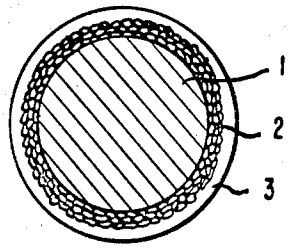
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PROCESS OF INSULATING WIRE BY ELECTROPHORESIS PLUS NON-ELECTROPHORESIS COATING STEPS

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PROCESS OF INSULATING WIRE BY ELECTROPHORESIS PLUS NON-ELECTROPHORESIS COATING STEPS

Toshihiko Tanaka and Shigeo Masuda, Hyogo, Japan, assignors to Sumitomo Electric Industries Ltd., Osaka, Japan

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ABSTRACT OF THE DISCLOSURE

A method for preparing an insulated electrical conductor comprising an electrophoretic coating step, a second coating step and a baking step is disclosed.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application of copending application Ser. No. 759,974, filed Sept. 16, 1968, and now U.S. Pat. 3,547,788.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to insulated wires suitable for use as the coils in motors, transformers, magnets and the like, and to a method of making the same.

(2) Description of the prior art

Heretofore insulated wires produced by an electrophoretic coating method having satisfactory characteristics were less than satisfactory due to difficulties with chapped appearance, film thickness, pinholes and baking. For example, with prior methods, insulated wires were produced by applying voltage between a conductor and an electrode placed in a coating bath containing an insulating coating and at least water was used as the insulating varnish (for example, water soluble coating, and water dispersive coating). In using a water soluble coating, it was very difficult to obtain a desirable film having a uniform thickness, because the resin applied by adsorption by electric energy formed a film having a high resistivity. Further with methods using a water soluble coating a number of pinholes formed. On the other hand, in using a water dispersive coating, though the resistivity of the film formed by the resin which was applied by adsorption of electric energy was not higher than that of the water soluble coating, this method had faults such as cracking formed during baking and the coating film was lacking in gloss.

It is an object of the invention to produce insulated wires having a uniformly coated film which is not eccentric using a method which comprises depositing a coating on a conductor by electrophoresis employing an insulating coating medium containing a resin and at least water, applying a second insulating coating medium on said coating, and baking them.

DESCRIPTION OF THE INVENTION

This invention comprises forming a uniform insulating coating layer applied by electrophoretic methods, applying a second insulating coating and then baking. More specifically, the process of this invention comprises (1) electrophoretically coating a metal conductor using an insulating coating medium containing a resin and at least

water by applying a voltage between a cathode immersed in said insulating coating medium and the metal conductor as the anode immersed in said insulating coating medium to obtain an electrophoretically-coated metal conductor; (2) applying a second insulating coating medium containing a resin to the electrophoretically coated metal conductor of Step (1) and electrophoretically-coated metal conductor having a second coating; and (3) baking the electrophoretically-coated conductor having the second coating. According to this invention, it is possible to produce insulated wires having a very high degree of reliance due to uniformity of the coated wires without lowering the productivity as compared with the prior methods. By the process of this invention, it is possible to produce insulated wires having high degree of reliance by only two coating application steps and one baking step.

DETAILED DESCRIPTION OF THE INVENTION

In explanation of this invention in more detail, reference is made to the attached drawings. A uniform coating film without any eccentricity is produced by depositing a resin **2** on a conductor **1** by electrophoresis using an insulating coating containing at least water in the insulating coating bath or coating medium, applying a second insulating coating thereon, and baking the so-coated conductor. In the electrophoretic coating step, a DC voltage or an AC voltage with an added DC voltage is applied to a coating composition dissolved or dispersed in water to deposit the coating uniformly around the conductor by electric energy, whereby a film with no eccentricity is formed around the conductor. After applying the electrophoretic coating, a second insulating coating is applied to the electrophoretically coated conductor. Because the precipitated resin on the conductor using an electrophoretic method includes the solvent, which is not part of the coating film and additionally usually includes gases, if it is subsequently baked in a baking oven, generally the precipitated coating hardens without completely melting forming an insulating coating film, with the results differing according to kind of the resin used and baking conditions employed. Consequently, due to the included gas and water, pinholes sometimes are formed and thus the surface of the film is not smooth. According to the method of this invention, after precipitation of the coating by electrophoresis, the same or a different insulating coating is subsequently applied onto the precipitated coating obtained in the first step to fill any spaces between the precipitated coating particles. The process of this invention results in an easily produced and highly efficient process for producing insulated wires having a smooth surface and without pinholes. In further explanation of this in more detail, the coating precipitates on the conductor in a granular form when using the water soluble coating and the electrophoretic coating method is used forming a thick film. This coating hardens without complete melting in the baking oven, and consequently, it has faults of forming a coarse surface and many pinholes.

