

## Supplementary Information

### **Fabrication of dual-side metal patterns onto textile substrates for wearable electronics by combining wax-dot printing with electroless plating**

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#### **S1. Synthesis of paper-based Cu patterns**

Commercial printer papers (Double A<sup>®</sup>, A4 size, 80 g/m<sup>2</sup>) and photo-papers (Epson Ultra Premium, A3 size, 235 g/m<sup>2</sup>) were selected as the flexible substrates, and precisely cut into rectangular patches (5×5 cm). Radio-frequency circuits were designed in Adobe Illustrator CS6 program in monochrome mode. The pristine papers were ultrasonically rinsed with acetone, ethanol and distilled water, respectively, and then dried at 60 °C for 30 min. The as-cleaned paper samples were immersed into the acetone solution with 0.125 % APTMS for 5 min, and then heated at 120 °C for 10 min. Dipping and heating of samples were carried out for 3 cycles. Afterwards, waxes were transferred from commercial wax impregnated papers to APTMS modified papers with the aid of a stylus printer. Wax patterns were in accordance with the input images of Radio-frequency circuits. The activation procedure was achieved by immersing the printed papers into Au colloid solution. Finally, the selective Au-activated papers were dipped into the electroless copper plating bath (200 ml) at 60 °C for 2 h. Formulations and operation conditions of the electroless copper plating were listed as Table S1. After plating, the samples were carefully rinsed with distilled water, ethanol and then dried in an oven for 1 h at 60 °C.

## **S2. Synthesis of linen fabric-based Ni patterns**

The linen fabrics (45×45 count/cm<sup>2</sup>, 24 mg/cm<sup>2</sup>, 138 μm thick) were purchased from Taicang Biqi Novel Material Co., Ltd, and precisely cut into rectangular patches (10×15 cm). The preparation of linen fabric-based Ni patterns was carried out by a multistep process which included degreasing, APTMS modification, wax-pattern printing, Au activation and electroless nickel plating followed by rinsing and drying. The pristine linen fabrics were degreased in alkaline solution to remove oils and other organic chemicals, followed by rinsing with distilled water until the pH value reached neutral. The as-cleaned linen fabrics were immersed into APTMS solution for 5 min, and then heated at 120 °C for 10 min. A homogeneous APTMS molecular coating was obtained by repeating immersion and subsequent heating thrice. The APTMS modified linen fabrics were placed on the paper inlet of the stylus printer with wax impregnated paper aligned on the top. Afterwards, waxes were dotted onto the bottomed fabrics under the pressure from the printer head. After printing, wax patterns printed linen fabrics were obtained on the paper eject assy. The activation procedure was achieved by immersing the printed fabrics into a stable aqueous suspension containing Au nanoparticles. Finally, the selective Au-activated linen fabrics were dipped into the electroless nickel plating bath (200 ml) at 60 °C for 2 h. Nickel nucleated on these catalytically active sites, then further patterned nickel reduction and growth occurred. Formulations and operation conditions of the electroless nickel plating were listed as Table S1. After plating, the samples were carefully rinsed with distilled water, ethanol and then dried in an oven for 1 h at 60 °C.

### **S3. Synthesis of cuprammonium fabric-based Ni patterns**

Cuprammonium fabrics (45×45 count/cm<sup>2</sup>, 8 mg/cm<sup>2</sup>, 138 μm thick) were purchased from Taicang Biqi Novel Material Co., Ltd, and precisely cut into rectangular patches (10×15 cm). The fabrication of cuprammonium fabric-based Ni patterns was similar to that of cuprammonium fabric-based Cu patterns. The only difference was the immersion-step in the electroless plating bath. Herein, activated samples were dipped into electroless nickel plating bath (200 ml) at 60 °C for 2 h. After electroless plating, the samples were carefully rinsed with distilled water, ethanol and then dried in an oven for 1 h at 60 °C.

Table S1

Formulations and operation conditions of electroless copper and nickel plating bath.

