Current Density Change of Anode Spot at Ag-CdO Breaking Contact

Kagehiro ITOYAMA

Faculty of Education, Nagasaki University

Nagasaki-shi 852

(Received October 31,1974)

1 Introduction

A contact arc has a great influence upon a contact erosion, a transfer and so on. For this arc, the author has been studing for the current density change of anode spot breaking arc by using a high-speed camera. It is very important physically and technically to obtain such results, even if a roughness which is caused by a halation and so on exists in this measurement. These values of the arc current density of anode spot were almost coincided with the theoretical ones obtained by the energy balance theory at anode spot(1). And the current density changes with a lapse of time were in good accordance with the theoretical curves obtained by recombination theory in the early stage of the breaking of contact(2).

However, the current density changes cannot be explained by only recombination theory, and the experimental results differ from the theoretical curve in the middle stage of breaking.

In the present paper, an influence of ionization is considered to give a good explanation for the breaking arc of Ag-CdO contact.

2 Results

The changes of the current density at anode spot as a function of time are shown in Fig. 1, Fig. 2 and Fig. 3. As shown in these figures, the value of the arc current density is $10^5 \sim 10^4$ A/cm^2 immediately after the breaking. But the current density of anode spot J- decreases with the lapse of time, and it is nearly constant in the midle stage of the breaking. The value of the constant current density is about 1×10^3 A/cm^2. Under the condition of the constant arc current density, the arc seems to be nearly stationary.

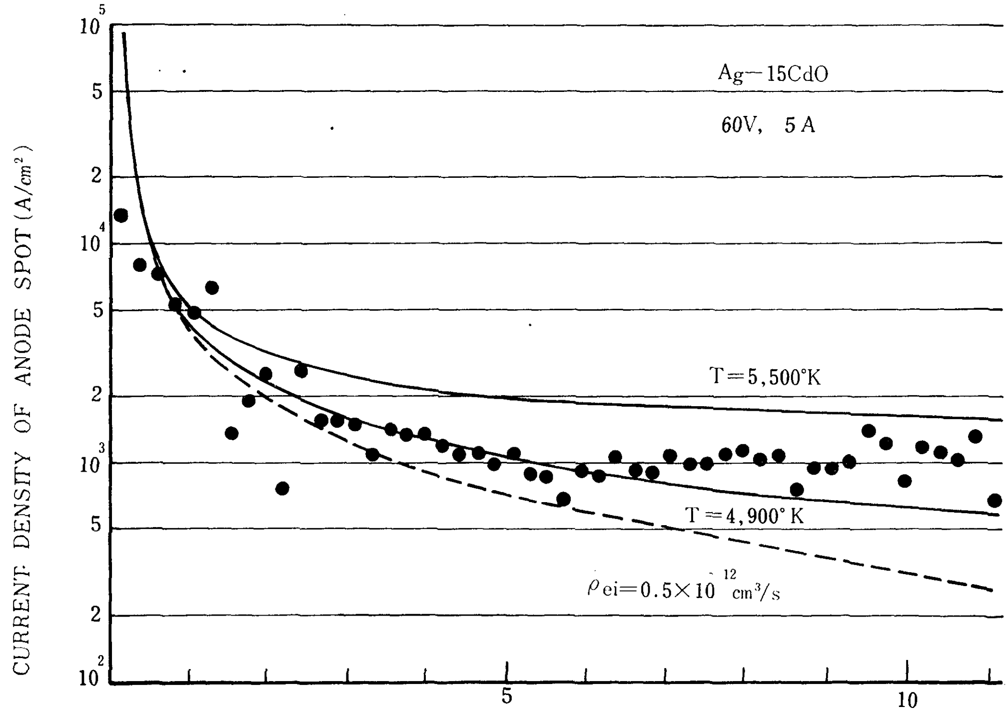

Fig. 1-Change of arc current density at anode spot with the lapse of time: Ag-15%CdO contact, DC60V 5A.

