DEGRADATION OF ELECTROPLATED SILVER COATINGS UNDER THE INFLUENCE OF AN ELECTRIC ARC

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When electric current is cut off an electrical arc gets stared between electrical apparatus contacts. The arc temperature reaches values up to 6500°C /1/ and higher.

At the cut-off of 50Hz alternating current the arcing time ranges from 0.5 to 9 ms. High temperature of the arc brings about ionization of the arc channel, radiation, heating of the contact surfaces and their erosion resulting from evaporation of a part of the material and also oxidation of surface layers. When a certain number of switching cycles is done those disadvantageous phenomena cause degradation of contact surfaces and deterioration of the switchgear operating conditions, which can bring about its breakdown.

Protective coatings of silver or less often of gold, platinum or palladium are applied to reduce effects of the arc action on contact surfaces. Their application involves a problem of selecting optimal coating thickness for that would be adequate for operating conditions of the switches and most of all for the cut-off current intensity.

A method of scanning electron microscopy together with an x-ray microanalysis has been applied to investigate into degradation processes of protective silver coatings. Tests have been performed by Scanning Electron Microscope JSM-5610 LV with Energy Dispersive X-ray Spectrometer JED-2201 (JEOL, Japan).

Fig. 1 presents photographs of contact surfaces obtained by secondary electrons (left column) as well as by characteristic x-ray radiation of silver atoms (middle column) and copper atoms (right column). Each row gives a number of on-off cycles performed by a switch where from the given contact has been dismounted at the alternating-current commutation I=4A, U=230V and resistance load. As can be seen in Fig.1 initially the silver layer vanishes at the contact point and the underlying copper shows and then the silver-less area gradually grows.

Similar tests have been performed for a second series of switches, where contacts of three-times thicker silver layer have been mounted. Fig.2a shows dependences of surface concentrations of Ag and Cu on a number of switching cycles n while in Fig.2b the same results are presented in the three-times smaller scale for the second-series switches. As can be seen the rate of

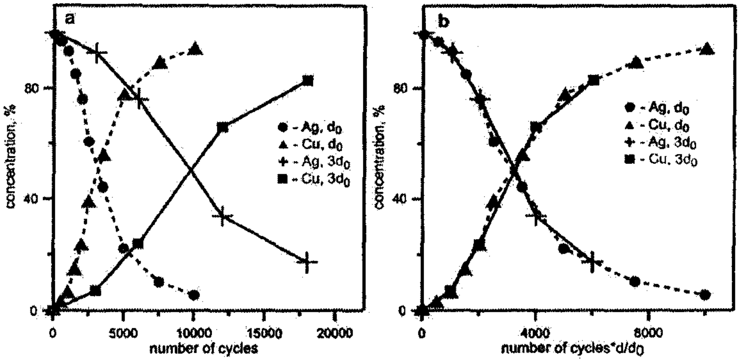

Fig. 2 Surface concentrations of silver and copper vs. a number of switching cycles: a) natural scale, b) three-times reduced scale for a triple layer.

A computer stand for recording voltage drops in a switch as well as its temperature over each switching cycle /1/ has been used to record the mentioned changes.

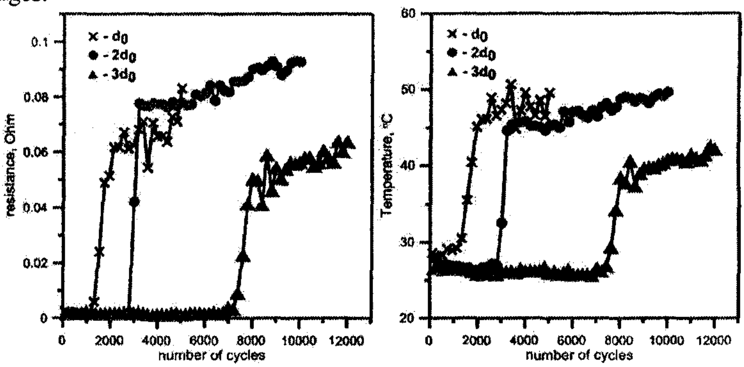

Fig.3 Transition resistance (a) and temperature (b) vs. a number of switching cycles for various values of the silver coating thickness.

Figs 3a and 3b present transition resistance changes and temperature increase for switches of single, double and triple coating thickness. As can be seen with some determined for each switch number of cycles $N_w(d)$ done transition resistance and temperature begin to rapidly grow: transition resistance - by up to 30÷40 times and temperature - by 20÷30°C. By comparing diagrams of Figs 2 and 3 one can find that the rapid increase of resistance and temperature begins when surface concentration of copper grows up to ca 20±5%, which means that the contact point surface is already all copper. It is also worth noting that the cycle number at which resistance and temperature growth occurs is surface the concentration increase for copper and decrease for silver linearly depends on the coating thickness.

