spot can be obtained by dividing  $x_i - x_{i+1}$  by a duration between one frame to the next frame.

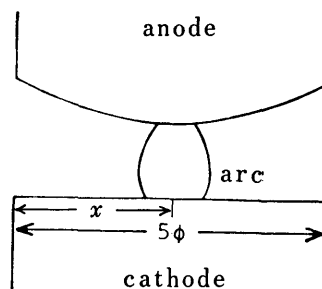


Fig.1.— Schematic shape of contact arc photographed.

### 3. Results

The examples of the photographic series of the arcing of each contact are shown in Fig. 2 to Fig. 5. As shown in these figures, the shift of Au contact is violent passably among the duration of all arcing. In this arcing, multi-discharges, which have a few paths for the discharge, are found in a few frames. The cathode spot of Ag contact changes also violently as well as Au contact, however its shift becomes slowly gradually intermediately after the breaking. The cathode spot of Cu contact shows a very slow behavior. But, the violent shift can be found in a few frames at the last stage of arcing. The shift of cathode spot for Ni contact is slower than it for Cu contact, the cathode spot, of Ni does not almost change from one position. In order to consider numerically for the behavior of cathode spot, the shiftlength of cathode spot which changed with a lapse of time was obtained. Fig.9.

The changes of the shift length of cathode spot for each contact are shown in Fig. 6to

In case of Au contact, its shift is violent passably and the maximum shift length one frame to the next frame, symbolized  $l_{mx}$ , is about 0.5 mm. The maximum shift width of cathode spot,  $l_{mw}$  which the cathode spot shifted on the cathodes urface in one arcing, extends almost 1 mm. The evaporation area on the cathode is wide passably and its area was estimated to be about 1 mm<sup>2</sup>. As the cathode spot area was estimated to be about 10<sup>-3</sup> mm<sup>2</sup>, the evaporation area is about one thousand times for the cathode spot area. This behavior shows a similar feature for the change of current and voltage.

In general,  $l_{mw}$  and  $l_{mx}$  increase with the increase of current and voltage.

As shown in Fig. 7, the behavior of cathde spot on Ag contact shows a similar feature for Au contact in early stage of breaking. But, the shift length of cathode spot becomes small remarkably from about 4 msec. after the breaking. In this case,  $l_{mx}$  on Ag extends about 0.2 to 0.3 mm wide, and the behavior of cathode spot becomes a similar motion

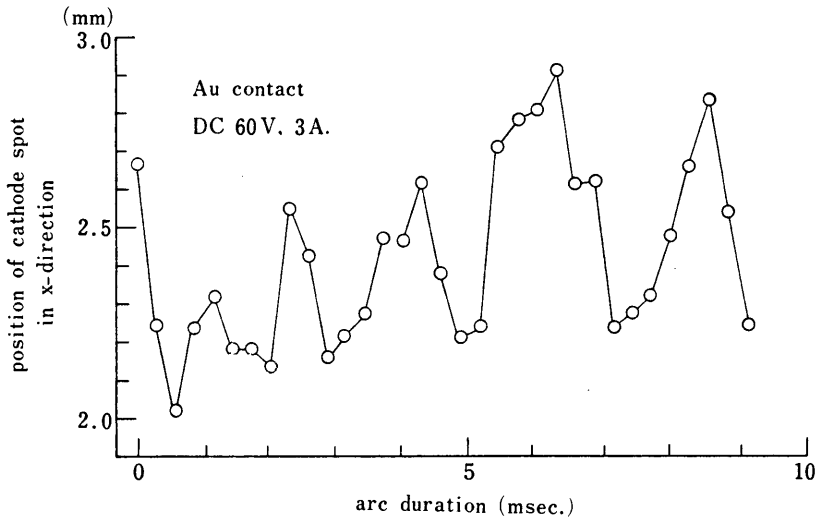


Fig.6.—The behavior of cathode spot of Au contact with a lapse of arc duration at DC 60V and 3A.