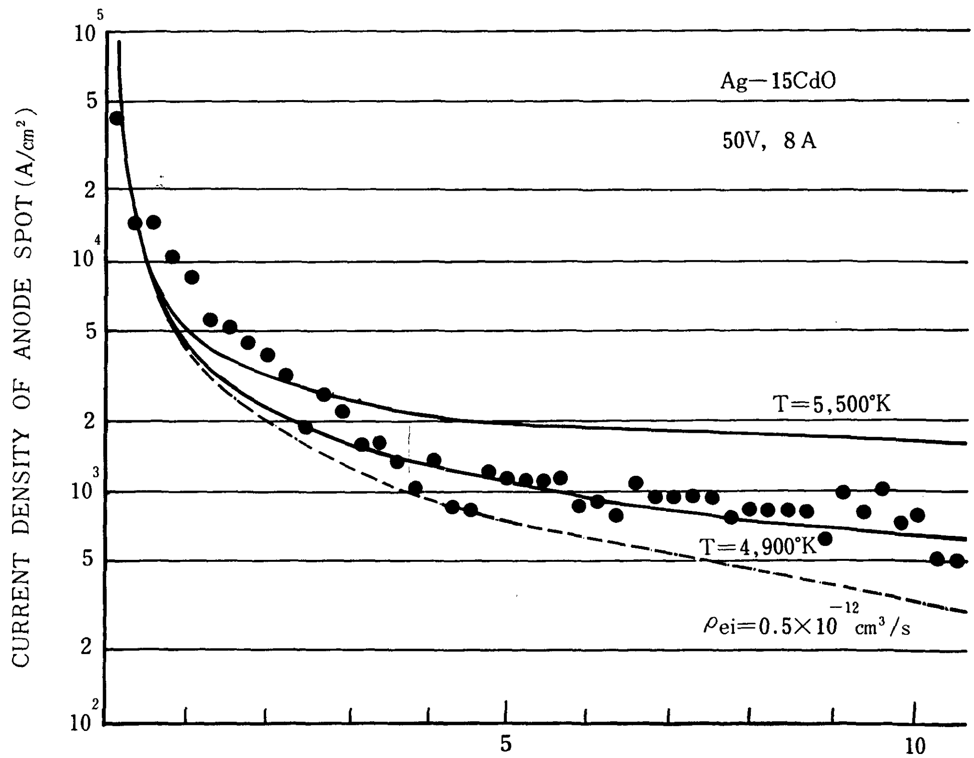

Fig. 2-Change of arc current density at anode spot with the lapse of time: Ag-15% CdO contact, DC50V, 8A.

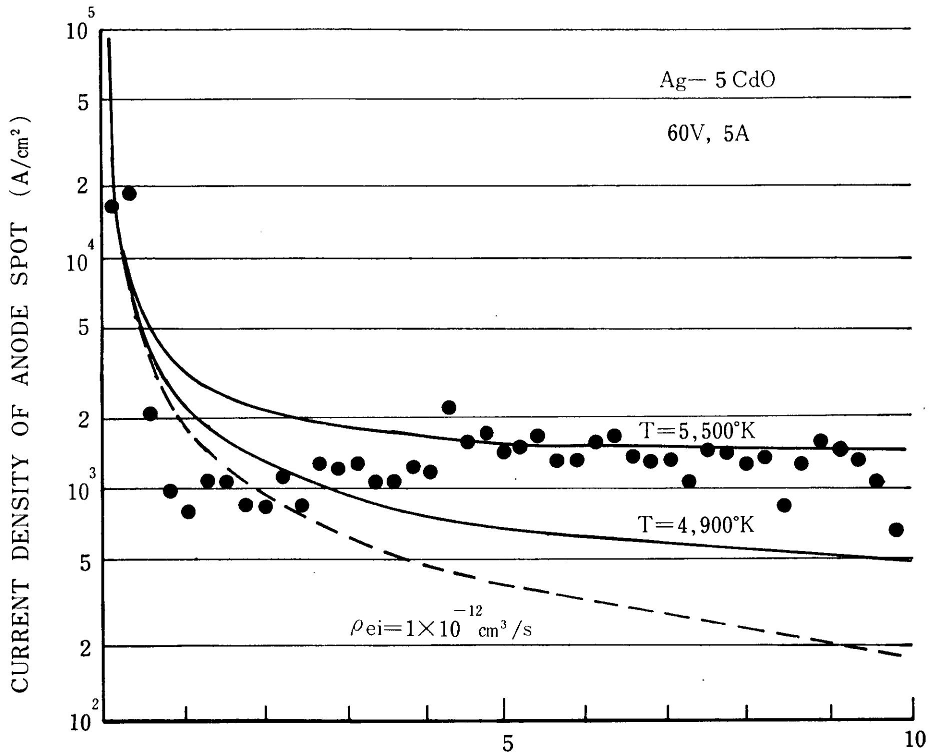

Fig. 3-Change of arc current density at anode spot with the lapse of time: Ag-5% CdO contact, DC60 V, 5A.

3 Discussion

3-1 Discussion for Ion-Electron Recombination

According to the model of breaking arc which the present author had already presented, the breaking arc of contact is divided to two stage, one is the early stage which ions and electrons decrease by recombining in the high density plasma and the other is the middle stage which the thermal ionization takes the leading part in the contraction zone [2].

In the early stage of the breaking, n_{er}, the electron density which dicreases by the recombination, is given in eq(1).

$$n_{er}=\frac{n_{eo}}{1+n_{eo}\rho_{ei}t} \qquad (1)$$

where n_{eo} is the initial value of n_{er}, ρ_{ei} is an ion-electron recombination coefficient.

If n_{eo} is larger than 1, eq. (2) is obtained from eq.(1).

$$n_{er}=\frac{1}{\frac{1}{n_{eo}}+\rho_{ei}t}\doteqdot\frac{1}{\rho_{ei}t} \qquad (2)$$

While, Langmuir gave an expression for the random current density passing through a plane arbitarily oriented in the plasma: [3]

$$J_e=en_e\left(\frac{kT}{2\pi m}\right)^{1/2}=2.5\times10^{-14}n_eT^{1/2} \qquad (3)$$

As it is assumed that the electrons and the ions flow into the electrodes while recombining early in the breaking, n_e obtained from eq. (2) is the electron which is collected to the electrodes.