Further, when a thick film is needed it is generally necessary to increase the electric voltage and electric current used and the entire or a part of the precipitated film sometimes is destroyed due to accelerated electrolysis of water and dissolution of conductor metal. Hence, the thickness of the film is limited using a water soluble coating. Thus, it is very difficult to precipitate approximately 15μ–20μ of film thickness onto a conductor considering productivity. The process of this invention overcomes these problems, that is, in appearance, pinhole and film thickness. With this invention, forming a film having a thickness of from 1 to 90%, preferably from 20 to 95%,

and more preferably from 50 to 90% by weight based on the desired total film thickness can be accomplished by electrophoretic coating, and then the remainder of the total film thickness is applied, and baked.

In using a water dispersive coating, the thickness of the film is not as limited as compared with the use of a water soluble coating. However, if the coating is applied thickly all at one time and baked, the resulting coating film easily cracks on passing through the baking oven and is lacking in gloss. Accordingly, it is difficult to produce insulated wires having the satisfactory characteristics above described. As shown in examples of this invention, insulated wires having excellent properties, without cracking of the coating film, can be obtained.

Insulated wires having a specific thickness in which the coating is applied all at the same time by electrophoresis have a serious fault, that is, low breakdown voltage in addition to the problems in film thickness, pinholes and cracking and the like, as described above. According to the process of this invention, since the insulated wires are produced using two application steps and one baking step, it is possible to enhance remarkably the productivity and the resulting insulated wires have much improved reliance and characteristics as compared with the insulated wires obtained by mere electrophoretic coating alone. In the process of this invention, an insulating coating may be applied using conventional techniques after baking the resin on the conductor applied by electrophoresis. Further, it is possible to use repeated coatings and bakings using prior art techniques depending on the characteristics desired.

The insulating coating used in this invention for electrophoresis coating containing at least water in the medium thereof comprises, for example, the following resins as the main component: polyester resins, phenol ester resins, melamine ester resins, acryl resins, acrylate resins, epoxy ester resins, polyimide resins, ester imide resins, polyamide imide resins, polyethylene resins, methacryl resins, trifluoride resins, tetrafluoride resins and vinyl chloride resins and the like.

These resins are dissolved or dispersed in a solvent comprising water and using ammonia or amines to prepare coatings. It is, of course, possible to add pigments, fillers and hardening agents to the coatings as desired. As the solvent, organic solvents which are soluble or partially soluble in water may be used besides water. A resin concentration of from 3 to 30%, and preferably from 5 to 15% by weight can be used. Further, as the coating for baking in this invention, it is most preferable to use coating resins which do not precipitate on mixing with water and which dissolve the electrodeposited resins, or to use a coating comprising at least water and water soluble solvents which dissolve the electrodeposited resins.

Further, the coating for baking used in this invention may be those produced by dissolving resins using organic solvents. However, where coatings are used for baking in which water insoluble organic solvents are used or the coatings in which water soluble organic solvents are used, and the resins precipitated on the conductor by electrodeposition are insoluble in a mixture of water and solvents, it is preferable to dry the electrophoretic coating film prior to the second coating application in order to remove the adverse influence of water. Furthermore, the second coatings can be used in the range of from 1 to 80% by weight of concentration and at from 1 cps. to 30,000 cps. of viscosity.

The power source used in this invention is direct current. But alternating current added to direct current can be used. It has been known that glossy plating can be obtained when alternating current is added to direct current in metal plating. Similarly in the electrophoretic coating, if alternating current is added to the direct current used, it is possible to operate at a high DC voltage and to obtain insulated wires having good appearance yet having less pinholes with the same film thickness.