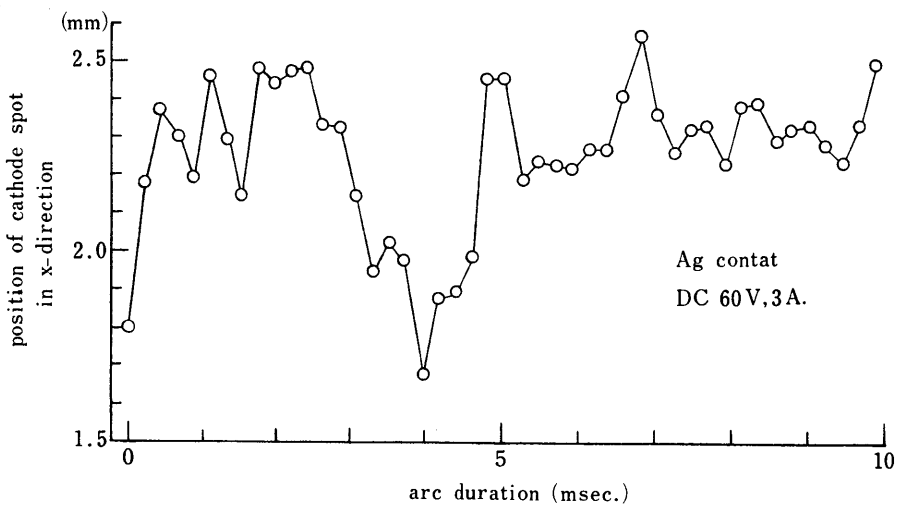


Fig.7.—The behavior of cathode spot of Ag contact with a lapse of arc duration at DC 60V and 3A.

for Cu contact rather than Au contact from middle stage after the breaking.

As shown in Fig. 8, the behavior of cathode spot on Cu contact is slow. The cathode spot dose not shift so much from one point in which arc arose at first, and the shift length  $x$  is almost below 0.1 mm. But, the case which the shift length is over 0.1 mm are found in a few frams in the last stage of the breaking. In general, the behavior of Cu contact has a tendency that the shift length in the last stage of the breaking is larger than it in early stage of the breaking. The maximum shift width  $l_{mw}$  is about 0.5mm and increases with the increase of current or voltage.

In case of Ni contact, as shown in Fig. 9, the behavior of cathode spot is the slowest of all contacts used in this work. The shift length is almost below 0.1 mm, and dose not shift abruptly among all duration of arcing. The maximum shift width  $l_{mw}$  is about 0.3 mm.

From above-mentioned results, the cathode spot shifts at random on the cathode surface of every contact, and behavior becomes to slow the order of  $Au < Ag < Cu < Ni$ .

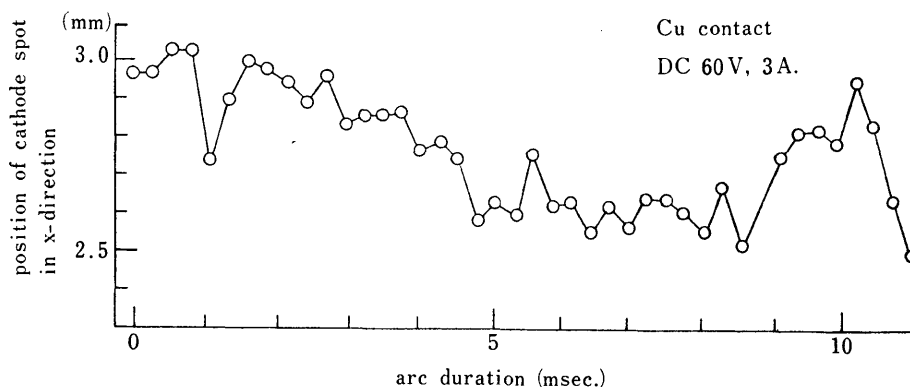


Fig.8.—The behavior of cathode spot of Cu contact with a lapse of arc duration at DC 60V and 3A.

