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Preparation of silver-coated copper electromagnetic shielding coating and its application in power frequency electromagnetic field

Ping Liu ^{1, a}, Peng Wang ², Yongqiang Deng ¹, Fayuan Wu ¹, Xiaomin Dai ¹ and Yue Wang ²

¹ State grid of Jiangxi electric power research institute, Nanchang, China

² Nanjing xianzhi new material technology co. LTD, Nanjing, China

^aLiuping_dky@163.com

Abstract. In this paper, the shielding effectiveness of the electromagnetic shielding composite coating with copper powder and silver coated copper powder as the base material was tested by preparing the polyurethane matrix with 0.95~1.01 isocyanate index and adding flaky ferro-silico-aluminium powder. The field comparison experiment shows that the silver-clad copper-based electromagnetic shielding composite coating has a good efficiency of power frequency electromagnetic shielding, which is up to 30.71dB. It has a broad application prospect in the field of electromagnetic protection of power transmission and transformation facilities.

1. Introduction

With the gradual improvement of the performance requirements of current electronic equipment for electromagnetic compatibility and the increasing attention paid to electromagnetic radiation injuries, how to reduce the spatial radiation of electronic equipment work, protect the stability of important targets and the health of related personnel has become an important topic in the field of electromagnetic compatibility research. Power frequency electromagnetic field is a typical low-frequency electromagnetic field, which refers to the rated frequency of power generation, transmission, transformation and distribution equipment as well as industrial and civil electrical equipment in the power system. China adopts 50Hz, and some countries and regions use 60Hz as the power frequency. Studies have shown that power frequency electric field and magnetic field pose potential threats to human health [1-2]. Although there is no direct clinical evidence for the direct correlation between power frequency electromagnetic radiation and specific diseases, relevant statistical data have shown this hazard. Therefore, it is of great practical significance to study materials which interact with electromagnetic field under power frequency and explore their application in power frequency protection.

The frequency of the alternating electric field is lower than that of the radio frequency. In order to achieve the purpose of shielding, copper and copper alloy materials with high conductivity [3] can usually be used, and metal plates such as iron, ferro-alloy [4] and permalloy [5] with high permeability and equal conductivity can also be used. In order not to generate the potential difference, it can be made into a shield after grounding. At the same time, specific materials and composites are often used to achieve special shielding effects. For example, if the complex number of narrow conductors is used to



form a comb or netlike electrical shielding plane, the eddy current and loss caused by the alternating magnetic field during the material shielding electric field can be effectively reduced [6]. The composite coating made of carbonyl nickel powder and water-borne varnish can effectively shield the power and magnetic fields. Generally speaking, the shielding effect of composite shielding materials such as coating is not as good as that of metal alloy materials, but it also has the characteristics of small effect on radio frequency signal and no secondary electric potential, which is indispensable. In order to improve the shielding effect of composite materials, the dielectric constant and tangential loss value of the materials should be improved to accumulate the electric field energy with higher density per unit volume.

Polyurethane has good properties of powder coating and film formation, so it is used in the preparation of waveguide magnetic film. The structure of polyurethane has an important effect on the directional arrangement of special alloy powders. The polyurethane structure also has an important effect on the electromagnetic properties of composite films due to the distribution of polar groups and the interaction with alloy powders. In order to make the alloy powder was well coated in resin, and forming of thin film materials under power frequency electromagnetic field has a relatively high dielectric constant and loss tangent, we adopt the commercialization of copper powder and the preparation of silver coated copper powder as the main active ingredient, using polyurethane as film former, respectively, were two kinds of electromagnetic shielding composite coatings, and the electromagnetic shielding effectiveness were studied.

2. Experiment

2.1. Instrument reagent and material

Poly adipate butanediol ester diol with molecular weight of 1000, 2000 (98%), 1, 4-butanediol (99%), diphenylmethane 4,4'-diisocyanate (99%), polypropylene glycol adipate (99.7%), copper powder (99.7%), flat ferrosilium aluminum powder (50%-90%), acetone (AR), butanone (AR), ethanol (AR), silver nitrate (AR), ethyl acetate (AR), hydrochloric acid (AR), sulfuric acid (AR), N,N-dimethylformamide (AR).

