10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

COMPOSITE ELECTRICAL CONTACTS BASED ON SILVER

Nadežda M. Talijan
Jasna T. Stajić-Trošić
Vladan R. Ćosović
Aleksandar S. Grujić
Institute of Chemistry, Technology and Metallurgy, Njegoševa 12, 11000 Belgrade, Serbia and Montenegro

Endre L. Romhanji
Faculty of Technology and Metallurgy, Karnegijeva 4, 11000 Belgrade

ABSTRACT
Composite materials with combinations of silver and oxides of different metals are materials with significantly improved electrical and mechanical properties. Ag-CdO electrical contacts produced by inner oxidation of the Ag-Cd alloy possess certain advantages compared to basic alloy. Owing to uniform distribution of very fine CdO grains in silver matrix they have high hardness and high electrical conductivity, higher than Ag-Cd and Ag-CdO contact materials produced by the powder metallurgy method. This paper presents part of study of making Ag-CdO electrical contacts by the inner oxidation of Ag-Cd alloys with different amount of Cd, with special attention to the influence of the temperature and duration of oxidation to the thickness of oxidized layer.
Keywords: Electrical contacts, Ag-CdO, inner oxidation

1. INTRODUCTION
Electrical contact materials based on silver and silver oxide (Ag-CdO) have been used for many years for different electro equipment which work with different cuts of electrical circuit. Limitation in working period of silver electric contacts is realized as attrition of silver when circuit is cut [1,2]. Ag-CdO electric contacts have been produced by two main methods: powder metallurgy and by the inner oxidation of Ag-Cd alloys with different Cd content. The goal of the process of production is obtaining good and homogeneous oxide dispersion in a silver matrix in order to meet the requirements of following main electrical properties: low erosion (in make and break operations), high extinction of the electrical arc, good resistance against welding, high value of hardness and low contact resistance [1,2,3]. It should be mentioned that although Ag-CdO layer is two phased system, its electric conductivity is better than conductivity of solid cadmium solution in silver [1,2,3]. Inner oxidation is oxidation process in metal-gas system. Conditions of inner oxidation is simplified in binary systems under condition that one of the components have higher affinity to the oxygen, or that other component does not form stable oxides under normal conditions. Basic indicator of metal affinity to the oxygen is its normal potential and free energy of oxide forming. Normal potential of silver shows small affinity to the oxygen and silver does not form stable oxides under normal conditions. If metal which is more electropositive is in the alloy with other, more electronegative metal which normal potential is just a little bit lower, affinity of that more electronegative metal to the oxygen remains unchanged and it might oxidize, while other more electropositive metal remains non-oxidized. That is also for binary system Ag-Cd [1,2]. Owing to uniform distribution of very fine CdO grains in silver matrix, Ag-CdO electric contact materials have high hardness and high electrical conductivity, higher than Ag-Cd and Ag-CdO contact materials produced by the powder metallurgy method. During the exploitation, minor increase of electrical resistance and minor loss of contact material of the contact

pair occurs compared to pure Ag or sintered Ag-CdO electrical contacts. With the increase of Cd content in the alloy hardness increases and the electrical conductivity decreases. Cd content in the range from 9-11 mass% does not induce significant changes of the electrical resistance and loss of mass during the exploitation of the contact pair. Ag-Cd alloys with 9-11 mass% Cd are very suitable for production of electrical contacts with different shapes and geometries by the plastic deformation [4,5]. In general, the oxidation rate depends on the Cd content in the Ag-Cd alloy, purity of the starting alloying components, diffusion of oxygen through the oxide layer and the purity of the formed oxide. Temperature and duration of oxidation are two most influential parameters for the oxidation rate and thickness of the oxide layer. Furthermore the oxidation rate and the thickness of the oxide layer, in the same temperature and time interval can be influenced by the oxygen pressure. The influence of the temperature of oxidation, duration of oxidation and amount of present cadmium to the quality and thickness of formed oxide was observed and discussed.

2. EXPERIMENTAL

Process of inner oxidation of Ag-Cd alloys with amount of Cd of 9.5, 11, 12 and 16 mass % was investigated. Ag-Cd alloys synthesized by melting of pure metals (99.90 mass %) Ag and Cd, were plastically deformed on low temperatures. Inner oxidation of the investigated alloys was done in electro resistive oven. For all mentioned alloys oxidation was conducted in air atmosphere under natural conduction of air at the temperatures 670^0C, 750^0C and 795^0C during 5; 9.5; 20.5; 36 and 48 hours. Measurements of thickness of oxidized layer were done on the metallographic microscope REICHART of POLYVAR – MET type. Vickers hardness (applying load of 5 kp) was measured after the applied oxidation regimes.

3. RESULTS AND DISCUSSION

Graphic dependence of thickness of oxidized layer for different Cd content in Ag-Cd alloys in applied oxidation regimes is presented on figures 1, 2 and 3.

