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# STRUCTURE AND PROPERTIES OF SINTERED Ag-$SnO_2$ ELECTRICAL CONTACT MATERIALS

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**ABSTRACT**
*The presented work covers part of experimental results of simultaneous study of microstructure, density, hardness and electrical conductivity of sintered electrical contact materials based of Ag-$SnO_2$ with 8.10 and 12 mass% $SnO_2$. The mentioned characteristics were analyzed in the function of different sintering regimes and after additional mechanical treatment (forging and rolling). The influence of small addition of $In_2O_3$ (2.9 mass%) on the increase of dispersion of main oxide $SnO_2$ in Ag matrix is observed and presented also.*
**Keywords:** Ag-$SnO_2$, electrical contact materials, powder metallurgy, structure, mechanical properties, electrical conductivity

## 1. INTRODUCTION

Due to their excellent electrical and mechanical properties the metal-oxide electrical contact materials of Ag-CdO type have been used for many years for different low voltage devices of contactor type [1]. Based on the EU regulative considering toxicity of most commonly used metal-oxide CdO, further investigations of electrical contact materials are directed towards replacement of the toxic and harmful CdO with non toxic oxide dispersed in silver matrix, in order to obtain new ecological electrical contact materials. The new ecological electrical contact materials have many advantages from the technical, economical and environmental point of view [2,3]. It was found that the Ag-$SnO_2$ materials have the most favorable properties. Nowadays, it is known that electrical and mechanical properties of Ag-$SnO_2$ electrical contact materials can be improved by adding small amounts of $In_2O_3$, $Bi_2O_3$, CuO and $WO_3$ [3,4]. These additives increase dispersion of main oxides ($SnO_2$) in silver matrix and to the activation of sintering proces in order to gain optimal microstructure which results in improved electrical and mechanical properties.

## 2. EXPERIMENTAL

The influence of content of main oxide $SnO_2$ (8, 10, 12 mass%) and addition of $In_2O_3$ (2.9 mass%) on structural, mechanical and electrical characteristics of the Ag-$SnO_2$ electrical contact material was investigated. The studied electrical contact material based on Ag-$SnO_2$ with small addition of $In_2O_3$ was produced by powder metallurgy (PM) method from pure powders (Ag - 99.9%, $SnO_2$ - 99.9%, $In_2O_3$ - 99.99%). The silver powder used for investigations was obtained by chemical process and the $SnO_2$ and $In_2O_3$ powders are the commercial powders produced by Merck. Average particle size of the powders used in investigation was below 325 mesh, however the $SnO_2$ and $In_2O_3$ powders had more than 50% of submicron particles. Therefore the homogenization was done in several steps both wet and dry. Uniformity of the obtained mixtures was controlled with the use of scanning electron microscope (SEM). The samples were pressed into 80×20×5 mm plates by the hydraulic press with the pressure of 98 MPa in steel dye. 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. The samples were sintered in electro-resistive oven with programmable digital temperature controller with the accuracy ± 1$^{o}$C in the air atmosphere. The applied sintering regimes are presented on Figure 1. After sintering the samples were forged and hot rolled with the low degree of reduction to the final thickness of 2 mm.

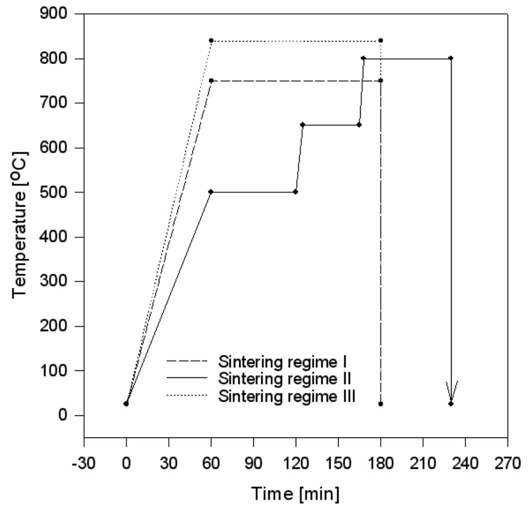



*Figure 1. Applied sintering regimes in sintering process of investigated Ag-$SnO_2$ and Ag-$SnO_2In_2O_3$ electrical contact materials*

The microstructure was observed on polished and etched cross-sections of the samples using the metallographic light microscope Leica DM ILM. Density of the samples was determined by standard methods. Vickers hardness (applying load of 5 kp) was measured after the applied sintering and mechanical treatment regimes. Electrical conductivity of the investigated materials was measured using the Foerster SIGMATEST 2.069 eddy current instrument for measurements of electrical conductivity of non-ferromagnetic metals based on complex impedance of the measuring probe, with the 8 mm probe. Technological procedure of production of investigated materials by powder metallurgy method (PM) is presented on Figure 2.

