Preparation and Application of Carbon-Based Conductive Ink Based on Graphene

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Abstract. The rapid development of the printing electronics industry had promoted the development of conductive inks. The conductive fillers of carbon-based conductive inks had the characteristics of wide source, low price and good stability, and had great application value. This paper analyzed the performance of carbon-based conductive inks with different raw material ratios. The conductive inks having a graphene content of 16%, 18%, 20%, and 22% were numbered A, B, C, and D, the resistivity and fineness of the four sets of inks were measured, and the printability of the carbon-based conductive ink in the practical application of the screen printing circuit was investigated. The experimental results showed that the resistivity decreases with the increase of graphene content, and the resistivity of conductive ink D was the smallest, which was 10.26 Ω cm; the fineness increases with the increase of graphene content, and the value was within the range of screen printing ink fineness. When the graphene content was 22%, the conductivity was better, and the quality of the screen printing sample wasalso higher.

Keywords: Graphene · Conductive ink · Conductive properties · Screen printing

1 Introduction

Conductive ink is a functional composite composed of conductive filler, binder, solvent and additives, conductive filler plays a key role in this [1, 2]. Conductive fillers are mainly divided into three major systems: metal, carbon and organic polymer [3]. Among the carbon-based conductive fillers are graphene, conductive carbon black, carbon nanotubes, etc., carbon-based conductive inks have excellent properties such as high electrical conductivity, excellent mechanical strength, light weight and low cost, but its adhesion is poor, the coating structure is unstable, and quality problems are prone to occur in practical applications. Therefore, the development of a new type of conductive ink with low cost and high performance has become a hot topic [4, 5]. Among carbon materials, graphene is a new energy material, which is a single-layer sheet composed of carbon atoms. It has high specific surface area, low resistivity and extremely fast electron

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migration velocity [6–10]. It is widely used in electronic label printing, printed circuit boards, electronic switches, membrane switches, etc., and has broader research prospects and market value compared with other conductive inks [11, 12].

Therefore, based on the fixed polyurethane resin system, the effects of different raw material ratios on the performance of carbon-based conductive inks were studied. The best carbon-based conductive inks were obtained by analysis.

2 Experimental

2.1 Experimental Materials and Instruments

The raw materials of the experimental materials used in the research process are polyurethane resin, absolute ethanol (analytical grade), glycerol (analytical grade), polyethylene wax (analytical grade), graphene (high purity), conductive carbon black (LZ80-85), deionized water, defoamer (J0401).

The experimental Instruments used in the experiment were an electronic balance (JY5002), a digital display electric stirrer (JJ-3), a collector type magnetic heating stirrer (DF-2), and a scraper fineness meter (QXP), screen drying box (WJ-HG9010), vacuum screen printing machine (WJ-VS9010), manual screen printing machine (6080), digital multi-meter (DT-9205A), ink adjustment knife (GH-02), Anton Star digital electronic magnifying glass (A7).

2.2 Preparation and Proofing of Carbon-Based Conductive Inks

(I) First use the electronic balance to weigh the polyurethane resin with 16% mass fraction, 11% glycerol, 2% polyethylene wax, 18% deionized water, 2% conductive carbon powder, 1% defoamer. Further, 16, 18, 20, 22% graphene and 34, 32, 30, 28% absolute ethanol.

(II) A certain amount ofacrylic resin, solvent and auxiliary agent are placed in the reaction vessel to be fully dissolved, and then stirred by a collecting magnetic heating stirrer to obtain an ink binder. The filler is further dissolved, and then uniformly stirred by a collecting magnetic stirrer to obtain a conductive ink.

(III) The graphene mass fraction is 16%, the ink number A; 18%, ink number B; 20%, ink number C; and 22%, ink number D.

IV) Designing the proofing rectangular strip:1st is 6 cm × 3 cm, 2 nd is 8 cm × 3 c m, and 3rd is 8 cm × 4 cm, the total area of the proofing strip is 74 cm^2.

(V) Make a screen printing plate.

(VI) Sample proofing: conductive inks A, B, C, and D were proofed by screen printing to obtain proof samples a, b, c, and d.