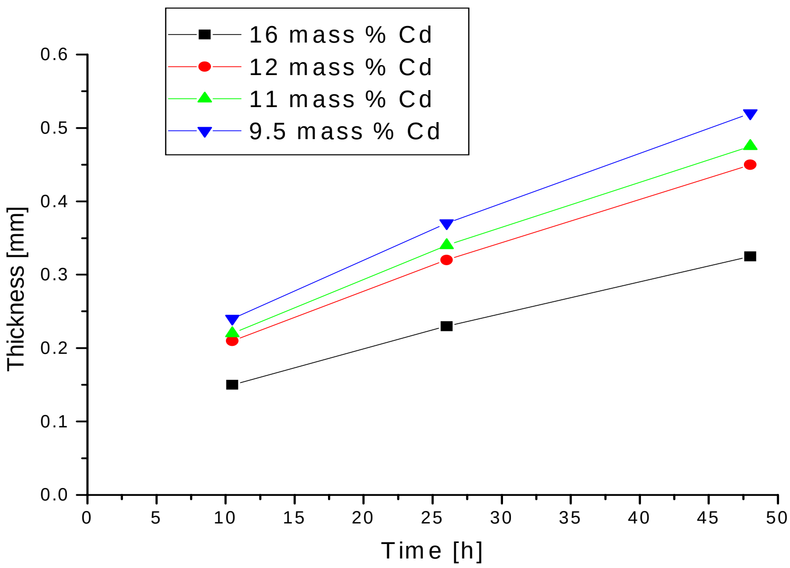

Figure 1. Dependence of thickness of oxidized layer for Ag-Cd alloys with different Cd content: inner oxidation on 670^0C

After comparing of changes of thickness of oxidized layer with temperature and time, it is obvious that oxidation rate is the highest for the alloy with the least amount of Cd and the lowest for the alloy with highest amount of Cd. At the same time it might be concluded that temperature has the highest influence on the process of inner oxidation [6]. At higher temperatures inner oxidation is faster.

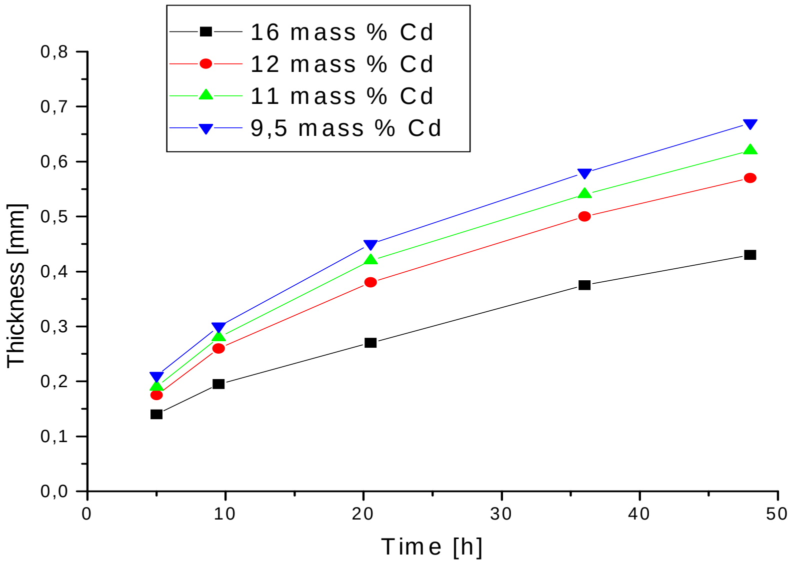

Figure 2. Dependence of thickness of oxidized layer for Ag-Cd alloys with different Cd content: inner oxidation on 750^{0}C

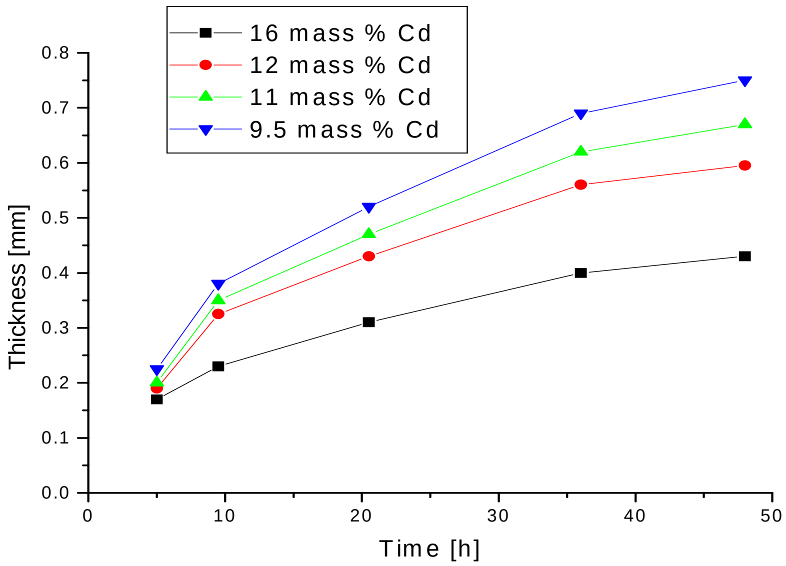

Figure 3. Dependence of thickness of oxidized layer for Ag-Cd alloys with different Cd content: inner oxidation on 795^{0}C