Item	Electroless copper plating bath		Electroless nickel plating bath	
	Chemicals	Amount	Chemicals	Amount
Metal salt	Copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ )	5 g/L	Nickel sulfate ( $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ )	25 g/L
Complexing agent	KNa-tartrate ( $\text{C}_4\text{H}_4\text{O}_6\text{KNa} \cdot 4\text{H}_2\text{O}$ )	25 g/L	Sodium pyrophosphate ( $\text{Na}_4\text{P}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$ )	25 g/L
Reducing agent	Formaldehyde (HCHO)	5 ml	Dimethylamine-borane (DMAB)	1.5 g/L
pH adjustor	Sodium carbonate ( $\text{NaCO}_3$ ) and sodium hydroxide (NaOH)	12.5-12.8	Ammonium hydroxide ( $\text{NH}_3 \cdot \text{H}_2\text{O}$ )	12
Temperature ( $^\circ\text{C}$ )	-	60	-	60
Time (h)	-	2	-	2

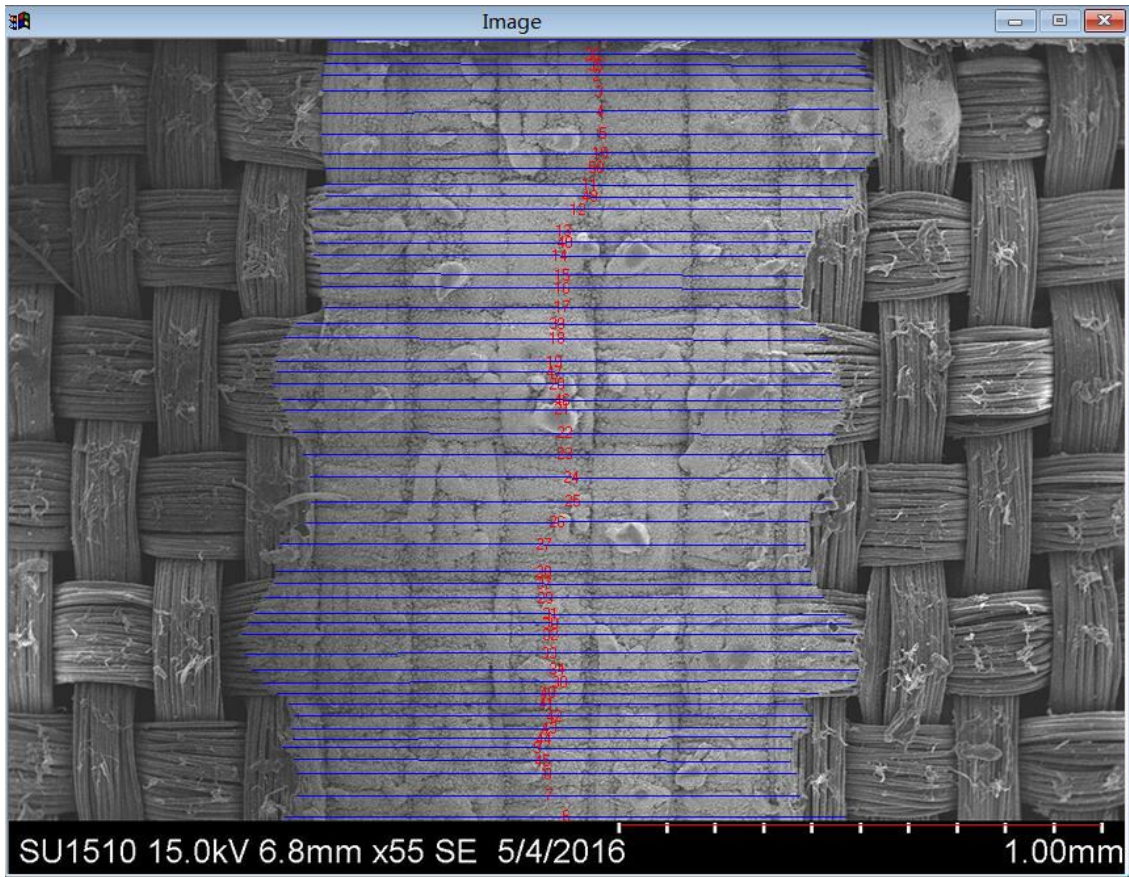


Fig.S1 Example of Cu line-width measurement in the “Nano Measurer” program for clarity.

