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Study on the effect of surface modifier on self-aggregation behavior of Ag nano-particle

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ABSTRACT

In this study, four kinds of Ag nano-particles were synthesized with poly (vinylpyrrolidone) (PVP), polyaniline (PAN), L-cysteine (L-cys), and oleic acid (OA) as modified groups. The properties of these Ag nano-particles were characterized by several techniques. Transmission electron microscopy (TEM) observation show four samples were close to monodisperse spherical with diameters about 7, 3, 10, and 5 nm, respectively. The interplanar spacing was calculated and the crystal was discussed with X-ray diffraction (XRD) results. Both Fourier transform infrared spectra (FTIR) and thermogravimetry (TG)-differential scanning calorimetry (DSC) has revealed the binding group of four molecules on Ag nano-particle's surface. After the Ag nanoparticles (NPs) deposited onto the substrate, surface modifier would collapse on the particle surface. Ag nanoparticles are easier to self-aggregate for the weaker binding of surface modifier. As a result, the conductive film is formed. The effect of modified group and temperature were discussed on the conductivity of the silver films.

1. Introduction

Recently, metallic nanoparticle ink-jet conductive inks have attracted tremendous interests due to their high-efficiency and environment-friendly process and potential electronics field applications [1–4]. The printing of metal inks, especially those containing silver nanoparticles (Ag NPs), have been found to be a very powerful tool for direct patterning of electrically conductive interconnects [4,5]. The capping agents are usually used to improve the stability of Ag NPs suspension ink. Those agents could cap on the surface of NPs thus reducing the particles' nucleation and growth rate as well as prohibiting agglomeration and sedimentation of synthesized nanoparticles [1,6–8]. However, the organic capping agents can prevent electrons moving from one particle to another and significantly decrease conductivity. The question can be overcome by heat-treatment of the electrical contact.

To date, most of the previously reported methods for the preparation of conductive films via solution processing require further treatments after printing the nanoparticle films [1,9,10]. However, the plastic substrates and polymer films used in flexible plastic electronics are usually heat-sensitive [11]. So further treatment processes could destroy the plastic substrates or polymer films. Accordingly, some attempts were tried to understand the heat-treatment conditions (heating temperature, time, pressure, and so on) [12–14], to be compatible with the plastic substrates. In 2011, the preparation of large-area conductive silver films on plastic substrates at room temperature, using these Ag NPs inks, has also been demonstrated by Polavarapu et al. [11].

To make the metal films conductive, Ag NPs will aggregate on the substrate in the process of the solvent evaporation. This method is expected to have high impact on future low-cost printable electronics. We here follow this notion and report the preparation of Ag NPs ink with capping agents of poly (vinylpyrrolidone) (PVP), polyaniline (PAN), L-cysteine (L-cys), and oleic acid (OA). Some researchers have reported these capping agents were used as a stabilizer in the process of the preparation of Ag NPs ink preparation [15–21]. However, we synthesized the Ag NPs with "one-step synthesis" in water phase, which is different from the literatures as for the synthesis procedure, dispersion medium and particle size. Most important, we have systematically studied the size, the crystal, binding group and the binding strength with the same synthesis method and similar size.

These Ag nano-particles were characterized by several techniques, such as TEM, XRD, IR and TG-DSC. The conductive silver films on the polyethylene terephthalate (PET) plastic and silicon substrate have been prepared by evaporating the solvent at room temperature. We also compared systematically the conductivity on substrates of four kinds of Ag NPs ink and discussed the effect of modified group and temperature on the conductivity of the silver films.

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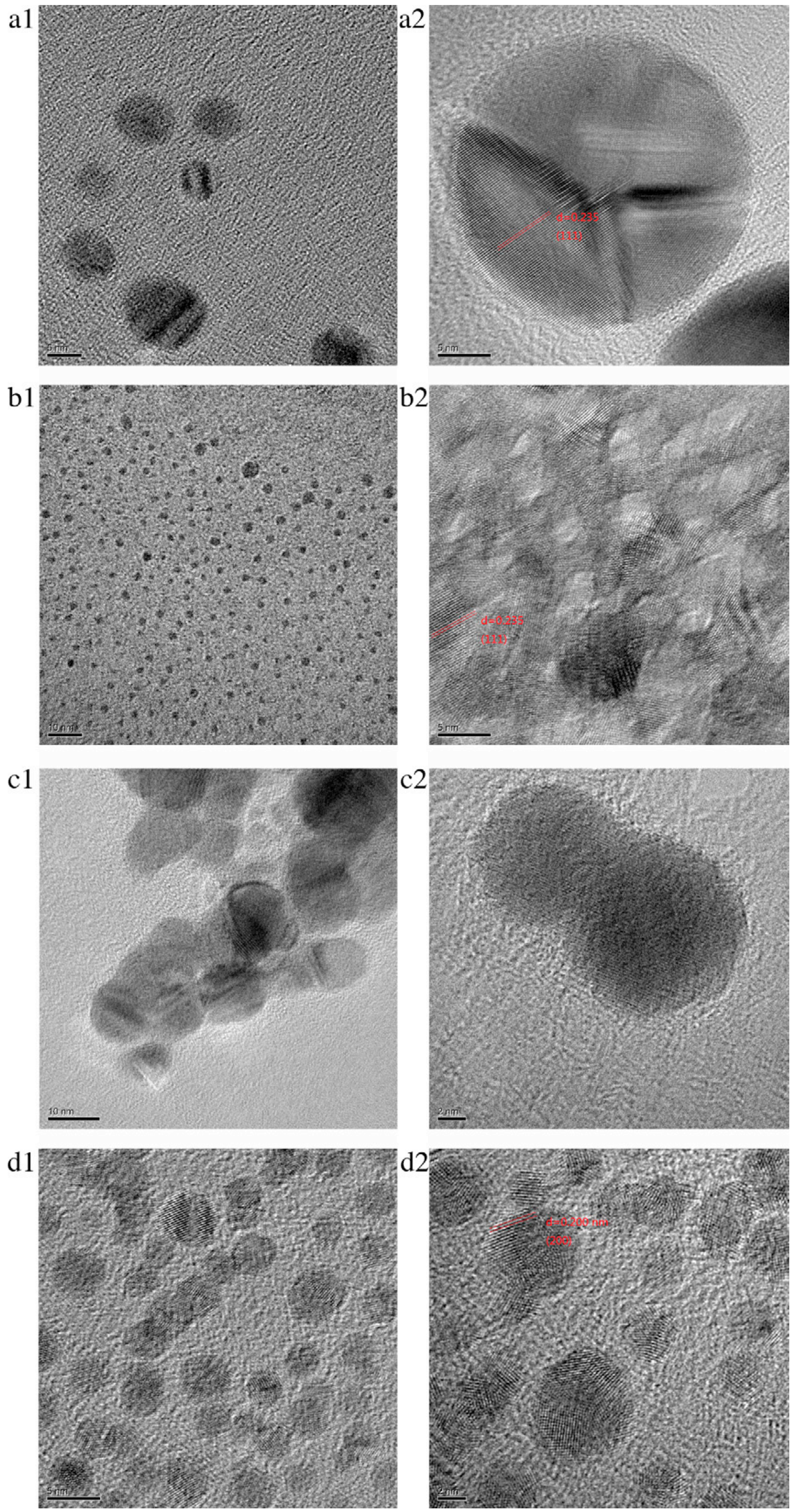

Fig. 1. TEM images of the silver NPs: Ag/PVP (a); Ag/PAN (b); Ag/L-cys (c); Ag/OA (d).