Electrical contacts based on Ag-CdO are less plastic (higher hardness) comparing to Ag-Cd alloy. Hardness of oxidized layer of alloy is not the same on the whole profile. It is the highest on the surface, and it decreases with increase of distance from the surface. At the certain distance from the surface hardness is constant and rapidly decreases at the border of oxidized and non-oxidized layer. Content of 9-12 mass % of CdO in the Ag-CdO alloys successfully influences the decrease of deformation and devastating of electrical contacts. With higher concentrations of CdO above 12 mass%, is possible of inner breaking due to intension caused by increasing of grains diameter after oxidation. As an illustration, optical micrograph of Ag-CdO electrical contact material experimentally obtained by inner oxidation process is presented on figure 4. Metallographic investigation have shown that the minimal thickness of oxide layer is about 66% of the total thickness of the Ag-Cd ribbon and

that the average thickness of the oxide layer, depending upon the temperature and duration of oxidation process is about 68-72 %. In the optimized process of oxidation high and homogenous dispersion of CdO in the silver matrix is obtained, as it can be seen on the optical micrograph (figure 4.) of the polished and etched cross section of the Ag-CdO sample.
In order to provide good bond between the contact material and contact holder by soldering, about 25% of the total thickness of the electrical contact material must not be oxidized.

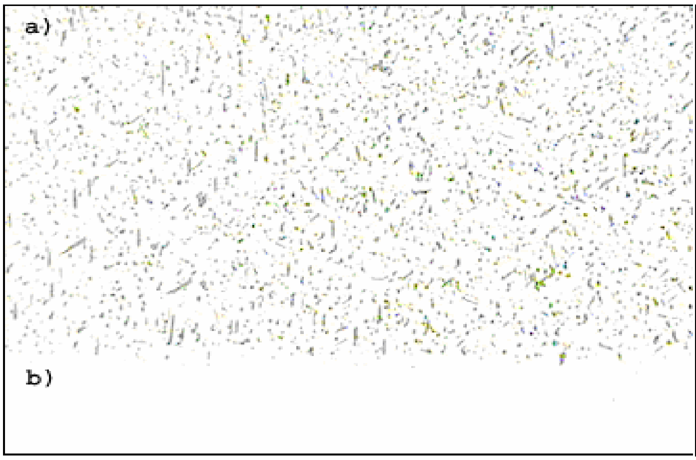

Figure 4. Optical micrograph of cross section of the Ag-CdO obtained by inner oxidation: a) oxide layer, b) poor Ag-Cd layer

Mean value of hardness after applied inner oxidation regimes is 80 HV for 9 mass% of Cd; 85 HV for 11 mass% of Cd; 91 HV for 12 mass% and 130 HV for 16 mass% of Cd. It is well known fact that hardness of oxidized layer is higher than hardness of Ag-Cd alloy, due to presence of CdO.

4. CONCLUSION

Thickness of oxidized layer during heating depends on conditions of process: temperature and duration of oxidation, amount of cadmium in Ag-Cd alloys and oxygen pressure on the surface of the alloy. Step of oxidation Ag-Cd alloy is lower comparing to the oxidation step of porous materials of Ag-Cd synthesized by powder metallurgy processes, but quality of electrical contacts made by inner oxidation is much improved because of more uniform distribution of cadmium oxide in silver matrix. The hardness of oxidized layer is higher than hardness of Ag-Cd alloy, due to presence of CdO. Investigated process of making of electrical contacts by inner oxidation of Ag-Cd alloy allows getting complex forms of electrical contacts economically.

5. REFERENCES

[1] Trifunović D. D.,Talijan N. M.: “Composite Ag-CdO electrical contacts obtained by inner oxidation”, Proc.of. V Yug. Simp. of Metallurgy, 1992., Belgrade
[2] Talijan N.: ”Functional composite materials”, Journal of Metallurgy, 2000., Vol.6, p. 81-94 (in Serbian)
[3] Technical literature of “DODUCO” – Germany
[4] Bernard J., Moreau J.: ″Les difference modes d′oxidation des alliages″, Rev. Metallur., 1962., 3, p. 161
[5] Gluhl W., Wassermann G.: Z. Metallk., 1950., 41, p. 178
[6] Talijan N., Stajić-Trosić J., Ćosović V., Grujić A., Nedeljković D., Jordović B.: ″Composite Ag-CdO electrical contacts made by inner oxidation″, 6th International Power Systems Conference, Timisoara, Romania, 2005.

6. ACKNOWLEDGEMENT:

This work has been supported by the Ministry of Science and Environmental Protection of Serbia.