PREPARATION OF FLEXIBLE FABRIC BASED ELECTRONIC CIRCUIT USING INKJET PRINTING CO ELECTROLESS PLATING TECHNIQUE

Fateme Mohtaram[1], Fateme Haghdoost[1], Vahid Motaghitalab[1] & Akbar Khodaparast Haghi[1]

[1] *University of Guilan, Faculty of engineering, department of Textile engineering, Rasht, Iran*
fatememohtaram@yahoo.com, fatemeh_haghdoost@yahoo.com, motaghitalab@guilan.ac.ir, Haghi@guilan.ac.ir

Abstract: A convenient method has been developed for applying patterned nickel tracks on polyester fabric for electronic applications. The process comprises inkjet printing of an aqueous palladium (II) solution on surface treated polyester fabric, followed by reduction to metallic palladium and electroless nickel plating. The nano-structure of the nickel pattern was investigated using scanning electron microscopy (SEM) and the size of the nanoparticles were in a rang of 20-100nm.In addition the electrical conductivity was evaluated using four probe technique and results showed reliable and stable conductivity about 2632S/m. Using a desktop inkjet printer,the procedure was successfully applied for manufacturing inter digitated conductive pattern as used for many applications such as antenna, electronic circuit, coil, ECG sensor, and capacitor .

1. Introduction

In recent years, ink-jet printing has been attracted tremendous interest in flexible electronics. There are more researches to apply nanoparticles in ink-jet printing ink [1]. Direct printing of metals from aqueous solution is an important target for the ink-jet printing of electronic components; a liquid based ink which would deposit a solid metallic pattern in a digitally defined procedure on different substrates is highly desirable. A major challenge in applying ink- jet processes for direct writing and metallization is the formulation of suitable inks [2].
The inks must contain the appropriate metal precursors and a carrier vehicle. In addition, they may contain various binders, dispersants and adhesion promoters, depending on the nature of the precursor and the particular application. In the case of inks for metallization, the content of the metal precursor ink must be adjusted to provide the required resolution with good adhesion and the desired electronic properties for the final conducting printed patterns. Ink composition is critical because it defines the way in which the ink can be jetted, the adhesion to the substrate, the line resolution and profile, and controls of the mechanism of metal formation [2]. Nickel and nickel alloys have a broad application in industry, regarding to their good corrosion resistance in various mediums: mineral and organic acids, chlorinated and fluorinated atmospheres. Electroless nickel thin films are often considered engineering coatings on account of their exceptionally high hardness, remarkable wear and corrosion resistance properties [1–3]. The properties of these coatings are usually depend on the crystal microstructure, which in turn is influenced to a large extent by the co-deposited phosphorus content [4–7].In this paper, feasibility of nickel electroless plating by means of inkjet printing was investigated.

2. MATERIALS AND METHODS

White polyester fabrics (51×38 count/cm^2, 64 g/cm^2, taffeta fabric) were used as substrates. Electroless plating was carried out by multi-step processes which included: scouring, rinsing, etching, rinsing, sensitization, rinsing, activation with inkjet printing, drying, electroless nickel plating, rinsing and drying. The specimens were scoured in15 g/l NaOH solution at 70 °C prior to use. The samples were rinsed in distilled water .Surface sensitization was conducted by immersion of the samples into an aqueous solution containing 10 g/l $SnCl_2$ and 20 ml/l 38% HCl at for 10min. The specimens were rinsed in distilled water and activation process carried out by inkjet printing. For printing purposes a hp single head office printer was used to print palladium ink as shown in figure 1.

Figure 1. image of the printer used

A Hewlett Packard DeskJet 1280 printer (resolution 600×600 dpi; DIN A3 format) was used for printing by use of the black cartridge only ("HP45": full part number 51645G); however, an empty tri-color cartridge ("HP78": full part number C6578D) needed to remain installed for the printer to work properly. The foamless, spring-bag type black cartridge was emptied, rinsed in water and ethanol to remove any residual original ink and finally filled with 15ml palladium ink. Palladium ink: An inkjet printable solution containing palladium ions was prepared by first stirring 0.1g palladium chloride and 38%HCL in 1 liter distilled water then the solution heated to be concentrate and printable. The foamless, spring-bag type black cartridge was emptied, rinsed with water and ethanol to remove any residual original ink and finally filled with 15ml palladium ink. Composition and operating conditions of the plating baths show in table 1.

