Supplement

Current-induced morphological evolution and reliability of Ag interconnects fabricated by a printing method based on nanoparticles

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Experimental

The samples for Ag interconnects were prepared in the dog-bone shape with a length of 1 mm by the reverse offset printing method on 125 μm thick polyimide (PI) substrates. The Ag ink (Dong-Jin SEMICHEM Co. Ltd), which contains 18.9 wt% of nanoparticles in the size of 20 ~ 30 nm, was used for printing. The dimension of an Ag interconnect, fabricated through reverse offset printing method, was 20 μm in width and 100 nm in thickness. Reverse offset printing was conducted in the following sequential processes by Korea Electronics Technology Institute (KETI) as demonstrated in Fig. S1:

1. Blanket roller was coated with ink by ink squeezing.
2. The negatively patterned cliché was rolled with a blanket roller to produce the desired pattern on the blanket roller.
3. The patterned roller was rolled on the PI substrate to attach the pattern on the substrate.

After reverse offset printing on the PI substrate, the samples were dried for 1 hour at 100 °C to eliminate the solvent and prevent collapse of the metal line. In addition, the microstructures and electrical resistance of the Ag interconnects were evaluated with respect to anneal temperature, 250 - 350 °C with ramping rate of 3 °C/min and dwell time for 30 minutes. Ag interconnects fabricated by the reverse offset printing method was compared to Ag interconnects fabricated by the vacuum evaporation deposition method. Electrical reliability tests were conducted on a probe station using DC current supplied by a Keithley 2400 source metre under the temperature range of 50 - 150 °C and the current density range of 10^3 - 10^6 A/cm^2. The failure criterion was defined to be a 20% change in resistance.

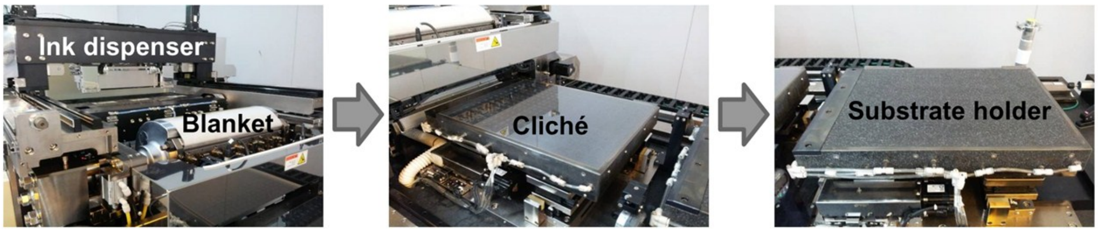

FIG. S1 Reverse offset printing procedure: (a) Image of ink coater for blanket roller. (b) Image of reverse off of desired patterns on blanket roller through negatively patterned cliché. (c) Image of process patterning on polyimide substrate using patterned roller.

Current and temperature effect on electrical reliability

To investigate the current and temperature effect on electrical reliability, Ag interconnects prepared by a printing method were tested under various accelerated temperature and current stressing conditions. As shown in Fig. S2, the resistance change was measured as a function of temperature and current density. With increasing current density and temperature during temperature and current stressing, the resistance of the Ag interconnect increased with elapsed time. The resistance increase was more sensitive to increases in the temperature than it was to increases in the current density. Finally, the combination of heat and current caused Ag interconnect failure, with an abrupt resistance increase after a certain time. Generally, the resistance of the metal film decreases with increasing annealing temperature due to the increased elimination of organic impurities and increased densification of the metal film. However, these experiments showed that the resistance increase under the combination of temperature and current stressing condition is different than the effects produced by the annealing process. It was important to understand the evolution of morphology under the combination of temperature and high current density and how changes in microstructure are related to the electrical property of the films.

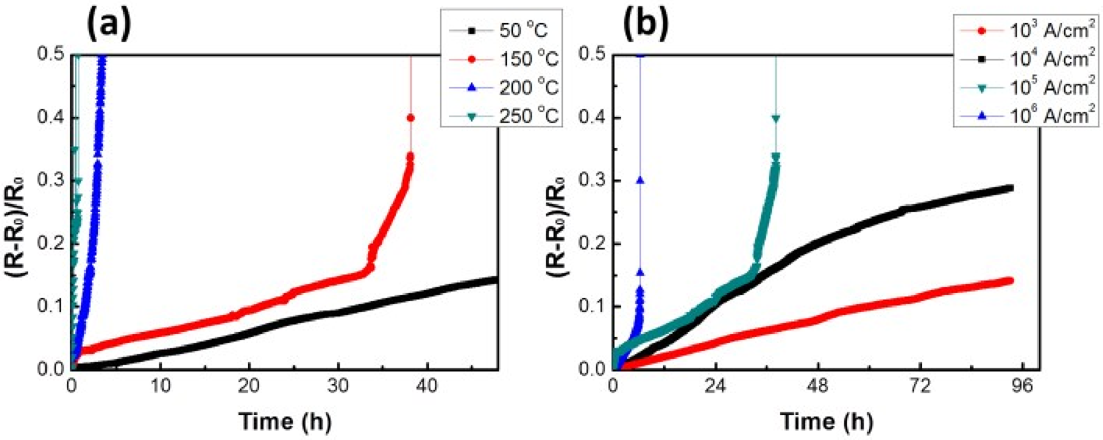

FIG. S2 Resistance change of Ag interconnects by reverse offset printing method: (a) At the temperature of 50 / 150 / 200 / 250 °C under current density of 10^5 A/cm^2. (b) Under current density of 10^3 / 10^4 / 10^5 / 10^6 A/cm^2 at the temperature of 150 °C.