The cathode placed in the electrophoresis bath into which a water soluble coating or water dispersive coating is used is generally composed of an electrically conductive material, whereby desirable insulated wires are obtainable. However, it is preferable to dispose a diaphragm composed of a porous material between the cathode and the conductor considering lengthy operations and work efficiency with possible wire breakage. When the conductor enters the liquid, precipitation of the coating, electrolysis of water and dissolution of conductor metal are caused momentarily. These momentary phenomena are prevented by use of the porous material, and electrolysis of water and dissolution of the metal conductor can be minimized. Further, the anode as the conductor sometimes contacts the cathode on breaking of the wire. This contact can be prevented using a diaphragm composed of a porous material, and, consequently, working time at breaking of wire is shortened. Moreover, accidents with the power source and meters caused by overcurrent at contact can again be prevented from occurring.

Reference is made to the attached drawing. The figure shows the structure before baking the wire to which an insulating film is applied by the process of this invention. Conductor **1** has a layer **2** applied by electrophoretic coating and layer **3** is applied by a usual coating method. The examples given hereinafter are merely exemplary and not limiting. All percentages are by weight unless otherwise indicated.

EXAMPLE 1 (COMPARATIVE)

A cell was filled with an epoxy-ester type water soluble coating at a 10% concentration adjusted to pH 7.8. The coating containing triethyl amine was prepared by polymerizing a fatty acid, maleic acid and an epoxide as the main ingredients. 180 v. of DC voltage was applied between an electrode 20 cm. in length and 10 cm. in diameter placed in the liquid cell and a copper wire conductor, as the anode having 0.4 mm. diameter was passed through. 700 ma. of electric current flowed between the electrodes and the resin deposited on the conductor. The conductor was passed through at a rate of 15 m. per minute. The conductor from the electrophoretic coating cell was baked in a baking oven of 4 m. length at 470° C. The structure and characteristics of the insulated wire so prepared are shown in the table given hereinafter.

EXAMPLE 2 (COMPARATIVE)

A cell was filled with a phenol ester type water soluble coating containing ammonia at a 10% concentration adjusted to pH 7.8. The coating was prepared by polymerizing bisphenol A and a fatty acid as the main ingredients. 75 v. of DC voltage was applied between an electrode placed in the liquid cell and a copper wire of 0.4 mm. diameter. The electric current flowing between both electrodes was 450 ma. The wire speed was 17 m./min. The conductor coated by electrophoresis was then baked in a baking oven having a 4 m. length adjusted at 450° C. The structure and characteristics of the insulated wire are shown in the table.

EXAMPLE 3

A conductor was coated by electrophoresis at the same conditions as in Example 1 by passing the conductor through a varnish bath filled with an epoxy-ester type water soluble coating having a 40% concentration and the same composition as in Example 1 (6000 cps. of viscosity) before baking. The coating was subjected to precipitation into porous parts of the electrodeposited coating particles with using a die. The conductor was then baked in a baking oven having 4 m. length adjusted at 470° C. to obtain an insulated wire having a uniform flat surface. The structure and characteristics of the resulting insulated wire are shown in the table.

EXAMPLE 4

A phenol ester type water soluble coating having a 40% concentration and the same composition as in Example 2 (viscosity 4000 cps.) was applied by a die to a conductor having 0.4 mm. diameter coated by electrophoretic coating by the same conditions as in Example 2. The conductor was passed through a baking oven at 450° C. The structure and characteristics of the wire are shown in the table.

EXAMPLE 5

An electrodeposition cell was filled with a phenol ester type water soluble coating having the same composition as in Example 2 and 10% concentration adjusted to pH 7.5. 80 v. of DC voltage was applied between a cathode placed in the cell and a copper wire having 0.4 mm. diameter with an electric current of 500 ma. passing between both electrodes. The conductor was passed through the coating cell at a rate of 17 m./min. to be subjected to electrodeposition. Just after the conductor was coated by electrophoresis it was treated by applying an epoxy ester type water soluble coating used in Example 1 having a 20% concentration (viscosity, 1500 cps.) by a wiper roller, followed by passing through a baking oven at 500° C. The structure and characteristics of the wire are shown in the table.

EXAMPLE 6

After drying the deposited resin on the conductor which is coated by electrophoretic coating at the same conditions as in Example 1 using a hot blast, a polyester resin coating prepared from terephthalic acid and ethylene glycol as the main ingredients (concentration 20%, viscosity 8000 cps., solvent: cresol) was applied by a felt wiper. The conductor was then baked in a baking oven adjusted at 470° C. to obtain an insulated wire having good appearance. The structure and characteristics of the insulated wire are shown in the table.