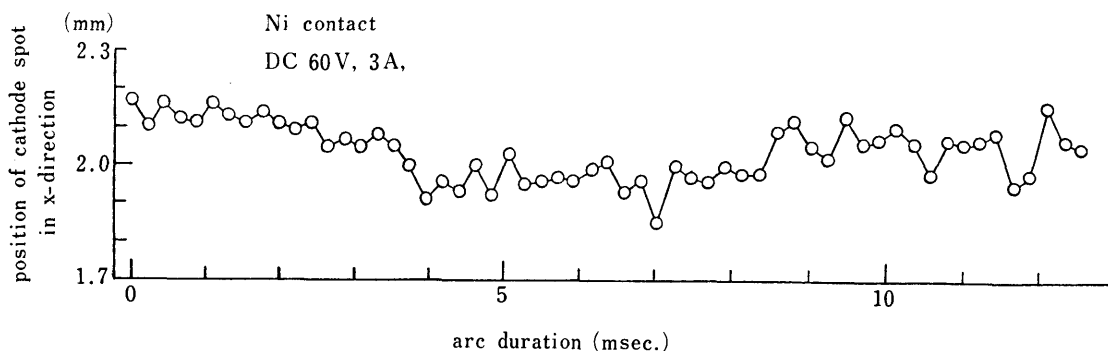


Fig.9.—The behavior of cathode spot of Ni contact with a lapse of arc duration at DC 60V, and 3A.

#### 4. Discussion.

An oxide film on the cathode surface has a influence upon the shift of cathode spot<sup>2)</sup>.

The present author tried to discuss for these phenomena in consideration on a formation of oxide film and a decomposition temperature of oxide.

For the materials of the field emission type, an arc arises easily in such case as the oxide film exists on the cathode surface, and the behavior of cathode spot becomes steady<sup>3)</sup>. If the oxide film at a near-by the cathode spot is decomposed by a temperature of arc, it is considered that the cathode spot shifts to the part which the oxide film exists. For the shift of cathode spot, the difference of behavior arises from the difference of the heat of formation or the decomposition temperature for the oxide film.

As shown in Table 1, the oxide film of Au cannot be formed easily and can be decomposed easily. So the shift of cathode spot on Au is large and its behavior is unstable. The oxide film of Ag can be decomposed easily as well as Au-oxide film, however, the behavior of cathode spot is not so violent as it for Au, because Ag-oxide film can be formed easily in comparison with Au-oxide. The Cu-oxide film can be formed easily and can be decomposed at only a high temperature. Therefore, it is considered that the shift of cathode spot on Cu is small. The decomposition temperature of Ni-oxide film is the highest of all oxide in Table 1. So, the shift of cathode spot is the smallest of all contact used, since Ni-oxide film can not be decomposed easily.

The shift width decreases with the decrease of current and voltage. A cathode spot area becomes so narrow with the decrease of current and voltage that a decomposition area for oxide film also becomes narrow. It is considered that the shift width becomes small because of this reason.

The shift length was observed in only x-direction in this work. Therefore, a real shift length is larger than the present results. The author will estimate the real shift length by simulation for the shift of cathode spot.

Table 1.-A heat of formation of oxide and a decomposition temperature for each contact<sup>(4)</sup>,<sup>(5)</sup>.

oxide	Heat of formation (Kcal/mol)	decomposition temperature (°K)
Ag <sub>2</sub> O	- 7.306	300
Au <sub>2</sub> O <sub>3</sub>	+19.3	250
CuO	-37.1	1026
Cu <sub>2</sub> O	-39.84	1800
NiO	-58.4	1998

## 5. Conclusion.

The behavior of cathode spot was observed for the contact of Au, Ag, Cu and Ni by using a high-speed camera.

- (1) The cathode spot shifts at random.
- (2) The behavior of cathode spot becomes gentle in the order of Au<Ag<Cu<Ni for each contact.
- (3) The existence of oxide film has a great influence upon the behavior of cathode spot by consideration of a formation of oxide and a decomposition temperature of oxide.
- (4) The shift width of cathode spot decreases with the decrease of current or voltage.

## Acknowledgement

The author is grateful to M. Kurushima, K. Goto and T. Kagae for their help in this work.

## References

- (1) K. Itoyama : Trans. I.E.C.E., Japan, 57-C, No. 10, p.343 (1974).
- (2) R. Holm : Electric Contacts (4th edition 1967), p.274, Springer-Verlag.
- (3) A. von Engel (translated by K. Yamamoto, T. Okuda) : Ionized Gases (2nd edition 1965), p.242, Corona Publishing Co., LTD.
- (4) Japan Chemical Society : Kagaku Binran (1), p.38, Maruzen.
- (5) Japan Chemical Society : Kagaku Binran (2), p.819, Maruzen.

