Journal of Ceramic Processing Research. Vol. 9, No. 6, pp. 646~648 (2008)

J O U R N A L O F
Ceramic Processing Research

Effect of Y_2O_3 addition on the microstructure and density of $AgSnO_2$ contact material

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$AgSnO_2$-Y_2O_3 compound powders were prepared by a mechanical alloying (MA) method, $AgSnO_2$-Y_2O_3 contact material was fabricated by pressing, sintering, repressing and resintering, the effect of Y_2O_3 addition, repressing and resintering on the microstructure and density of $AgSnO_2$ contact material was investigated. The results show that there are drastic dedensifications or swelling, cracks and pores in $AgSnO_2$ contact material fabricated by powder metallurgy, which thus has a lower density. The addition of Y_2O_3 is helpful in improving the microstructure and density significantly. The density increases significantly after repressing and resintering, and can reach 8.42 g/cm^3.

Key words: Mechanical alloying (MA), $AgSnO_2$ contact material, Repressing, Resintering, Density.

Introduction

With increasing requirements for the miniaturization, long lifetime, high reliability of low voltage electrical apparatus and ecological protection, conventional AgCdO materials have been gradually restricted because of their damage to the environment and human health in the manufacturing process and in service [1-4]. Hence, many investigations have been made to replace AgCdO contact materials and the literatures published show that $AgSnO_2$ contact materials have excellent electrical properties, which are comparable to those of AgCdO contact materials [5-7]. However, it was also found that the contact resistance and temperature increase of $AgSnO_2$ are higher than those of AgCdO materials under the same conditions because silver and SnO_2 can be separated easily during the process of arc erosion and SnO_2 will aggregate on the surface of contacts, the anti-arc-erosion of $AgSnO_2$ is lower in the AC3 operation condition and $AgSnO_2$ materials are difficult to machine due to the higher hardness of SnO_2 [8-10], much research has been made to tackle these problems and it is reported that trace additives can improve the workability and electrical properties of $AgSnO_2$ materials [11, 12]. In order to further understand the role of trace additives in the $AgSnO_2$ materials, the effect of trace Y_2O_3 additions and repressing and resintering on the density and microstructure is investigated.

Experimental Procedure

The sample chemical compositions were 90 wt%Ag/10 wt%SnO_2 and 90 wt%Ag/9 wt%SnO_2/1 wt%Y_2O_3. A mechanical alloying method was adopted to prepare $AgSnO_2$ and $AgSnO_2$-Y_2O_3 compound powders. These powders were milled together in a vibrating mill under argon gas, and the rotating velocity, milling time and the ratio of milling ball mass to powder mass were 400 rpm, 60 h and 60/1 respectively. The powders were examined with a JSM-6700F scanning electron microscope. Specimens were formed using a common mould stamping method, the total pressure of forming was 700 MPa and the dimensions of specimens were Φ20 mm × 5 mm. The specimens were sintered at 700 °C for 4 h and then repressed at 300 MPa and resintered at 700 °C for 1 h. The microstructures of specimens were observed using an OLYMPUS GX71 optical microscope. The density of the samples was tested according to Archimede's law.

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Results and Discussion

Morphology of $AgSnO_2$ powder

Fig. 1(a) and Fig. 1(b) are SEM micrographs of the $AgSnO_2$ compound powder at low and high magnification respectively. It can be seen from Fig. 1 (a) that the powder

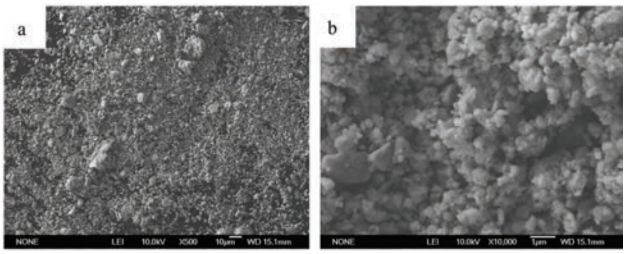

Fig. 1. SEM micrographs of $AgSnO_2$ compound powder milled for 60 h at low and high magnification. (a) low magnification (b) high magnification.

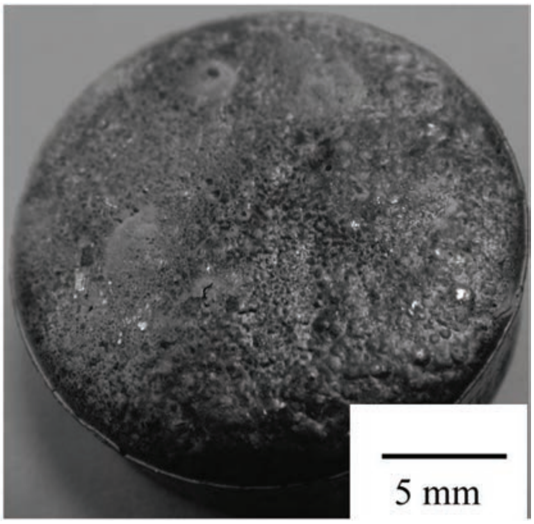

Fig. 2. Macrograph of $AgSnO_2$ material sintered at 700°C for 4 h.

milled for 60 h is very fine and has little aggregation, while Fig. 1 (b) shows that the powder has a uniform size and good dispersion.