2.3 Carbon-Based Conductive Ink Performance Testing

2.3.1 Measure the Density of Carbon-Based Conductive Inks

The prepared four sets of conductive inks were respectively taken into 10 ml in a measuring cylinder, and each set of conductive ink was subjected to three experiments, and the average value of the three groups was used as the fixed value of the density, and the measurement results are shown in Table 1, the prepared ink density values are not much different.

Table 1. The results of conductive ink density measurement

Ink	Quality (g)	Density (g/cm^3)
A	7.94	0.79
B	8.31	0.83
C	8.77	0.88
D	9.12	0.91

2.3.2 Measure the Ink Layer Thickness of Carbon-Based Conductive Inks

The weight of the coated paper to be printed and proofed by the electronic balance is m; the total weight of the coated paper and the transferred ink after screen printing is M; according to the transferred ink quality, the total area of the rectangular strip to be proofed, and the prepared The density of the conductive ink is obtained, and the thickness of the ink layer of each sample is obtained. The measurement results are shown in Table 2, the thickness of the ink layer to be proofed is within the allowable range of the screen print.

Table 2. The results of conductive ink layer thickness measurement

Sample	h (μm)
a	8.55
b	8.63
c	7.52
d	8.76

2.3.3 Measure and Calculate the Resistivity Of Carbon-Based Conductive Inks

Take each set of experimental samples, measure the resistance value of each rectangular strip with a multimeter; calculate the resistivity of the prepared conductive ink by the formula (2.1), and the data is recorded in Table 3.

$$\rho = \frac{RS}{L} = \frac{Rhd}{L} (2.1)$$

It can be seen from Table 3 that as the mass fraction of graphene increases, the resistivity of the conductive ink gradually decreases, and the electrical conductivity gradually increases.

Table 3. The results of conductive ink resistivity measurement

Ink	Resistivity (Ω cm)
A	15.17
B	13.58
C	10.69
D	10.26

2.3.4 Measurethe Fineness of Carbon-Based Conductive Inks

In this experiment, the prepared conductive ink was measured for fineness using a QXP type scraper fineness meter. Each group was measured 3 times, and the average value of three times was the value of ink fineness. The measurement results are shown in Table 4. As can be seen from Table 4, the fineness of the ink is within the range of screen printing fineness [13]. However, the ink particles are too large to cause blockage, resulting in low screen printing quality and even reduced mechanical properties of the printing plate [14].

Table 4. The results of conductive fineness measurement

Ink	Fineness (μm)
A	12
B	12
C	13
D	14

2.4 Application of Carbon-Based Conductive Inks

According to the designed RFID antenna, the screen required for the experiment was prepared by the direct plate making method; the prepared four sets of different graphene content inks were selected as experimental samples; the coated paper was selected as the printing material; and the printing was performed by a manual screen printing machine. The quality of the print was analyzed after thorough drying at room temperature.

2.4.1 Partial Enlargement Analysis of Printed Samples

The printed sample is shown in Fig. 1, and the partial enlarged view is shown in Fig. 2. Among them, (a) graphene is used in an amount of 16%, (b) graphene is used in an amount of 18%, (c) graphene is used in an amount of 20%, and (d) graphene is used in an amount of 22%. When the graphene content is 16%, the viscosity is small, the fluidity is good, and the boundary of the printed product has a side leakage phenomenon; When the graphene content is 18 and 20%, the fluidity and uniformity are generally the same, and the edge seepage is also small; When the graphene content is 22%, compared with the other three groups of conductive inks, the ink has moderate viscosity, good printing adaptability, good fluidity and uniformity, and the printed corners and boundaries of the printed products are clear.