Narda EFA-300 low frequency electromagnetic analyzer (electric field probe y-0233, magnetic field probe av-0195).

2.2. Preparation of composites

2.2.1. Preparation of silver-coated copper composite powder. By means of chemical reduction, the surface of copper powder is coated with a layer of metallic silver to form a silver-coated copper composite metal powder. The preparation method is as follows:

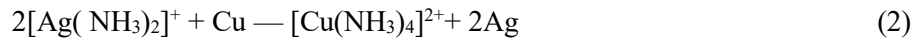
1) Preparation of silver ammonia solution: 3.5g of silver nitrate was weighed and 100mL of distilled water was added. After the silver nitrate was completely dissolved, appropriate amount of ammonia water (5%) was added slowly while stirring to make the silver nitrate solution appear transparent and non-precipitated.

(2) Preparation of the reduced solution: 3.9ml distilled water was measured, and 95ml ethanol was added while stirring. Then, 38% formaldehyde 1.1ml was added. After being fully mixed, the reduced solution was obtained.

3) Pretreatment of copper powder: soak the copper powder with 6% dilute sulfuric acid for 5 min, remove the oxide film on the surface, wash it with distilled water for 3 times, and remove the cleaning liquid.

4) Preparation of silver-plated copper powder: 6g copper powder was sensitized for 10 min in 30 g/L $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ hydrochloric acid sensitized solution. After washing and filtration, it was activated for 10 min with hydrochloric acid solution containing PdCl_2 0.5g /L, washed with distilled water, centrifuged and filtered, and then mixed with the reduced solution. Silver ammonia solution was added while stirring, and electroplated at room temperature for 30 min. Use water bath to control the temperature of the

reaction solution between 55 to 60 °C, continuously stirring reaction solution at the same time, the reduction of silver coated evenly on the surface of copper. The following reaction occurs when the two solutions are mixed:



The silver-coated copper powder was first washed with 30 mL dilute sulfuric acid with a mass fraction of 6%, and then washed with distilled water until the pH value was neutral and dried in a vacuum drying chamber.

2.2.2. Copper - based and silver - coated copper - based electromagnetic shielding composite coating.

1) Mix the copper powder (silver-coated copper powder) and ferro-silico-aluminum powder in a ratio of 13:1 and grind it in a horizontal planetary ball mill for 4 hours;

2) Put ball-milled mixed powder in muffle furnace to isolate air at 400 degrees for 1 hour;

3) Mix gas-phase silica with epoxy resin adhesive at 1:30 evenly;

4) Mix the powder with the resin and dilute it with the diluent to the appropriate concentration;

2.3. Electromagnetic performance test

2.3.1. *Brush coating of electromagnetic shielding composites.* Three cartons of the same shape, with thickness of 0.5cm and size of 33cm x 27cm x 25cm, were taken as the measurement device of the body. Where, the outer surface of carton A is uniformly brushed with paint A, the outer surface of carton B is uniformly brushed with paint B, and carton C is used as A blank with no treatment on the surface, as shown in figure 1:



Figure 1. a) carton A b) carton B c) carton C

2.3.2. Measurement method and experimental procedure. 1) Measurement method

The electromagnetic environment test of overhead transmission line is selected at the lowest position from the central sag with the wire file, the measuring instrument is set at 1.5m above the ground, and the measuring personnel is 2.5m away from the probe of the measuring instrument.