EXAMPLE 7

An electrodeposition cell was filled with an epoxy ester type water soluble coating having the same composition as in Example 1 and 10% concentration adjusted to pH 7.8. 130 v. of DC voltage was applied between a cathode placed in the electrodeposition cell and a conductor (wire) having 0.4 mm. diameter. Electric current flowing between both electrodes was 670 ma. The wire speed was 12 m./min. The conductor coated by electrophoretic coating was passed through a dryer having 1 m. length adjusted at 150° C. The conductor was then passed through a liquid bath of polyvinyl formal having a 15% concentration and a 500 cps. viscosity (solvent: cresol) to apply by a die, followed by baking in a baking oven at 350° C. The structure and characteristics of the resulting wire are shown in the table.

EXAMPLE 8

A cell was filled with a phenol ester type coating having the same composition as in Example 2 and a 10% concentration adjusted to pH 7.8. 80 v. of DC voltage was applied between a cathode placed in the liquid cell and a conductor (copper) having 0.4 mm. diameter. Electric current flowing between both electrodes was 500 ma. The wire speed was 15 m./min. The conductor coated by electrophoretic coating was passed through a dryer having 1 m. length adjusted at 200° C., followed by applying a polyurethane resin dissolved in m-cresol having 40% concentration (viscosity: 3000 cps.) using a die. The conductor was then passed through a baking oven at 350° C. The structure and characteristics of the resulting wire are shown in the table.

EXAMPLE 9

An epoxy ester type coating used in Example 1 having a 5% concentration (viscosity: 2200 cps.) was applied to a conductor coated by electrophoresis using the same conditions as in Example 1 with wiper roller. The solvent of the coating used was a mixture of 20 parts of water, 60 parts of dimethylacetamide and 20 parts of ethanol. The coated conductor was baked in a baking oven having 4 m. length adjusted to 470° C. to obtain an insulated wire having good appearance. The structure and characteristics are shown in the table.

EXAMPLE 10

A liquid cell was filled with a water dispersive coating containing ammonia having a 10% concentration adjusted to pH 7.5 which comprises an acryl resin prepared by polymerizing acrylonitrile and acrylate as the main ingredients. 40 v. of DC voltage was applied between an electrode having 20 cm. length and 10 cm. diameter placed in the cell and a copper wire having 0.4 mm. diameter as the anode. 300 ma. of electric current flowed between electrodes, whereby the resin was deposited on the conductor. A phenol ester resin having the same composition as in Example 2 which was dissolved in a solvent mixture consisting of 20 parts of water, 50 parts of dimethylformamide and 30 parts of ethanol was then applied by a felt wiper. After that, it was baked in a baking oven adjusted at 430° C. The wire speed was 15 m./min. An insulated wire having good appearance was obtained. The structure and characteristics are shown in the table.

EXAMPLE 11

After depositing an acryl resin on the conductor by the same method as in Example 1, an acryl resin, dissolved in a solvent mixture comprising 20 parts of water, 10 parts of butanol and 70 parts of dimethylacetamide at 5% concentration, was applied to said conductor, which was then baked in a baking oven at 420° C. to obtain an insulated wire having good appearance. The structure and characteristics are shown in the table.

EXAMPLE 12

A liquid cell was filled with an epoxy ester type water soluble coating as used in Example 1 having 10% concentration adjusted to pH 7.8. A nickel-plated copper wire having 0.4 mm. diameter was used as the conductor. 60 v. of DC voltage was applied between a cathode having a 20 cm. length and a 10 cm. diameter and the conductor as the anode. 450 ma. of electric current flowed. Onto the resin deposited on the conductor by electrophoretic coating, the same kind of epoxy ester type water soluble coating having a 20% concentration (viscosity: 1500 cps.) was further applied by a wiper roller. The conductor was then baked in a baking oven adjusted at 450° C. The wire speed was 20 m./min. Thus an insulated wire having good appearance was obtained. The structure and characteristics of the wire are shown in the table.