Table 1. Composition and operating conditions of the plating baths

Plating baths composition	*concentration*
Nickel sulphate,6 H_2O	*1.5g*
Sodium hypophosphite	*4.5g*
Sodium citrate	*3g*
Boric acid	*4.5g*
PH	*8.5*
Temperature	*70˚c*
Deposition time	*2hr*

2.1. Conductivity measurements

The metal deposited patterns were tested for conductivity using the appropriate equipment. The conductivity of the films provides a measure of the underlying microstructure since any discontinuities or anomalies arising from the deposition process would lower conductivity. The electrical conductivity (σ) is a measure of how well a substance passes electrical current and may be determined from the resistivity (ρ) which is the inverse of conductivity. Resistivity may be determined through the following relationship:

$$R_s = \frac{V \times W \times t}{I \times L} \quad , \quad \sigma = \frac{1}{R_s} \qquad (1)$$

Where V is the measured voltage, t is the sample thickness in meters, w is the sample width in meters, l is the sample length in meters and I is the inputted current in amperes.
A homemade four-probe electrical conductivity measurement apparatus was used to evaluate the average the electrical conductivity throughout sample [10]. A circuit diagram of the four-probe apparatus is shown in figure 2(a). For each measurement, the ink-jet metal deposited sample was clamped in between four probes. The other accessories including multimeter and power supply connected to test chamber as shown in figure 2-b.

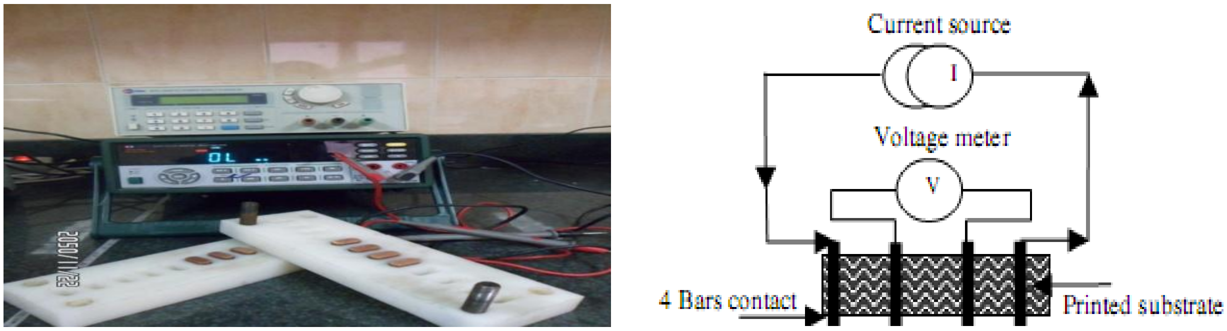
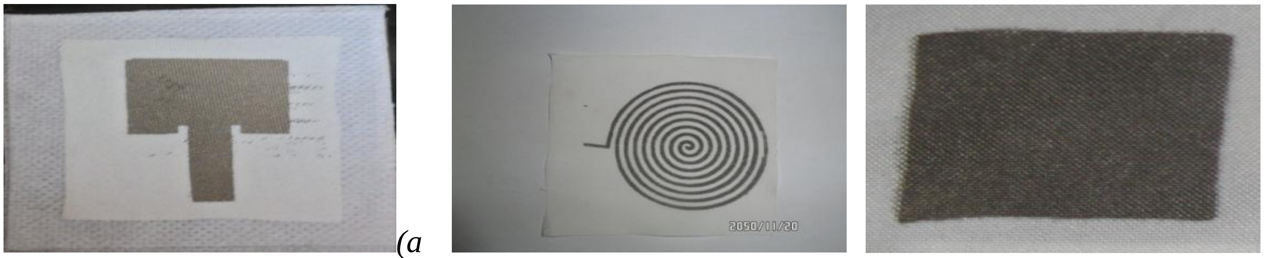