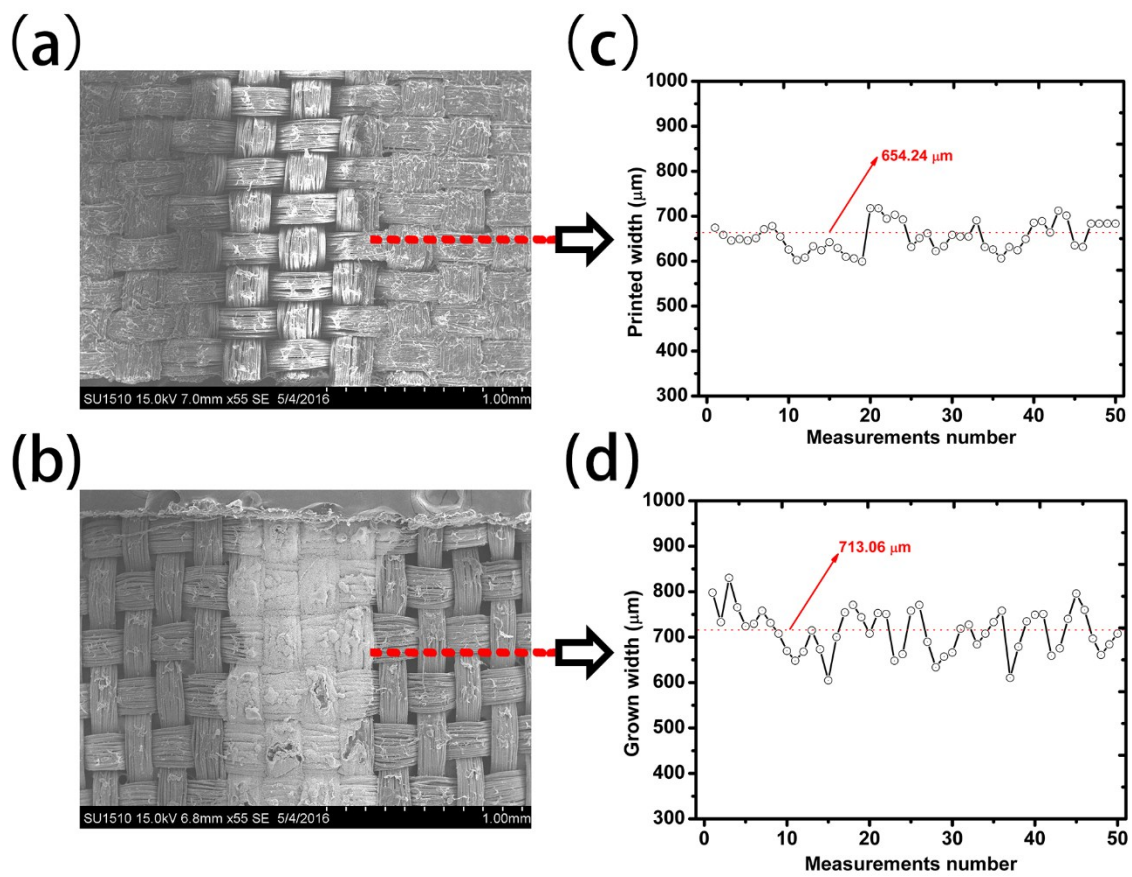


Fig.S2 SEM images of the second track (the nominal width is 700  $\mu\text{m}$ ) on wax pattern (a) and Cu pattern (b), corresponding line-width distributions (c and d) were shown on the right.