Substituting the value of n_{er} into eq. (3), the current density of anode spot is obtained.

From eq. (2) and eq. (3), eq. (4) is obtained.

$$4\times10^{13}J_eT^{-1/2}=1/\rho_{ei}t \qquad (4)$$

As shown in eq. (4), the recombination coefficient, ρ_{ei} depends on the arc temperature.

The present author had already presented the arc temperature of Ag-CdO contact to be 4900°K by measuring a relative intensity of arc spectrum pair[4]. T. Aida et. al. had presented to be 5500 °K measured from the relation between the spectral-lines intensities and the excitation energies[5]. The current density changes of anode spot is discussed by estimating to be 4900°K to 5500°K about the arc temperature of Ag-CdO contact.

3-2 Influence of Thermal Ionization

According to the model of breaking arc, the anode fall is formed in front of the anode spot under the condition of $\ell \gtrsim \lambda_e$; where ℓ is a distance between the electrodes, λ_e is a mean free path of electron. The electrons which is ionized in the contraction zone of the anode fall will enter into the anode spot. Therefore, it is considered that the electron density, n_e which enters into the anode spot is the electron density which decreases by the recombination, n_{er} and the electron density which is made by the thermal ionization, n_{et}. Namely,

$$\begin{aligned} n_e &= n_{er}+n_{et} \\ &= \frac{1}{\dfrac{1}{n_{eo}}+\rho_{ei}t}+n_{et} \fallingdotseq \frac{1}{\rho_{ei}t}+n_{et} \end{aligned} \qquad (5)$$

This n_{et} is the electron density which is obtained by Saha's equation for thermal ionization.

$$\log \frac{n_{et}^2}{n_o} = -5040\frac{V_i}{T}+\frac{3}{2}\log T+15.385 \qquad (6)$$

where n_o is the total atom density, V_i is the ionization potential, and T is the arc temperature in the contraction zone. The total atom density, n_o is given in eq. (7).

$$n_o=P/kT \qquad (7)$$

where k is Boltzmann's constant, P is the pressure in the contraction zone. As P is the pressure in the contraction zone, it is almost seemed to be a vapor pressure from the anode spot. An anode spot temperature of Ag-CdO contact is slightly higher than a boilling point of CdO and is lower than its point of Ag, and a ratio of Cd and Ag atom in arc column is about 30 percents[5]. So the vapor presure is estimated about 1 atom.

The ionization potential of contact materials is 7.5V to 9.0V. As the arc arises in an air, it is considered that nitrogen molecures ionize. Therefor, it is estimated that the effective ionization potential is the mean value of each potential for Ag, Cd and N. The constant which is used for the calcuration is shown in Table 1.

Table 1

vapor presure	P	1 atom
arc temperature	T	4900°K~5500°K
ionization potential	V_i	7.54V for Ag 8.95V for Cd 14.5 V for N
effective ionization potential		10.3 V

The curves obtained by using eq. (5) are shown in a real line in Fig. 1, Fig. 2 and Fig. 3. A dushed line shows the curve obtained by only recombination theory. In this case, the recombination coefficient is estimated, about 0.5×10^{-12} cm^3/s on Ag-15% CdO, about 1×10^{-12} cm^3/s on Ag-5%CdO. These curves envelop the top of the results at 5500°K and envelop the bottom of the results at 4900°K of the arc temperature. In consideration of a roughness of a measurement which is caused of a halation and so on, it is considered that these curves almost coincide with the experimental results. In other words, the curves obtained by eq. (5) is almost resonable for the current density changes of anode spot at Ag-CdO contact.

4 Conclusion

The contact arc at breaking of Ag-15%CdO and Ag-5%CdO contacts was photographed by the high-speed camera, and the current density changes of anode spot were obtained by this measurement.

The current density of anode spot is inverse proportion with the time early in the breaking. These changes are considered to be influence of the ion-electron recombination.

The electron density obtained by eq. (5) almost coincides with the experimental results, although a roughness of a measurement which is caused of a halation and so on remains.

The author has been discussing for each constant which are used for the present calculation.

The author would like to acknowledge the continuing guidance and encouragement of Professor T. Aida of Kumamoto University.

References

(1) K. Itoyama: Trans. I. E. C. E., Japan, **57-C**, No. 10, p. 343 (1974)
(2) K. Itoyama: Proceedings of 7th ICEC, p.311 (1974).
(3) C. H. Corliss: J. Research NBS. **66 A**, p.169(1962).
(4) K. Itoyama: Trans. I. E. C. E., Japan, **56-C**, No. 3, p. 157 (1973).
(5) T. Aida and K. Watanabe: Papers of the Technical Group on Electro-Mechanica Components, I. E. C. E., Japan, **EMC** 70-35(1971).
(6) T. Aida: Papers of the Technieal Group on Electro-Mechanical Components, I. E. C. E., Japan, **EMC** 72-8(1972).