Figure 2. (a) Schematic presentation of the four-contact measuring device (b)Circuit diagram of a four-contact measuring apparatus

3. RESULTS AND DISCUSSION

Figure 3 demonstrate the flexibility of technique for preparation of variety of patterns regarding to different applications including textile antenna (Figure 3-a), textile capacitor (Figure 3-b) and textile ECG sensor (Figure 3-c). The success in deposition of such a sophisticated conductive pattern on flexible textile opens a horizon toward resolving the challenges in electronic textile roadmap. The conductive pattern is fabricated using a two step technique including inkjet printing followed by electroless depositions. Figure 4 shows the SEM image of printed pattern thermally treated at 50 °C for 30 min. As It can be clearly seen, the surface fracture occurs due to the formation of unstable Palladium particle and accordingly the weak adhesion of nickel particles on fabric substrate. However, thermal treatment at 70 °C results in conductive pattern without any spreading of pattern boundaries (Figure 5). According to SEM images (Fig 5 and 6), the size of deposited nickel nanoparticle have been measured in a range of 20-100 nm. In addition, in average a range of conductivity about 2632 S/cm was measured using the four probe electrical conductivity test .



(a) (b) (c)

Figure 3. Some of the deposited nickel patterns on polyester fabric (a) Antenna. (b) Capacitor. (C) Ecg sensor

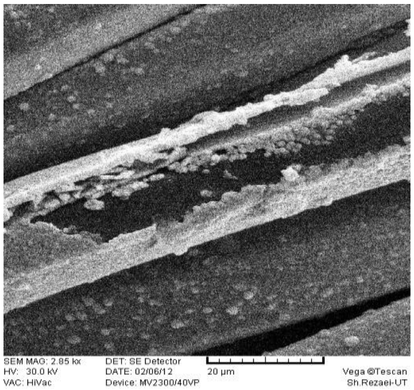


Figure 4. SEM image of the sample temperature stabilized 50 °C to 30 minutes

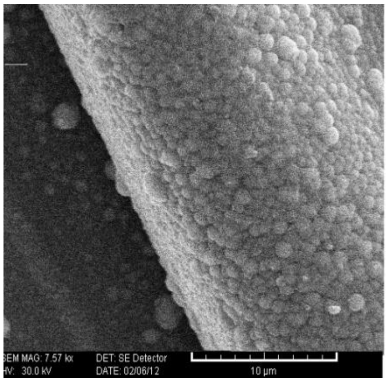


Figure 5. SEM image of the sample temperature stabilized 70 °C to 30 minutes

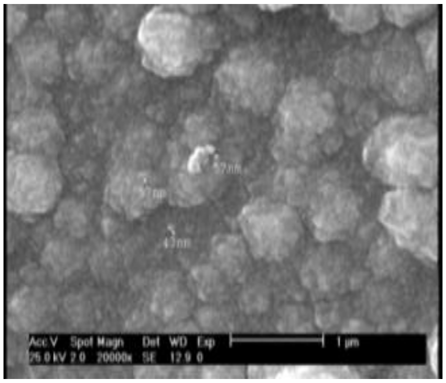


Figure 6. SEM image of deposited nanoparticle

4. CONCLUSIONS

A method of printing metallic electrical conductive patterns on fabric substrates by ink-jet printing of palladium ink then reducing electroless plating of nanoparticles of nickel has been developed. The current technique compared to conventional printing processes is much simpler and cheaper, environment and user friendly and capable of producing conductive patterns in ambient conditions. The developed ink-jet deposition of metals is one of the most convenient method of inserting conductive materials into the textile texture compare to other methods such as sewing, embroidery, weaving and knitting. The conductivity measurement revealed a 2632 S/cm using four probe technique. The highly flexible and sophisticated pattern was achieved for diverse demands including textile antenna, textile capacitor and textile sensor.

5. References

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