EXAMPLE 13

A liquid cell was filled with an epoxy ester type water soluble coating as used in Example 1 having 10% concentration adjusted to pH 7.8. A copper wire having 0.26 mm. of diameter was used as the conductor. 100 v. of DC voltage with an added 50 v. of AC voltage was applied between a cathode having a 20 cm. length and a 10 cm. diameter with the copper wire conductor as the anode. Onto the resin deposited on the conductor by electrophoretic coating, the same kind of epoxy ester type water soluble coating having a 30% concentration (viscosity: 3500 cps.) was applied by a wiper roller. The conductor was then baked in a baking oven adjusted at 430° C. The wire speed was 22 m./min. An insulated wire having good appearance was obtained. The structure and characteristics are shown in the table.

EXAMPLE 14

A liquid cell was filled with an epoxy ester type water soluble coating used in Example 1 having a 10% concen-

tration adjusted at pH 7.8. A nickel-plated copper wire having 0.26 mm. diameter was used as the conductor. 35 v. of DC voltage with an added 25 v. of AC voltage was applied between a cathode having a 20 cm. length and a 10 cm. diameter placed in the liquid cell and the conductor wire. Onto the resin deposited on the conductor by electrophoretic coating, the same kind of epoxy ester type water soluble coating having a 20% concentration was applied by a wiper roller. The conductor was then baked by a baking oven adjusted at 430° C. The wire speed was 22 m./min. An insulated wire having good appearance was obtained. The structure and characteristics of the wire are shown in the table.

EXAMPLE 15

A liquid cell was filled with an epoxy ester type water soluble coating used in Example 1 having 10% concentration adjusted at pH 7.8. A copper wire having a 0.4 mm. diameter was used as the conductor. A cylindric electrode having 10 cm. length and 10 cm. diameter was used as the electrode placed in the liquid cell, the whole of which was covered by an electrolysis diaphragm composed of a porous material (thickness: 2 mm., diameter of pores: approximately 0.1μ). 135 v. of DC voltage was applied between the cathode and the conductor as the anode. Onto the resin deposited on the conductor, the same kind of epoxy ester type water soluble coating having a 25% concentration (viscosity: 2000 cps.) was applied by a wiper roller. The conductor was then baked by a baking oven adjusted at 470° C. The wire speed was 22 m./min. An insulated wire having good appearance was obtained. The structure and characteristics of the wire are shown in the table.

TABLE

[Structure and characteristics of coated conductor wires]

Example	1[1]	2[1]	3	4	5	6	7
Water soluble resin	Epoxy esters	Phenol esters	Epoxy esters	Phenol esters	Phenol esters	Epoxy esters	Epoxy esters.
Over coat resin	None	None	Water soluble epoxy esters.	Water soluble phenol esters.	Water soluble epoxy esters.	Poly esters	Poly vinyl formals.
Wire diameter (mm.)	0.4	0.4	0.4	0.4	0.4	0.4	0.4.
Film thickness (μ)	9	9	20 (10+10)	20 (10+10)	12 (10+2)	19 (10+9)	21 (10+11).
Continuity (number of pinholes/5 m.)	22	18	0–2	0–2	0–2	0–1	0–1.
Abrasion resistance (strokes with 200 g. wt.)	6	9	12	16	14	16	23.
Cut through temperature (° C.)	130	180	150	220	190	230	215.
Mandrel diameter	Good for 1X	Good for 2X	Good for 1X	Good for 2X	Good for 1X	Good for 1X	Good for 1X.
Breakdown voltage (v.)	1,400	1,300	2,400	2,100	2,000	3,000	2,900.
Solvent resistance (50° C., 24 hrs.):							
Styrol	O	O	O	O	O	O	O.
Benzoyl	O	△	O	O	O	O	O.
Furfural	X	X	X	X	X	△	△.
Acetone	O	O	O	O	O	O	O.
Chemical resistance (50° C., 24 hrs.):							
Sulfuric acid (10%)	O	O	O	O	O	O	O.
Nitric acid (10%)	O	O	O	O	O	O	O.
Hydrochloric acid (10%)	O	O	O	O	O	O	O.
Sodium hydroxide (5%)	X	X	△	△	△	△	△.