2) Experimental steps

In order to compare the shielding effect of different electromagnetic radiation shielding coatings on power frequency electromagnetic fields in this experiment, it is necessary for personnel to fix the test box in close proximity, and the testing purpose can be achieved by eliminating the background under the same conditions. After starting up the electromagnetic radiation analyzer, when the time value changes relatively stable, 6 real time values are read at the speed of 6 s each time, and the average value is taken as the electromagnetic field intensity value. The specific steps of the experiment are as follows, and the experimental picture is shown in figure 2.

a) Directly measure the electromagnetic field of the body under the line according to the specified measurement method.

b) The staff stands on the side of the measurement probe and takes a fixed position to measure the electromagnetic field intensity under this condition.

c) The staff stands on the side of the measurement probe and holds the blank box (box C) in a fixed position to the electromagnetic field instrument probe to measure the electromagnetic field intensity under this condition.

d) The staff stands on the side of the measuring probe and holds the box A (coating A) in A fixed position on the electromagnetic field instrument probe to measure the electromagnetic field intensity under this condition.

e) The staff stands on the side of the measuring probe and holds the box B (coating B) in a fixed position on the electromagnetic field instrument probe to measure the electromagnetic field intensity under this condition.



Figure 2. Field experiment photos

3. Results and discussion

Table 1. Electric field intensity change and magnetic induction intensity

electromagnetic field conditions	Electric field intensity(E)(kV/m)	Rate of change ΔE (%)	Magnetic field intensity(B)(μT)	Rate of change ΔB (%)
a Blank	29.50	/	9.14	/
b with person	24.95	15.42%	9.10	0.44%
c person + carton C	23.78	19.39%	9.09	0.55%
d person + carton A	5.78	80.40%	8.92	2.41%
e person + carton B	0.86	97.08%	8.79	3.83%

Table 1 shows the measured data of electric field intensity change and magnetic induction intensity. The variation trend of electric field intensity and magnetic field intensity is shown in figure 3. It can be

seen from figure 3 that, when the experimental conditions change, the variation trend of power frequency electric field and power frequency magnetic field is similar. The electromagnetic field continued to decrease slightly after the blank box was covered over the probe. When the box with coating A is coated on the top of the probe, the electromagnetic field strength decreases obviously. When coating the top of the probe with paint B on the carton, the electromagnetic field strength has further significantly decreased.

The change rate of electric field intensity and magnetic field intensity is shown in figure 4. It can be seen from figure 4 that, although the change rate of electric field intensity and the change rate of magnetic field intensity have similar changes, the effect on magnetic field is relatively small. The maximum change rate is less than 5%, while the maximum change rate for electric field intensity reaches 97.08%.

