Damascene of metallic wires on imprinted flexible substrate

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In comparison of large-scale integration (LSI) process based on film deposition, lithography and etching processes, screen printing is a useful for large-area micron-sized wires such as printed circuit boards and solar cells because of low cost and high efficiency. In the previous research, we proposed a novel method to fabricate fine metal traces on flexible film with the damascene fabrication method[1], which can overcome restrictions of the conventional screen printing technology, however, the metal slurry could not be sintered at high temperature. In this study, we succeeded to damascene silver nanoparticles into imprinted polymethylene naphthalate (PEN) and following sintering the nanoparticles. The resistances of the wires were investigated.

We prepared a nickel mold of straight wires with widths of 20, 30, 40, 50, 60, 70 and 80 μm and with the depth of 18 μm. A PEN surface was thermally imprinted with the Ni mold by nanoimprinting device to obtain micro channels with the same shape of mold patterns (Fig1.a). The mold temperature was 250 °C and the molding pressure was 30 MPa. Then, the Ag paste was directly filled into the micro channels by damascening (Fig1.b). The squeegee speed was 10 mm/s. The squeegee angle was 60 °. The linear pressure was 0.04 N/mm. The squeegee hardness was 90 °. Finally, the damascened PEN film was sintered for 60 min at 250 °C (Fig1.c).

Figure 2 shows the SEM images of the wires with the width of 20 μm at each fabrication procedure. We found that Ag paste was filled into the micro wires well and Ag particles were sintered, which indicates that this damascene method can fabricate wires with the width of at least 20 μm. Figure 3 shows the relationship between width and resistance of wires. We found that it is not linear and the finer wire is it, the higher resistance it will have. Therefore, according to this trend, if the wire width is 10 μm or even finer, the resistance of wires will increase dramatically. One possible solution is to imprint deeper channels on PEN. Even though it is not easy to obtain a channel with high aspect ratio, we will fabricate wires on flexible materials with low resistance with this damascene method.

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[1] J. Wang, K. Nagato, K. Takahashi, T. Hamaguchi, M. Nakao, *Proc. of 40th Micro and Nano Engineering*, Lausanne, Switzerland, Sep. 22-26, 2014.

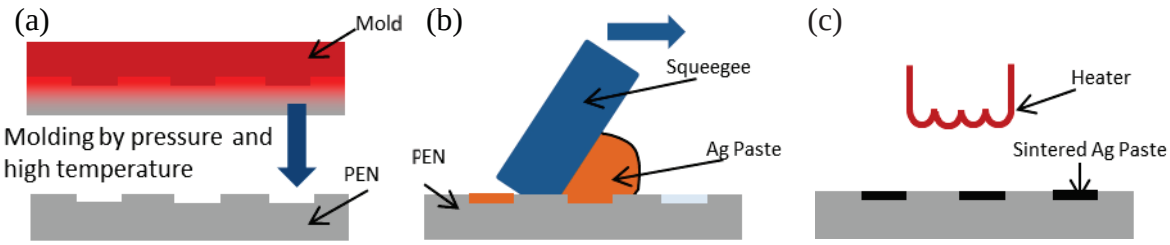

Figure 1: Schematic of fabrication procedure: (a) imprint the wire on PEN (b) damascening (c) sintering.

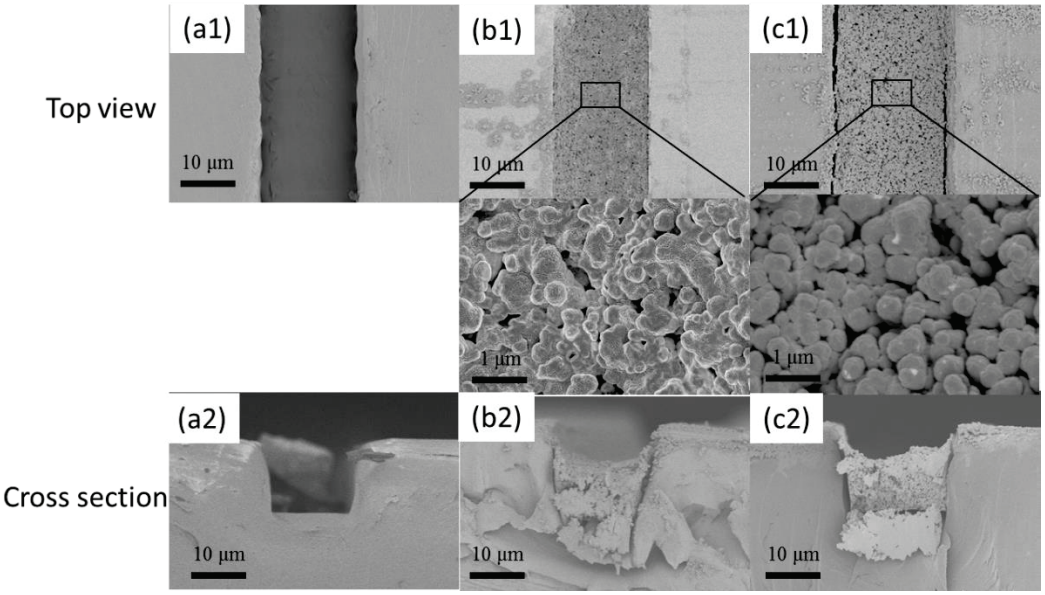

Figure 2: SEM images of the wire at different stages: (a) imprinted PEN (b) damascened silver nanoparticles (c) sintered silver nanoparticles.

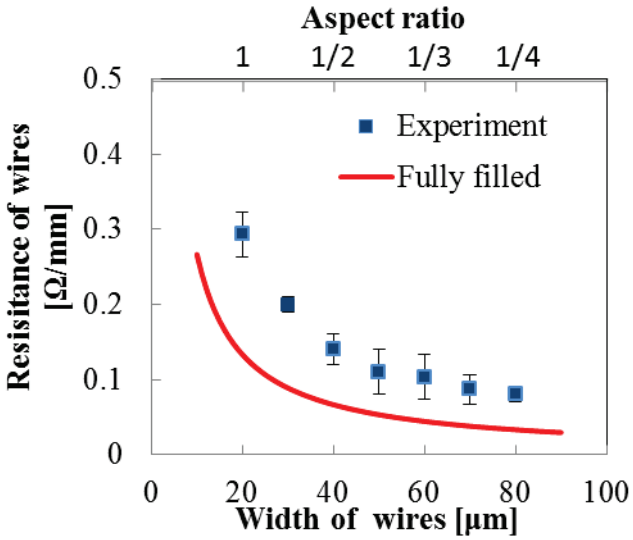

Figure 3: Relationship between width and resistance of wires.