도전성 은잉크 제조 및 셀룰로오스 종이 잉크젯 프린팅
Conductive Silver Ink and Its Inkjet Printing on Cellulose Paper

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1. Introduction

In ink jet printing technology, the characteristics of ink is very important to determine the quality of conductive electrodes as well as the process performance. There are a number of techniques to synthesize silver nanoparticles such as chemical reduction [1, 2], photochemical reduction [3, 4], metallic wire explosion [5] and sonochemical method [6]. To date, little research has been carried out on integrated full synthesis process and characterization of both silver nanoparticle and silver ink. Inkjet printing quality is strongly dependent on the quality of substrates. Recently, cellulose has been identified as a smart material [7]. Due to its piezoelectric property, cellulose film with ink-jet printing has potential application in flexible electronics, speakers, biosensors and actuators. Thus, cellulose can be a substrate for inkjet printing. However, so far no silver ink has been optimized for ink-jet printing on cellulose substrate. In this work, silver nanoparticle having diameter less than 50 nm was first prepared by modified polyol method and then conductive silver ink was prepared from silver nanoparticle using several solvents like ethylene glycol, di-ethylene glycol (DEG) and de-ionized water. After that, this ink was coated on cellulose substrate. This ink can be used for ink-jet printing on cellulose film without further modification.

2. Experiments

Silver nitrate used as the metal precursor to prepare silver colloids. Firstly, Silver nitrate was dissolved in Ethylene glycol by sonication. Another solution of Polyvinylpyrrolidone (PVP) was prepared in Ethylene glycol with heating at 120°C. Then both solution allowed to be gently stirred together for 4 hr at fixed temperature. This step results the formation of PVP capped silver nanoparticles. It is very important to remove all the excess PVP from the colloidal solution as they may reduce conductance of final silver ink. The resulting solution was then washed by centrifuging. This washing step was repeated three times and the final residue of silver nanoparticle with less than 50 nm size was obtained.

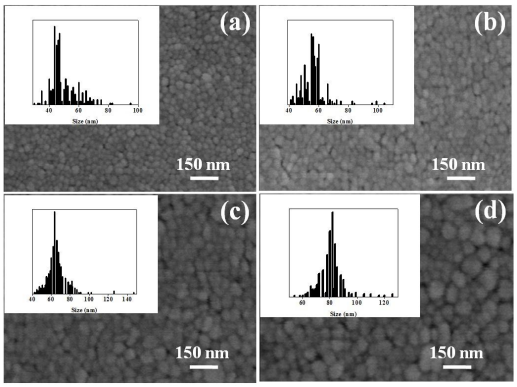

Fig. 1 SEM images (with size distribution) of Ag nano particles synthesized by heating at (a) 100 ºC, (b) 120 ºC, (c) 140 ºC and (d) 160 ºC and using PVP having MW 10,000

Small amount of Hydroxyethyl-cellulose (HEC) solution and DEG were added to the residue of silver nano particle. HEC acts as viscosifier to increase viscosity and DEG acts as surfactant to lower surface tension of solution. Finally, the conductive silver ink was achieved by using ultrasonic homogenizer.

The silver ink was coated on dry cellulose film and then sintered at different temperatures (150°C-250°C) under ambient atmosphere. Finally, the electrical properties were measured for sintered silver ink on the cellulose film.

3. Result and Discussion

The SEM images of silver nanoparticles synthesized with different reaction temperature are shown in Figure 1 and the dependence of the size of nanoparticle on the molecular weight of PVP was analyzed by atomic force microscopic (AFM) images (3D) of silver nanoparticles. It should be noted that, by using PVP having molecular weight 10,000 at 120°C reaction temperature resulted smallest silver nanoparticle of 47 nm.

The samples for electrical characterization was prepared by spin coating of silver ink on cellulose film and depositing gold electrode on those sample by sputterer. Finally, the 2-point probe station was used to measure resistivity. It was found that, solid content of silver ink is a key factor affecting the resistivity of silver ink. Using co-solvent of DEG & DI water as a solvent of silver ink resulted the lowest resistivity of that ink. To enhance electrical conductivity, the PVP capped silver nanoparticles underwent sintering and heating at 200°C for 20 minutes. These conditions can be regarded as the optimal condition for low electrical resistivity as only 1.63×10^{-5} Ω·cm. This silver ink can be used for inkjet printing for flexible electronics, actuators and sensors.

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