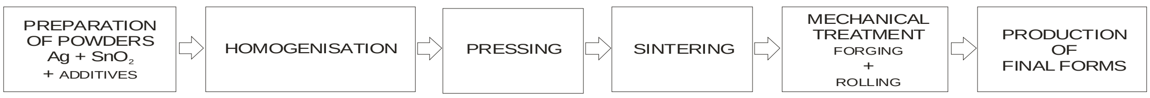
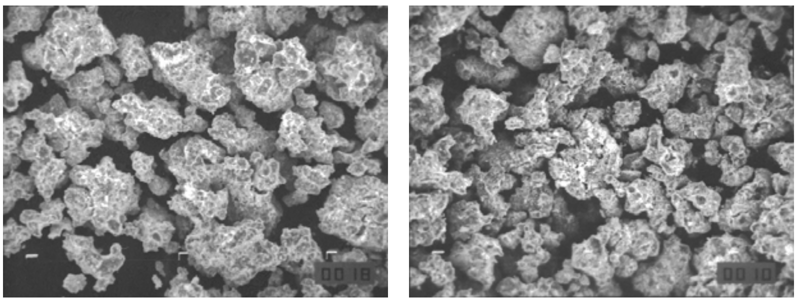



*Figure 2. Technological procedure of production of investigated Ag-$SnO_2$ electrical contact materials*

## 3. RESULTS AND DISCUSSION

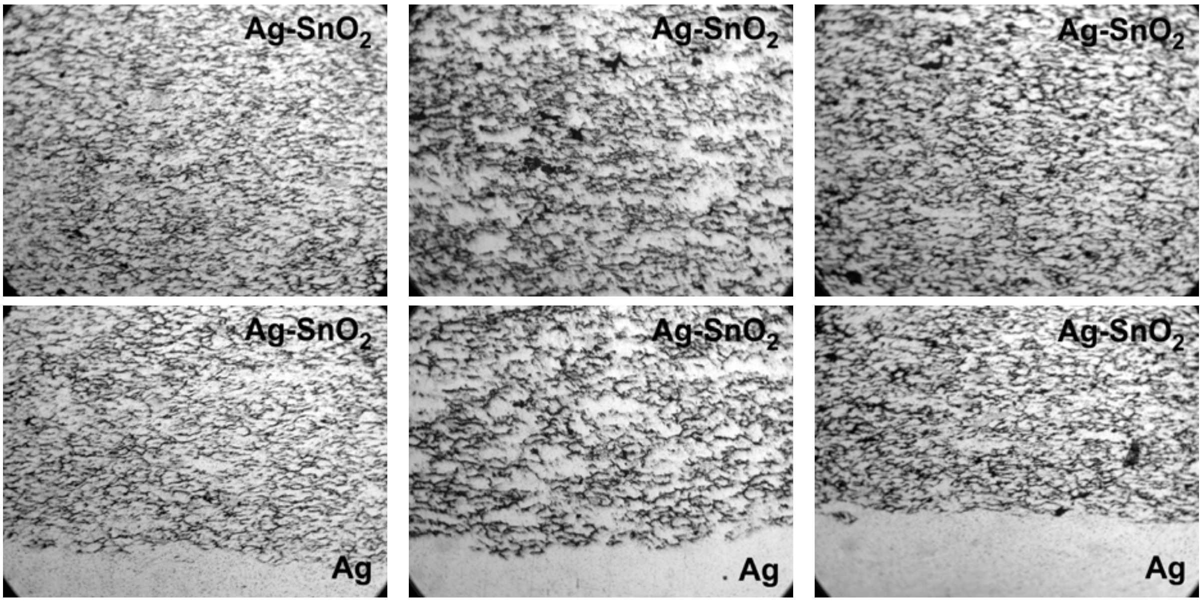
The SEM images of the Ag-$SnO_2$ (92:8) and Ag-$SnO_2$ $In_2O_3$ (87.8:9.30:2.90) mixtures that were used in investigation are presented on Figure 3.



*a)* *b)*

*Figure 3. SEM images (x500) of a) Ag-$SnO_2$, and b) Ag-$SnO_2$ $In_2O_3$ mixtures*