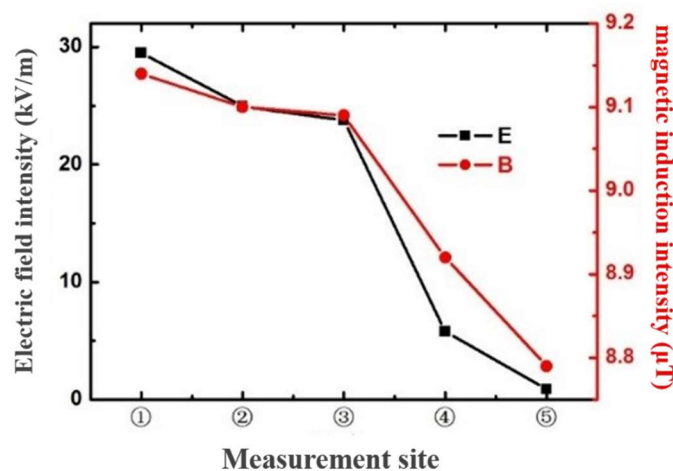


Figure 3. Variation trend of electric and magnetic intensity

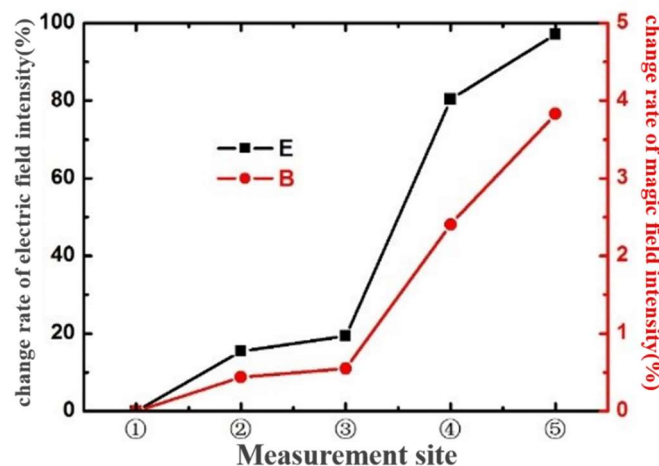


Figure 4. Variation trend of electric and magnetic intensity

In order to describe and analyze the Shielding effect of Shielding material, usually adopts the Shielding Effectiveness (Shielding Effectiveness, SE) said Shielding materials for electromagnetic Shielding ability and the effect, the unit in decibels (dB). For the low-frequency electromagnetic field, because the electromagnetic wave has a longer wavelength and the measured position is in the near field,

the electric field and magnetic field have different sizes and characteristics, so the definition of shielding effectiveness is also different. It is defined as follows:

Electric field shielding efficiency: there is a relationship between the electric field intensity E_0 at some place when there is no shielding body and the electric field intensity E_s at the same place when there is shielding body, as shown in equation (1) :

$$SEE = 20 \lg \frac{|E_0|}{|E_s|} \quad (3)$$

Magnetic field shielding efficiency: there is a relationship between the magnetic induction intensity B_0 at some place when there is no shielding and the magnetic induction intensity B_s at the same place when there is shielding as shown in equation (2) :

$$SEH = 20 \lg \frac{|B_0|}{|B_s|} \quad (4)$$

The shielding effectiveness obtained under different conditions is shown in table 2.

Table 2. Shielding effectiveness under different conditions

electromagnetic field conditions	Electric Field shielding effectiveness(dB)	Magnetic Field shielding effectiveness (dB)
a Blank	/	/
b with person	1.46	0.038
c person + carton C	1.87	0.048
d person + carton A	14.16	0.21
e person + carton B	30.71	0.34

The comparison of shielding effectiveness under different conditions is shown in figure 5. It can be seen from figure 8 that coating B has the best shielding efficiency, with the electric field shielding efficiency being 30.71db and the magnetic field shielding efficiency being 0.34db.

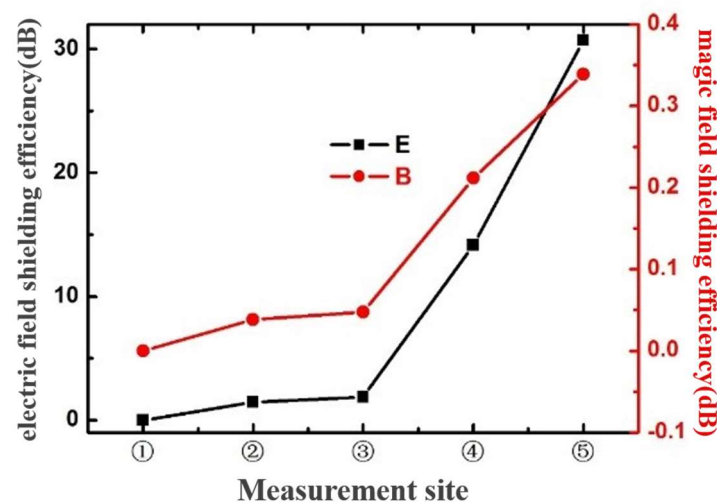


Figure 5. Contrast diagram of shielding effectiveness

4. Conclusion

Using polyurethane as film former, adopt the commercialization of copper powder and the preparation of silver coated copper powder as the main active ingredient in the preparation of the two in view of the power frequency electromagnetic shielding composite materials, the field test results show that the silver coated copper as base material of electromagnetic shielding composite coating has excellent electromagnetic shielding effectiveness, the factory frequency electric field shielding effectiveness is 30.71 dB, the magnetic field of the shielding effectiveness is low, 0.34 dB, due to electric field exceeds bid is frequent transmission facilities, and the magnetic field does not generally overweight, therefore, The copper clad electro-magnetic shield composite coating has a good application prospect in the field of electromagnetic shielding of power transmission and transformation facilities.

Acknowledgments

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