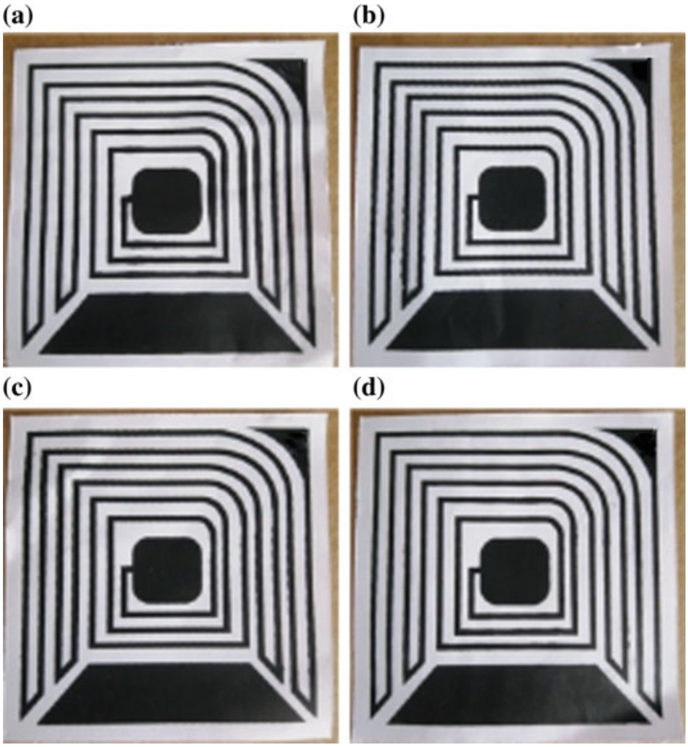

Fig. 1. The print sample

2.4.2 Abrasion Resistance Analysis of Printed Samples

The abrasion resistance test was performed on the printed product using a friction tester. The abrasion resistance of the printed product was calculated by the formula (2.2), and each group was measured 3 times, and the average value of three times was used as the value of the abrasion resistance, and the data is recorded in Table 5.

$$A_s = \frac{D}{D_0} \times 100\% (2.1)$$

It can be seen from Table 5 that the wear resistance of the inks produced meets the requirements for screen printing on the screen [15].

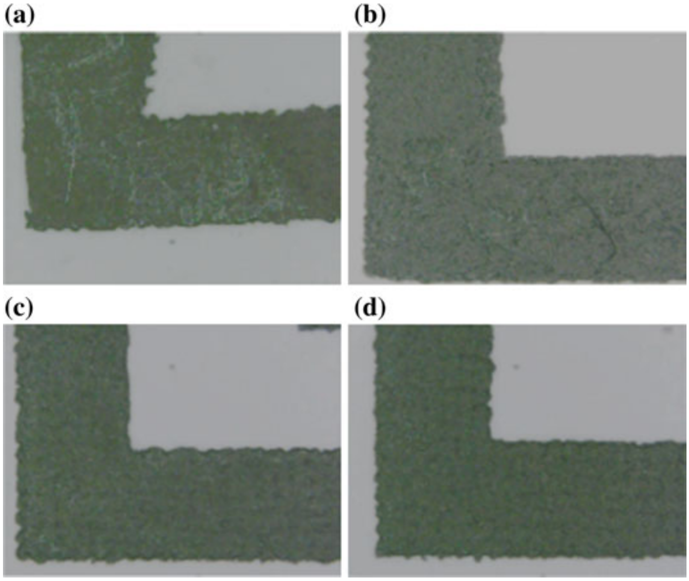

Fig. 2. The partial enlargement

Table 5. The results of abrasion resistance of printed samples

Printed samples	A_s (%)
a	88.06
b	88.15
c	92.09
d	92.75

3 Conclusions

Conductive inks are the key materials for electronic product printing. A good conductive ink formulation has good printability, and the printed ink layer has the characteristics of low resistivity, low curing temperature, and stable electrical conductivity. Therefore, the subject of the study on the preparation and application of graphene-based carbon-based conductive inks, the experimental results show that:

As the graphene content increases, the resistivity of the conductive ink gradually decreases; the resistivity of the conductive ink D is at least 10.26 Ω cm.The fineness of the conductive ink becomes larger as the graphene content increases, and the fineness values are within the allowable range of the screen printing ink.When the added mass fraction of graphene is 22%, the printing suitability and uniformity of the conductive ink are better than those of the other three sets of inks, and the printed matter boundaries and corners of the printed product d are clear and uniform.The best ratio of carbon-based conductive ink is: polyurethane resin, glycerol, polyethylene wax, deionized water, conductive carbon powder, defoamer, absolute ethanol, graphene added mass fraction of 16%, 11%, 2%, 18%, 2%, 1%, 28%, 22%. Carbon-based conductive inks are widely used in many fields and will be the focus of research in the field of materials in the future.

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