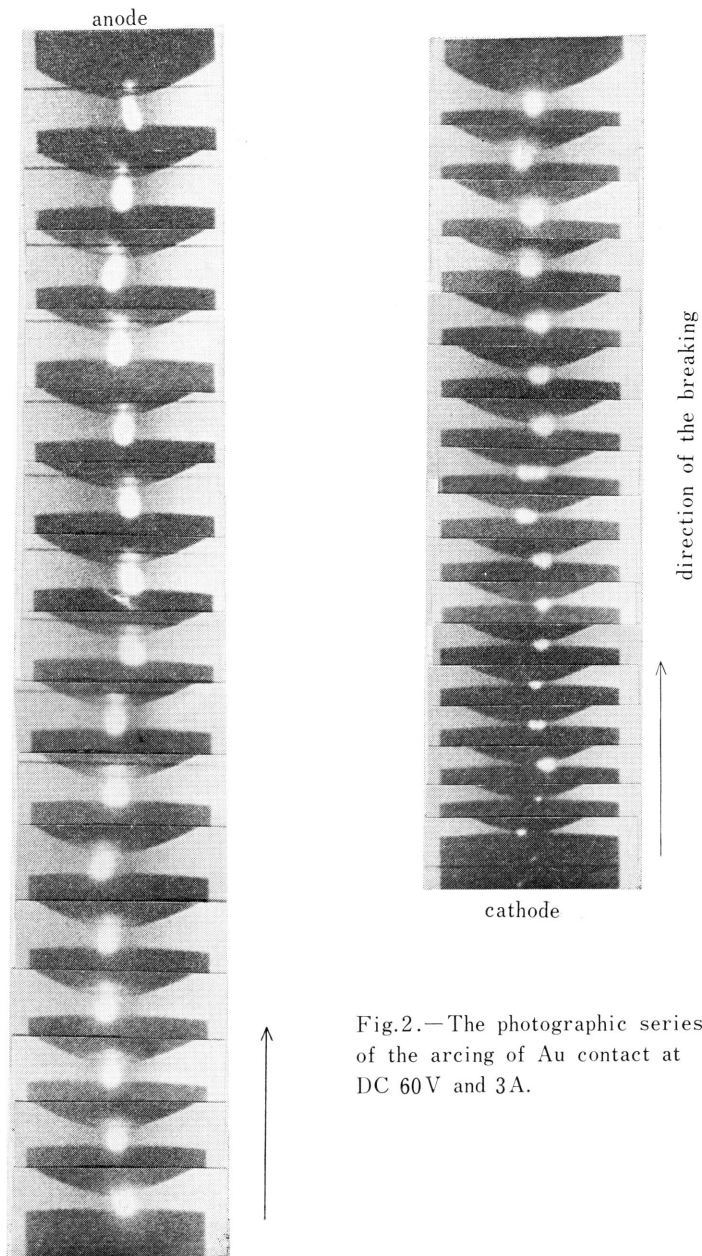


Fig.2.—The photographic series of the arcing of Au contact at DC 60 V and 3 A.