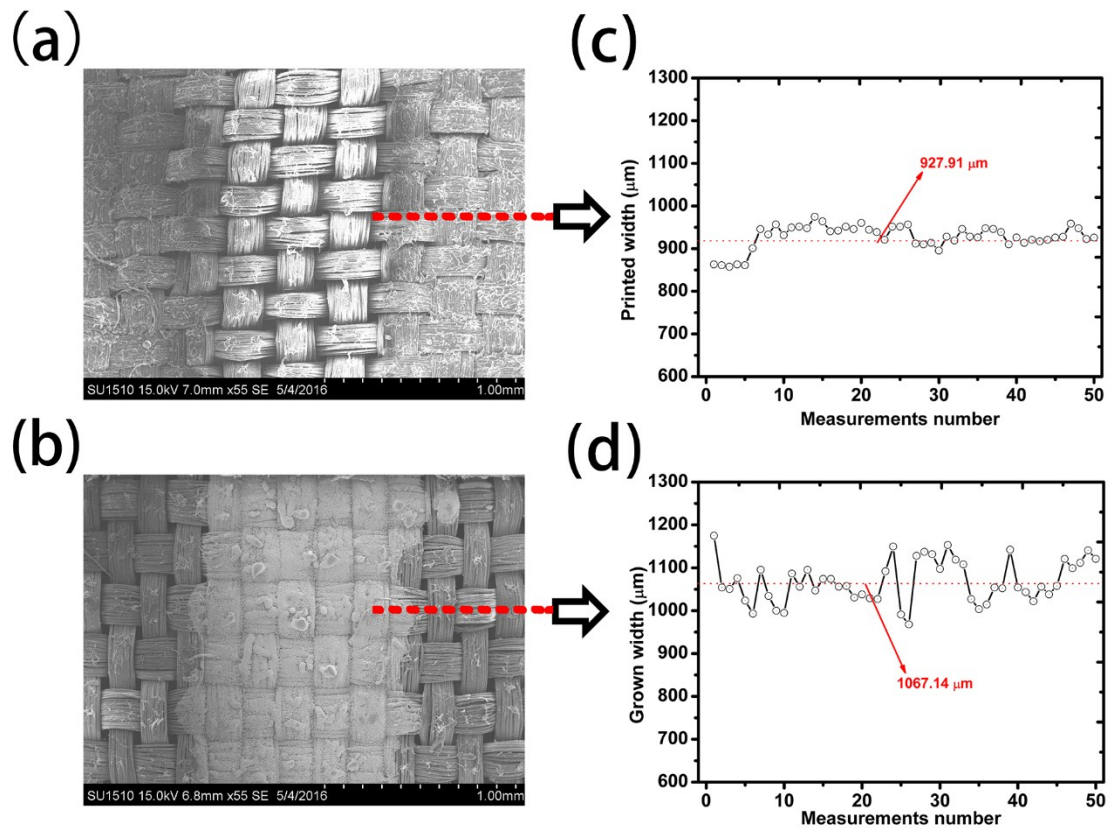


Fig.S3 SEM images of the third track (the nominal width is 1000 μm) on wax pattern (a) and Cu pattern (b), corresponding line-width distributions (c and d) were shown on the right.

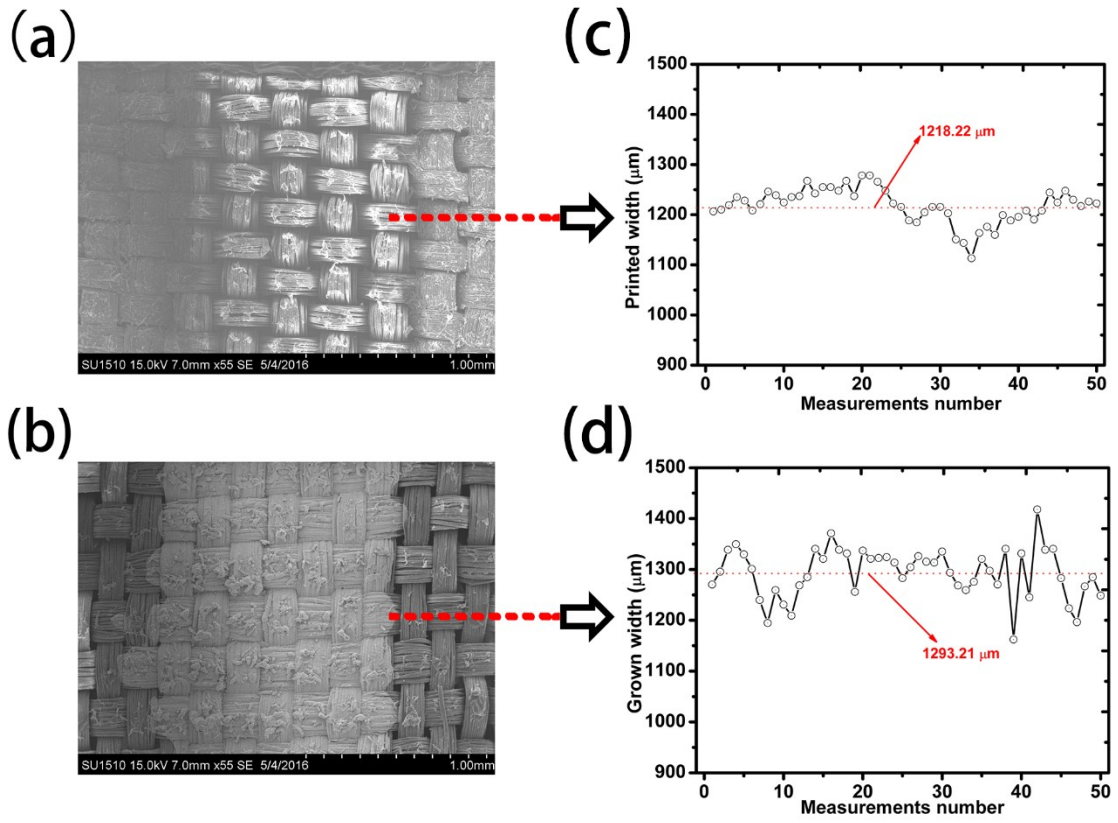


Fig.S4 SEM images of the last track (the nominal width is 1300  $\mu\text{m}$ ) on wax pattern (a) and Cu pattern (b), corresponding line-width distributions (c and d) were shown on the right.