Example	8	9	10	11	12	13	14	15
Water soluble resin	Phenol esters	Epoxy esters	Acryl resin	Acryl resin	Epoxy esters	Epoxy esters	Epoxy esters	Epoxy esters.
Over coat resin	Polyurethanes	Water soluble epoxy ester.	Phenol ester	do	do	do	do	Do.
Wire diameter (mm.)	0.4	0.4	0.4	0.4	0.4	0.26	0.26	0.4.
Film thickness (μ)	13 (10+3)	14 (11+3)	23 (20+3)	23 (19+4)	20 (15+5)	13 (9+4)	15 (12+3)	18 (12+6).
Continuity (number of pinholes/5 m.)	0–4	0–4	0–2	0–2	0–3	0–4	0–3	0–2.
Abrasion resistance (strokes wt. 200 g.)	18	14	19	17	13	14	17	19.
Cut through temperature (° C.)	200	140	180	180	160	150	160	160.
Mandrel diameter	Good for 1X	Good for 1X	Good for 1X	Good for 1X	Good for 1X	Good for 1X	Good for 1X	Good for 1X.
Breakdown voltage (v.)	2,000	1,700	3,200	3,300	2,300	1,600	1,700	1,900.
Solvent resistance (50° C., 24 hrs.):								
Styrol	O	O	O	O	O	O	O	O.
Benzoyl	O	O	O	O	O	O	O	O.
Furfural	△	X	X	X	X	X	X	X.
Acetone	O	O	O	O	O	O	O	O.
Chemical resistance (50° C., 24 hrs.):								
Sulfuric acid (10%)	O	O	O	O	O	O	O	O.
Nitric acid (10%)	O	O	O	O	O	O	O	O.
Hydrochloric acid (10%)	O	O	O	O	O	O	O	O.
Sodium hydroxide (5%)	△	△	△	△	△	△	△	△.

[1] Comparative.

NOTES.—O means that the coating film does not peel away when rubbed with a nail; △ means that the coating film does not peel away when rubbed with cloth; X means that the coating peels away when rubbed with cloth.

What is claimed is:

1. In a method of coating a metal electrical conductor with an insulating resin to obtain an electrically insulated metallic conductor comprising electrophoretically coating said metallic conductor by providing a cathode in a first insulating resin coating medium comprising a resin dissolved or dispersed in water, immersing said metallic conductor as an anode in said first insulating resin coating medium and applying a voltage between said cathode and conductor anode to thereby obtain an electrophoretically-resin-coated metallic conductor and baking said electrophoretically-resin-coated metallic conductor, the improvement which comprises producing a uniform and non-eccentric resin coating substantially free of pinholes on a metallic electrical conductor by a process which comprises:

(1) electrophoretically coating said metallic conductor with an insulating resin to obtain a first insulating resin coating having a thickness of from 1 to 99% by weight of the desired total resin coating thickness;

(2) without baking the coating produced by Step (1), non-electrophoretically applying a second insulating resin coating medium soluble in water to said first insulating resin coating to thereby obtain an insulated metallic conductor having the desired total insulating resin coating thickness, the resin of said second insulating resin coating medium being a resin which does not precipitate on mixing with water; and

(3) baking the resulting insulated metallic conductor.

2. The method of claim 1, wherein the second insulating resin coating medium partially dissolves the resin coated in Step (1).

3. The method of claim 1, wherein the second insulating resin coating medium consists essentially of a resin and an organic solvent in water and wherein said coating partially dissolves the resin coated in Step (1).

4. The method of claim 1 wherein the resin of Step (1) and Step (2) is selected from the group consisting of polyester resins, phenol ester resins, melamine ester resins, acryl resins, acrylate resins, epoxy ester resins, polyimide resins, ester imide resins, polyamide imide resins, polyethylene resins, methacryl resins, trifluoride resins, tetrafluoride resins and vinyl chloride resins.

5. The method of claim 4 wherein the resin concentration in the coating medium of Step (1) is from 3 to 30% by weight and in the coating medium of Step (2) is from 1 to 80% by weight.

6. The method of claim 1 wherein the electric voltage utilized for the electrophoretic coating step of Step (1) comprises a mixture of an alternating current voltage and a direct current voltage.

7. The method of claim 6 wherein the alternating current voltage is lower than the direct current voltage.

8 The method of claim 1 wherein the cathode used in the electrophoretic coating step of Step (1) is covered with a porous insulating material.

9. The method of claim 1 wherein the coating produced by Step (1) has a thickness of from 20 to 95% by weight of the desired total coating thickness of the coatings produced by Steps (1) and (2).

10. The method of claim 7 wherein the coating medium of Step (2) has a viscosity of from 1 to 30,000 centipoises.

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JOHN H. MACK, Primary Examiner

R. L. ANDREWS, Assistant Examiner