Copper Ink-Jet inks for Flexible and Plastic Electronics

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Abstract

One of the greatest challenges in fabrication of flexible and plastic electronics devices by printing is to obtain highly conductive patterns at sufficiently low temperatures which will not damage the heat sensitive substrates. Therefore, during the last decade, several approaches for the sintering of metallic nanoaprticles (NPs), usually silver, at low temperatures, were developed. However, the high cost of these silver based nano-inks limits fabrication of low cost plastic devices. Therefore, there is an unmet need for a low cost metallic ink with a low sintering temperature.

Here we describe the formation and printing of copper based ink-jet inks. Tailoring the nanoparticles stabilization mechanism enabled the formation of a low sintering temperature ink. It is shown that the use of these ink enables the formation of various devises printed on plastic, for example, copper based electroluminescent device and RFID antennas. Furthermore, the presence of anti-oxidation agents enables to achieve highly conductive patterns stable in air for a long time.

A variety of printing techniques such as inkjet, gravure and screen printings has recently attracted a great deal of attention because of their low-cost and large-scale manufacturability for electronic devices and their feasibility for application to flexible electronics [1-3]. Such printing processes inevitably require proper inks and pastes. To form the metal electrodes of the devices, much research has focused on the development of the inks mainly consisting of noble metal nanoparticles (NPs) such as Au and Ag with high electrical conductivity and oxidation resistance [4-10]. However, these noble metals increase the processing cost.

Alternatively, low-cost inks based on Cu NPs have been studied [11-18]. However, the rapid oxidation of metallic Cu NPs limits the electrical conductivity of the electrodes formed with the inks. Therefore, the applicability of air stable and large-scale synthesizable Cu inks, based on organometallic precursors, has recently been investigated [19-20]. Lee et al.[19] reported on inks based on the copper ion complex for conductive patterns. Their inks consisted of a Cu–formic acid complex synthesized by electrolysis. Copper electrode patterns were obtained after sintering the printed inks at 250 °C in hydrogen atmosphere. Yabuki et al. [20] introduced inks composed of complexes of copper(II) formate and n-octyl amine. The copper electrodes were formed by calcining the printed inks on glass substrates with an additional adhesive tape at temperatures as low as 140 °C undr nitrogen. Based on these reports, we considered copper(II) formate to be an advantageous precursor because of its potential for facile ink formulation and low-temperature processing.

Here we describe the formation of two copper based inks. The first ink, a copper NPs ink, is synthesized by chemical reduction of a copper precursor in presence of proper stabilizers, leading to the formation of 80 nm copper particles. The second is a copper precursor ink, obtained by the formation of a complex of copper with a proper amine, leading to the formation of a complex solution. Figure 1 presents some examples of the copper precursor inks characterized by the copper complex color.

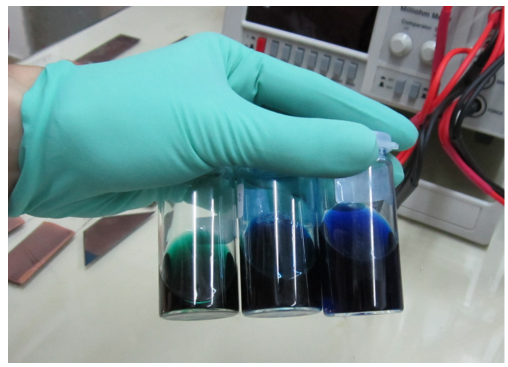

Figure 1. *copper complex inks.*

Figure 2 presents an HR-SEM image of the copper NPs and the dried ink deposited on a glass slide.

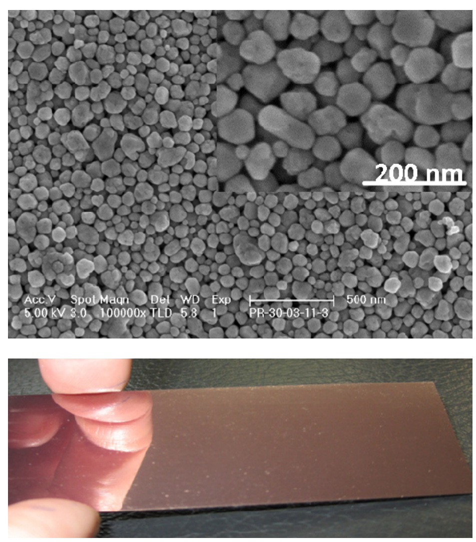

Figure 2*. HR-SEM image of copper nanoparticles and a glass slide coated by the copper ink.*

In order to evaluate the printability of these copper based inks by inkjet printing, a lab printer, OmniJet100 (Unijet) equipped with the Samsung's SemJet mini heads (30pl), was used. It was found that various patterns can be easily printed.

After sintering at various temperatures (under nitrogen), preliminary resistance measurements indicates that these inks are good candidates for conductive inks for plastic electronics.

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