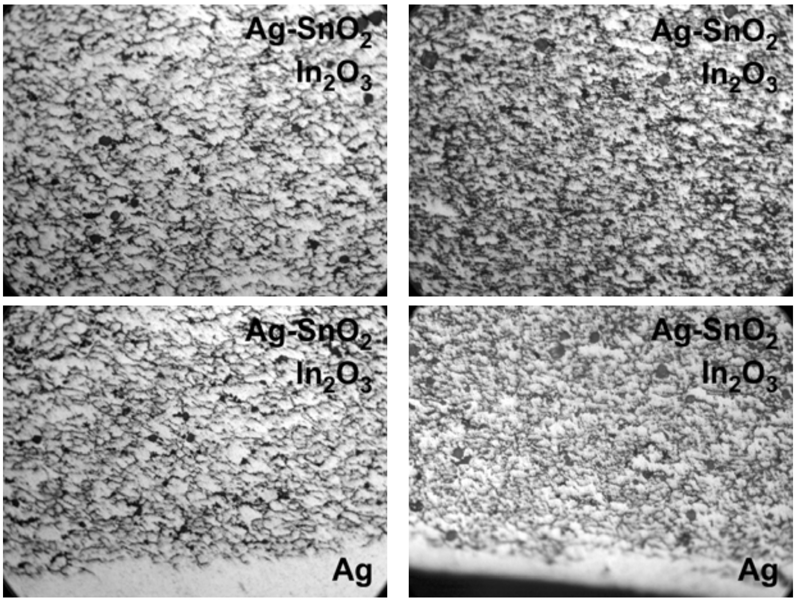
By continuous microscopic control of process of homogenization it was determined that despite the formation of agglomerates, due to very fine particles of the powders used, the good uniformity of mixtures was obtained which has provided reasonable values of density in the subsequent process of consolidation. Images of microstructures (cross-sections) of the investigated Ag-$SnO_2$ (92:8) electric contact materials after the applied sintering regimes and mechanical treatment are shown on Figure 4. The presented cross-sections are with and without Ag layer.




*I II III*

*Figure 4. Microstructure (cross-section) of Ag-$SnO_2$ (92:8) sintered at regimes I, II, III and additionally mechanically treated*

The obtained microstructures of the investigated Ag-$SnO_2$ $In_2O_3$ (87.8 : 9.30 : 2.90) electric contact materials after different sintering regimes and mechanical treatment are presented on Figure 5.




*I II*

*Figure 5. Microstructure (cross-section) of Ag-$SnO_2$ $In_2O_3$ (87.8: 9.30: 2.90) after sintering at regimes I, II and additional mechanical treatment*

Since the investigated electrical contact materials were produced from very fine powders, which have a high specific surface and good sinterability the obtained microstructure was homogenous and the porosity was very low. From Figure 4. and Figure 5. it can be seen that the components $SnO_2$ and $In_2O_3$ are uniformly dispersed in silver matrix. As a result a good mechanical properties and electrical conductivity were obtained. Summarized experimental results of density, hardness and electrical conductivity measurements of investigated electrical contact materials in relation to sintering conditions and mechanical treatment regimes are presented in the Table 1.

*Table 1. Mean values of density, hardness and electrical conductivity of investigated electrical contact materials with corresponding sintering conditions and mechanical treatment regimes*

| Sample No. | Ag (mass%) | $SnO_2$ (mass%) | $In_2O_3$ (mass%) | Sintering regime | Density g/cm$^3$ | Hardness HV/5kp | Electrical Conductivity MS/m |
|---|---|---|---|---|---|---|---|
| 1 | 88.0 | 12.00 | – | I | 7.2 | 73.2 | 26.98 |
| 2 | 90.0 | 10.00 | – | | 7.9 | 73.6 | 33.32 |
| 3 | 92.0 | 8.00 | – | | 7.4 | 70.8 | 35.75 |
| 4 | 92.0 | 8.00 | – | II | 9.6 | 91.6 | 36.04 |
| 5 | 92.0 | 8.00 | – | III | 9.8 | 102.0 | 38.57 |
| 6 | 87.8 | 9.30 | 2.90 | I | 9.0 | 77.2 | 27.13 |
| 7 | 87.8 | 9.30 | 2.90 | II | 9.4 | 84.2 | 30.75 |

The presented experimentally obtained results of microstructural analysis and determined mean values of density, hardness and electrical conductivity of the investigated Ag-$SnO_2$ and Ag-$SnO_2$ $In_2O_3$ electrical contact materials can be matched up to the mean values of the same characteristics of the Ag-CdO electric contact materials. Good results of density and hardness and consequently electrical conductivity were achieved for the Ag-$SnO_2$ with addition of $In_2O_3$ (2.9 mass%) also. This is completely understandable, since the small amounts of $In_2O_3$ (or other additives like $Bi_2O_3$, CuO and $WO_3$) will increase dispersion of main oxide in silver matrix and the activation of sintering process. This way the optimal microstructure can be obtained which would result in improvement of electrical and mechanical characteristics.

## 4. CONCLUSION

Maximal values of density, hardness and electrical conductivity of the investigated Ag-$SnO_2$ electrical contact material were obtained after sintering of the material at 840$^o$C for 2 hours. By comparing of the obtained experimental results of investigation of Ag-$SnO_2$ electrical contact materials with different $SnO_2$ content, it can be observed that sintering regime has the significant influence on the improvement of mechanical and electrical properties. It was found that the small addition of $In_2O_3$ to Ag-$SnO_2$ has caused foremost improvement of mechanical properties while keeping the good values of electrical conductivity. Obtained microstructural characteristics and values of density, hardness and electrical conductivity of the investigated Ag-$SnO_2$ and Ag-$SnO_2$ $In_2O_3$ electrical contact materials are comparable to the same characteristics of the electric contact materials based on Ag-CdO.

## 5. REFERENCES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## 6. ACKNOWLEDGEMENT


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