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ARTICLE

Microstructure and Properties of $AgSnO_2$ Composites by Accumulative Roll-bonding Process

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Abstract: $AgSnO_2$ composites prepared by a reaction synthesis method were investigated. The phases of $AgSnO_2$ composites were analyzed using X-ray diffraction. The microstructure, density, hardness and resistivity of $AgSnO_2$ composites after four-pass accumulative roll bonding (ARB) at 973 K were analyzed. Results show that microstructure and properties of $AgSnO_2$ composites are significantly affected by the ARB process. The pass number of ARB decides the distribution of SnO_2 particles in silver matrix. Roll bonding can promote the uniform distribution of SnO_2 particles in silver matrix; however, it can also cause second agglomeration of SnO_2 particles due to stacking. With the increasing of ARB number, the density and hardness increase. The resistivity has a slight reduction at the first-pass roll bonding, but then it increases with the increasing of ARB number.

Key words: reaction synthesis method; $AgSnO_2$ composites; accumulative roll-bonding

As one of the main electrical contact materials, silver metal oxide (AgMeO) composites have been widely used because of their excellent electrical contact characteristics[1,2]. For a long time, the application of electrical contact materials is mainly focused on AgCdO composites in China. However, Cd is a kind of toxic substances. Therefore, a large amount of Ag alloy material and other composites used to replace AgCdO composites were investigated. As a better replacement to AgCdO, $AgSnO_2$ composites show excellent arc erosion resistance, abrasion resistance, good anti-welding and some unique electrical contact characteristics[3,4]. But some recent researches have found that some problems in application exist in $AgSnO_2$ electrical contact materials[5,6]. In the electrical contact property test, $AgSnO_2$ composites showed rising contact resistance with the increasing of current. Another problem is that $AgSnO_2$ composites have a high hardness, which makes the forming difficult. Therefore, it may take a long time for $AgSnO_2$ composites to be used as a replacement of AgCdO.

Traditional researches focused on the composition design of electrical contact materials and achieved fruitful results, but very few researches considered the processing technology. Accumulative roll bonding (ARB) is effective means for the preparation of ultrafine grained materials[7]. The current ARB technology was mainly used in steel and aluminum alloy[8-10], but it is relatively rare in electrical contact materials. In the present paper, the microstructure of $AgSnO_2$ composites by ARB was studied and the density, hardness and electrical conductivity were tested.

1 Experiment

The silver powder with 45 μm particle size and purity > 99.95% and other reactants were used as starting materials

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to fabricate $AgSnO_2$ composites by a reaction synthesis method. The content of SnO_2 was 10 wt% in $AgSnO_2$ composites. The raw powder was mixed in planetary ball mill, and the mixed raw powder was pressed as a cylindrical body at 310 MPa. Then the cylindrical body was sintered in a vacuum sintering furnace at 800 K for 2 h. To increase the density of $AgSnO_2$ composites, re-sintering and re-pressing were adopted. $AgSnO_2$ sample of Φ2.0 mm×209.5 mm was obtained by extrusion at different temperatures.

ARB process of primary $AgSnO_2$ sample involved three main aspects. Firstly, 50% reduction per pass was obtained by hot rolling with a rate of 1200 mm/min. Before the next step, the annealing treatment at 573 K was needed in order to avoid the influence of residual stress. Secondly, the sample after rolling was cut and stacked to be the initial thickness, which was treated as the raw sample for next step. Thirdly, ARB process was repeated 4 times at 973 K. Before ARB process, the sample was preheated at 973 K for 5 min after annealing treatment at 573 K.

The hardness of the samples was measured by Vivtorinox hardness tester[11]. The average value of sample density was calculated using size and quality of each sample, which were measured 5 times for ensuring the repeatability. The resistance of the $AgSnO_2$ sample was measured using digital DC resistance tester (measuring accuracy: 0.02%) at room temperature. Microstructure of $AgSnO_2$ sample was observed using an optical microscope. X-ray diffraction (XRD) was used to analyze the phase composition of the sample.