Macrograph of sample

Fig. 2 is a macrograph of $AgSnO_2$ material sintered at 700 °C for 4 h. After sintering, there are large amounts of pores and swelling, and there are tiny pores and cracks on the side. Because $AgSnO_2$ compound powders absorb a large quantity of gas in the process of mechanical alloying, this results in poor sintering. Gases absorbed in the powders can not escape during the sintering process; subsequently cause pores and swelling or dedensification.

The radial and axial expansion ratio and densities of samples are given in Table 1. It can be seen that the radial and axial expansion ratios of $AgSnO_2$ material are much larger than those of the $AgSnO_2$-Y_2O_3 material, the sintering density of $AgSnO_2$ material without a Y_2O_3 addition is only 3.48 g/cm^3. However, the density of $AgSnO_2$ material with a Y_2O_3 addition increases by 45.5%, and can reach 6.38 g/cm^3. This indicates that there is an affinity between Y_2O_3 and silver, which is beneficial to the sintering densification of silver and SnO_2 powders giving a higher density.

Microstructure of sintered samples

Fig. 3(a) and Fig. 3(b) are the microstructures of $AgSnO_2$ and $AgSnO_2$-Y_2O_3 materials sintered at 700 °C and held for 4 h respectively. The black area is the silver matrix, while the white area is the SnO_2 phase. It can be seen from Fig. 3(a) that white SnO_2 particles aggregate in large areas, and there are some defects such as pores and cracks. From Fig. 3(b) it may be seen that fine SnO_2 and Y_2O_3 particles are distributed uniformly in the silver matrix, the aggregation of SnO_2, Y_2O_3 particles and silver is almost eliminated and the pores are decreased significantly. The analysis of the microstructures of the $AgSnO_2$-Y_2O_3 material further reveals that there is an affinity between Y_2O_3 and silver, which favors the sintering densification of $AgSnO_2$-Y_2O_3 material.

Table 1. The effect of a Y_2O_3 addition on the sintering property of $AgSnO_2$ compound powders.

	Axial expansion ratio (%)	radial expansion ratio (%)	density (g/cm^3)
$AgSnO_2$	40.0	10.0	3.48
$AgSnO_2$-Y_2O_3	22.0	5.2	6.38

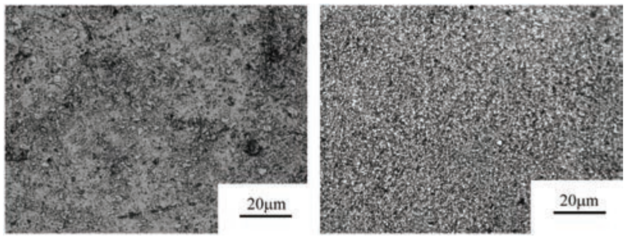

Fig. 3. Microstructure of $AgSnO_2$ and $AgSnO_2$-Y_2O_3 materials sintered at 700°C and held for 4 h. (a) $AgSnO_2$ material, (b) $AgSnO_2$-Y_2O_3 material

Effect of repressing and resintering on density and microstructure

The density of $AgSnO_2$-Y_2O_3 material after repressing at 300 MPa and resintering at 700 °C for 1 h is 8.42 g/cm^3. This has increased approximately 32% in comparison with that without repressing and resintering. The microstructure of $AgSnO_2$-Y_2O_3 material after repressing and resintering is shown in Fig. 4. It can be seen that the particles of Ag, SnO_2 and Y_2O_3 become much finer, SnO_2 and Y_2O_3 particles are dispersed in the silver matrix uniformly, and there are less pores and cracks, this results in a dense structure and a higher density. The reasons why repressing and resintering can increase the density of $AgSnO_2$-Y_2O_3 material are that repressing can make Ag and SnO_2 particles extrude each other, the pressure can cause silver to be deformed plastically, and thus drive the SnO_2 particles to move and rotate. The primary aggregated SnO_2 particles and the original SnO_2 particles with a bigger size will be

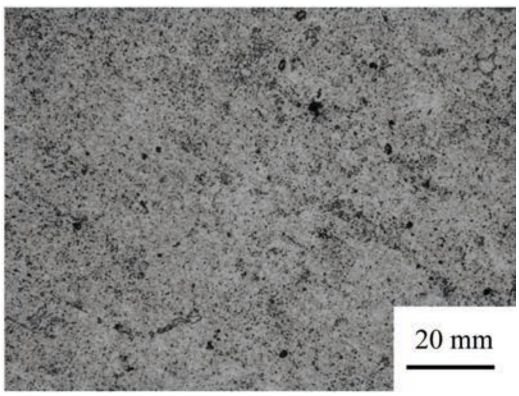

Fig. 4. Microstructure of $AgSnO_2$-Y_2O_3 material after repressing at 300 MPa and resintering at 700°C for 1 h.

crushed, and these finer crushed SnO_2 particles will flow under compression and be distributed more uniformly in the fine silver matrix, and resintering can make atoms diffuse creating a more microstructure. Also, repressing and resintering favor the elimination of internal defects and an increase in density.

Conclusions

(1) A trace Y_2O_3 addition can improve the sintering densification of $AgSnO_2$ compound powders.

(2) In comparison with the microstructure after pressing and sintering, repressing and resintering can make the microstructure more uniform and finer.

(3) Repressing and resintering favor an increase of density, the density of $AgSnO_2$-Y_2O_3 contact material can reach 8.42 g/cm^3 after repressing and resintering.

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