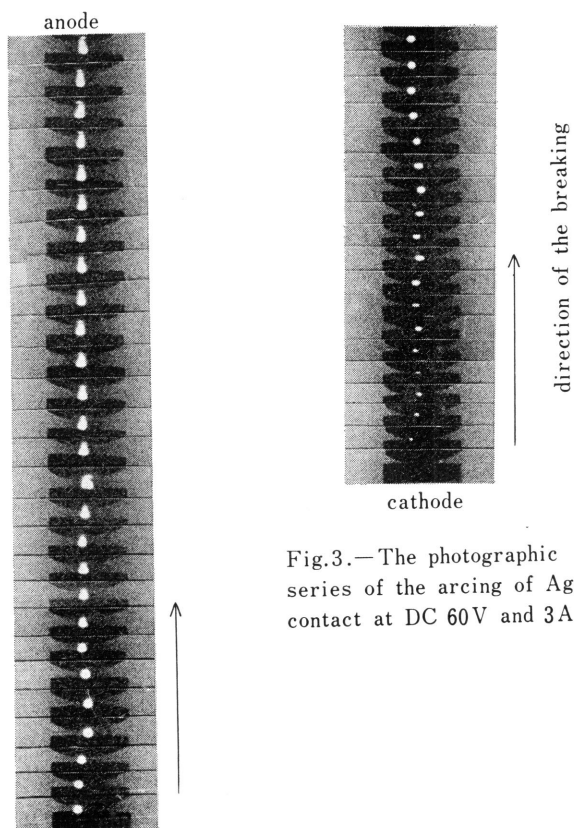


Fig.3.—The photographic series of the arcing of Ag contact at DC 60V and 3A.



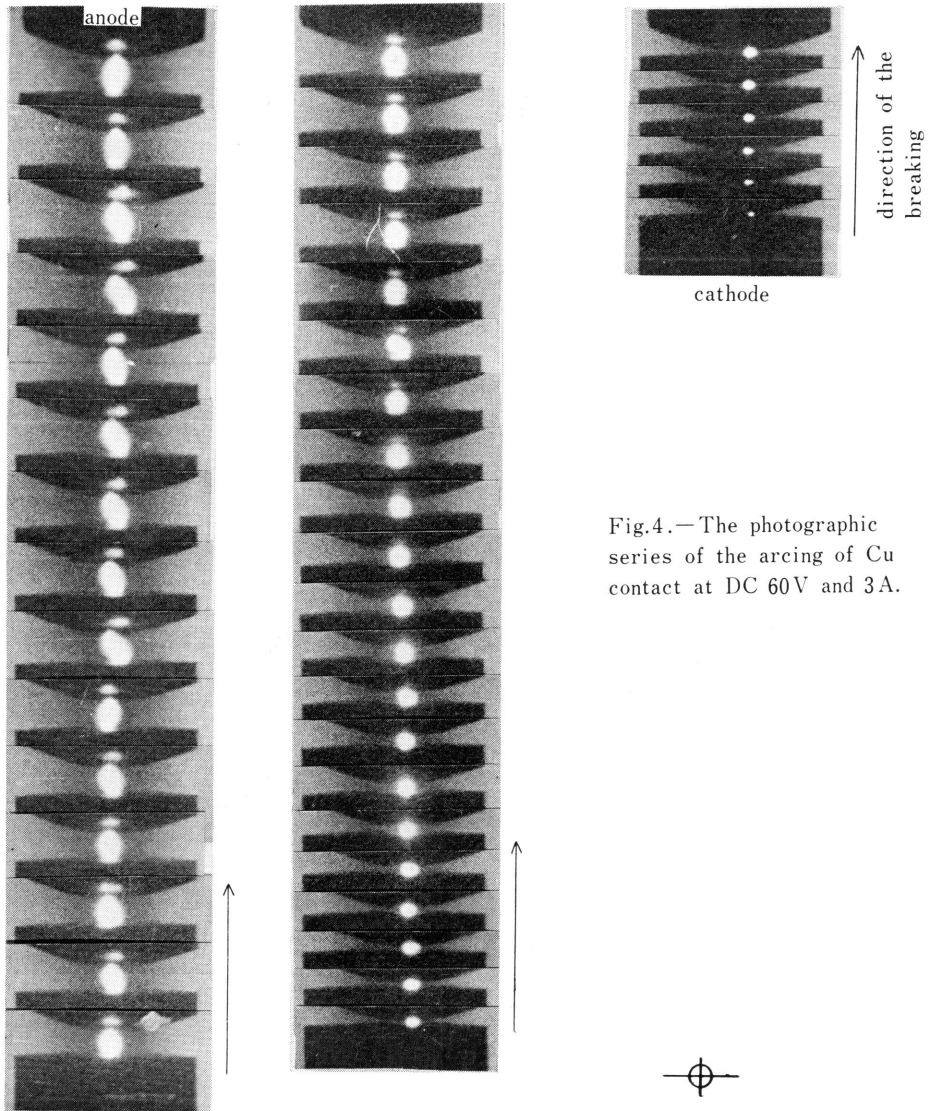


Fig.4.—The photographic series of the arcing of Cu contact at DC 60V and 3A.