2 Results and Discussion

2.1 Phase analysis

The X-ray diffraction results for $AgSnO_2$ composites before ARB process is shown in Fig.1. From Fig.1, it is clear to see that the $AgSnO_2$ composites can be fabricated by the reaction synthesis method and the phase composition are silver and tin oxide.

2.2 Microstructure

The microstructure of samples after different ARB processes is shown in Fig.2. From Fig.2, the SnO_2 particles in $AgSnO_2$ composites present an agglomeration state (A region in Fig.2a), but then they show a dispersed state with the increasing of roll pass (Fig.2b). Finally SnO_2 particles exhibit an agglomeration state again (B region in Fig.2d).

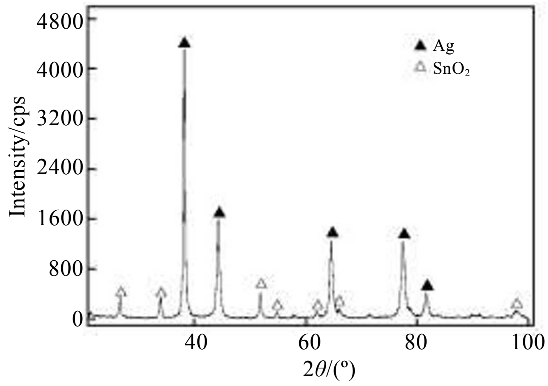

Fig.1 XRD pattern of the sample before ARB process

From Fig.2a to Fig.2b, the agglomerate SnO_2 particles change into dispersed state through first pass ARB, namely SnO_2 particles are evenly distributed in the silver matrix. The reason is that initial agglomerate SnO_2 particles in the sample are probably dispersed by strongly stress of ARB process.

With the increasing of roll pass, the agglomerate SnO_2 particles appear again (Fig.2d). This can be explained that the sample was cut and stacked after the first pass, which lead to overlap together of SnO_2 particles in the next procedure.

2.3 Property analyses

2.3.1 Density and hardness

The density and hardness variation of samples after ARB process are shown in Fig.3. The density and hardness of $AgSnO_2$ composites show an upward tendency with the increasing of rolling passes. The results can be summarized as follows:

On the one hand the frictional force is generated between the roller and the composites, which leads to the strong shear deformation in the $AgSnO_2$ composites. The SnO_2 particles are dispersed in Ag matrix with shear deformation. This causes the dislocation stacking near SnO_2 particles and strengthens dispersion[12].

On the other hand the surface of the $AgSnO_2$ composites is brought into the internal structure during the ARB process, which leads to plenty of compound interface in the $AgSnO_2$ composites. Some impurities in roller surface are also brought

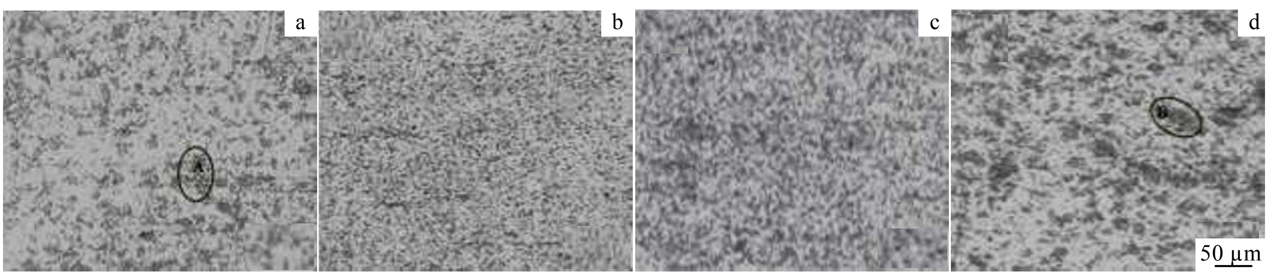

Fig.2 Microstructures of $AgSnO_2$ during ARB at 973 K: (a) primary sample, (b) 1-pass, (c) 2-pass, and (d) 4-pass