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Conductivity of silver paste prepared from nanoparticles

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Abstract

Conductivity of silver pastes using nanoparticles was investigated with sintering temperatures. Nano-sized silver particles with 50–100 nm in size were prepared by chemical reduction method. Silver pastes composed of nanoparticles (80 wt%), Pb-free frit (1.0 wt%) and organic vehicle (19 wt%) were screen printed on alumina substrates and sintered at temperatures ranging from 250 to 450 °C. As increasing the sintering temperatures, densification and grain growth were observed. When sintered at 400 °C, a distinct decrease in film thickness and a sharp increase in the rate of shrinkage took place, which in turn densification was developed at this temperature. With sintering temperatures, electrical resistivity of the films decreased due to denser microstructure and the films sintered at 450 °C showed 4.11 μΩ cm which can be compatible for various electronic devices.

Keywords: Silver; Nanoparticles; Paste; Conductivity; Thick film

1. Introduction

Nano-sized silver powder has been attracted for decades because it is an important substance of conductive inks, pastes and adhesives for various electronic devices [1]. A variety of studies have been focused on the preparation of silver nanoparticles [2–5] and pastes due to their high conductivity [6,7]. In recent years, silver paste with Pb-free glass has been developed [8] due to the danger of PbO-based glass to health and environment [9].

In our previous study [10], Pb-free silver paste with nanoparticles was prepared to achieve better conductivity. Lee et al. also reported that synthesis of monolayer-protected silver nanoparticles for using inkjet printing of nano-sized silver colloids [11]. Unfortunately, sintering of silver paste with Pb-free glass frit is quite difficult because sintering temperature of silver/Pb-free glass system is higher than that of paste containing PbO-based glass. Densification of silver paste-printed film is an important requirement to improve conductivity. Thus, silver nanoparticles can be a good candidate to achieve densification due to their high sinterbility [12].

Therefore, in this study, silver paste using nano-sized silver particles was prepared. Microstructures and related specific resistivity of the silver thick films with sintering temperatures were investigated.

2. Experiment

The nano-sized silver particles were prepared by the chemical reduction method using tri-sodium citrate as a surfactant and hydrazine monohydrate (N_2H_4) as a reducing agent. 0.1 M silver nitrate ($AgNO_3$) was reduced by hydrazine monohydrate in the presence of 0.05 M tri-sodium citrate. The reaction continued for 1 h with vigorous stirring until $AgNO_3$ was completely reduced. The whole procedure was carried out at room temperature. The synthetic silver colloids were washed with distilled water and ethanol, followed by centrifuged and dried overnight at 80 °C. The silver particles obtained were used for preparation of silver paste. 80 wt% of the silver nanoparticles was mixed with 1 wt% of Pb-free frit and 19 wt% of commercially obtained vehicles using a paste mixer (UM-103, Japan Unix). The silver paste was printed on alumina substrates using a screen mask (ST#400, 10 μm). The printed films were dried at 120 °C for 20 min to remove solvent and metallized at temperatures ranging from 250 to 450 °C for 15 min, respectively. Crystal structure of the silver nanoparticles was mesasured

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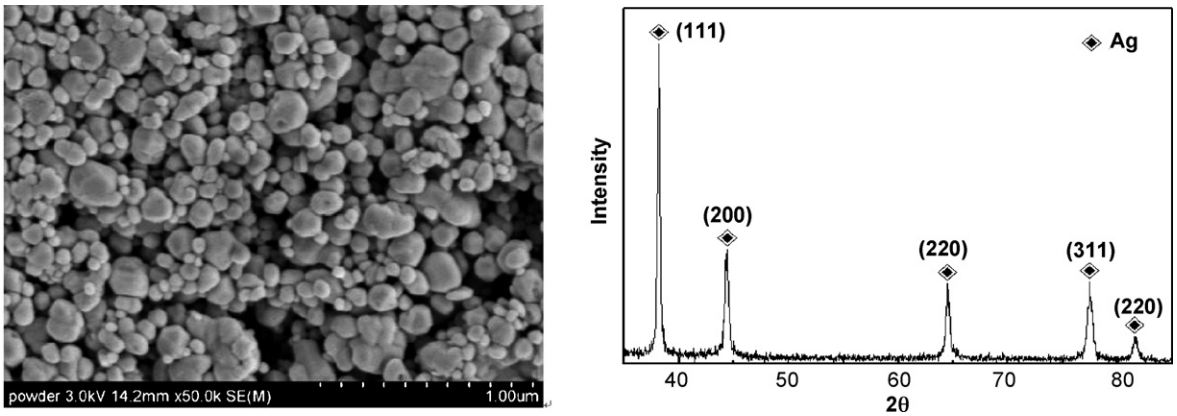