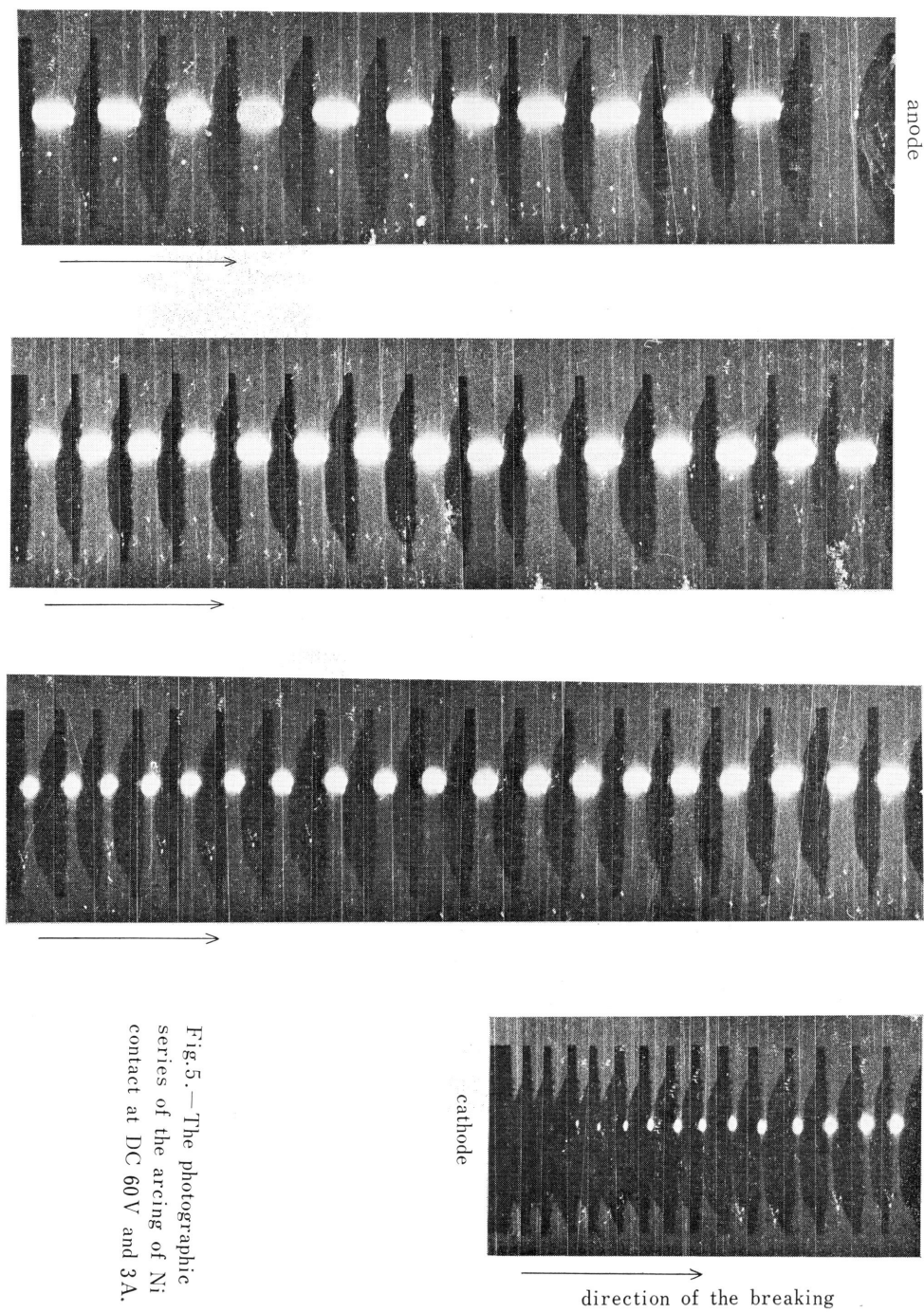


Fig. 5. — The photographic series of the arcing of Ni contact at DC 60 V and 3 A.