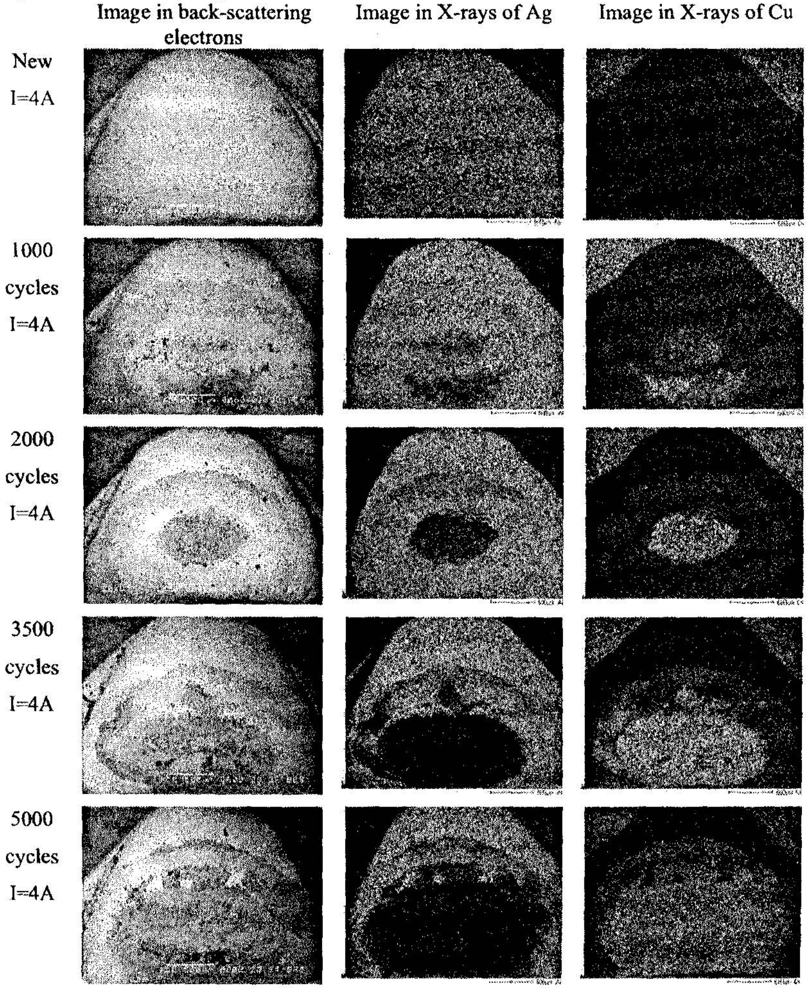

Fig. 1. SEM and X-ray element map images of contact after different numbers of cycles

The operation of switches involves changes in their transition resistance and operation temperature that follow from the degradation of contacts.

a non-linear function of the silver coating thickness (Fig.4), As can be seen in the figure the cycle number $N_w(d)$ is proportional to the squared thickness value.

$$N_w(d) = c\left(\frac{d}{d_0}\right)^2 \quad (1)$$

where: d_0 - thickness of an unit layer.

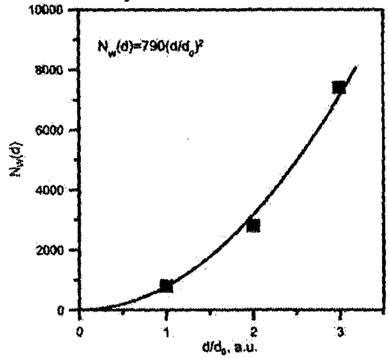

Fig.4, The number of switching cycles $N_w(d)$ that is needed for increase of transition resistance and temperature vs. silver coating thickness.

It follows from the comparison of Figs 2b and 4 that in order to obtain the same surface concentrations at triple thickness increase a three-times greater number of switching cycles is needed while resistance and temperature begin to grow at the cycle number that is nine times bigger. The difference follows from the fact that the moving contact is spherical of the R radius and the fixed contact is flat. It can be assumed that silver of a mean volume v evaporates during one switching cycle. For to obtain a direct contact with the exposed from under the silver copper surfaces silver should be removed from a spherical segment of the height equal to the layer thickness, whose volume is:

$$V \cong \pi d^2 R \quad (2)$$

then:

$$N_W(d) = \frac{V}{v} \sim d^2 \quad (3)$$

It follows from Fig.4 and the formula (3) that reliability of a silver-coated point contact grows as the squared layer thickness.

References

1. **Karwat Cz., Kolasik M., Kozak C., Żukowski P., Komarov F.** Czasopismo Naukowo -Techniczne - Mechanizacja i Automatyzacja Górnictwa, 7/402, Katowice, 2004.