Fig. 1. FE-SEM micrograph and XRD pattern of silver nanoparticles.

by X-ray diffraction (XRD). Field emission scanning electron microscope (FE-SEM) was used to analyze microstructures of both the silver nanoparticles and the printed films. The specific electrical resistance of the films was measured using four-point technique (CMT-SR1000N, Advanced Instrument Techno logy).

3. Results and discussion

Fig. 1 shows FE-SEM micrograph and XRD pattern of nano-sized silver particles prepared by reduction reaction. The spherical silver nanoparticles having size in the range of 50–100 nm were observed. XRD analysis probed the formation

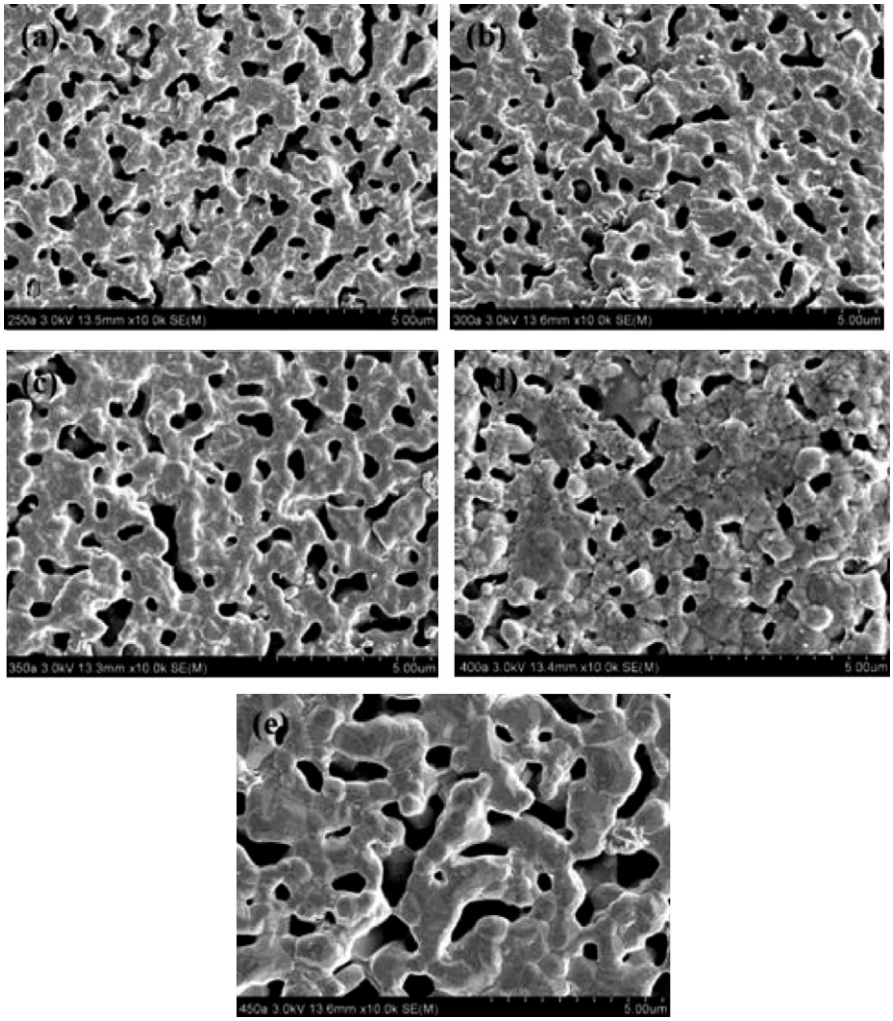

Fig. 2. Microstructures of the films with sintering temperatures at (a) 250 °C, (b) 300 °C, (c) 350 °C, (d) 400 °C and (e) 450 °C.