This invention relates to the formation of electrophoretic coatings and more particularly to an improved method of coating conducting surfaces of articles by electrophoretic techniques.

Present methods of painting articles having extended and irregular shaped surfaces include hand or automatic spray painting, electrostatic painting, brushing, or dipping. Electrophoretic techniques have been applied for coating articles having a relatively small surface area but these techniques have been restricted to the application of special coating materials.

Present methods of applying a paint film on large articles have resulted in the wastage of relatively large amounts of paint due to overspray or due to the accumulation of excessive paint material along certain surfaces of the coated articles. Also, these paint application techniques usually result in a relatively poor surface finish on the articles being coated due to uneven distribution of paint or due to surface blemishes.

In the past, it has also been rather difficult to obtain a relatively uniform film of paint over the entire surface of an article. Surfaces which are not readily accessible to the application of paint have not been satisfactorily coated. Recessed areas, such as rocker panels of automobiles, have only been coated at a great expense due to the requirements of special painting techniques or special hand labor operations to obtain a minimal protective coating against corrosion. Dipping the article in a paint bath to obtain a coating of its recessed surfaces has not proven satisfactory since the evaporation of solvents from the paint film with subsequent reflooding has resulted in washing off a portion of the adhered paint coating.

This invention pertains to an improved method of electrophoretically coating articles which will provide a uniform coat of paint on all its surfaces.

Electrophoresis has been defined as “the motion of charged particles through a suspending medium under the influence of an applied electrical field.” Electrophoretic coating may be carried out in any conventional electrolytic cell. The conducting surface of the article to be coated serves as one electrode. When the article to be coated is submerged in an electrolytic solution, an electrical circuit is completed to a second electrode to initiate the deposition of emulsified colloidal particles suspended in the solution. In an electrical field, these colloidal particles move toward the negative or the positive electrode showing that the dispersed particles carry either a positive or a negative charge. Upon contact with an electrode, the colloidal particles lose their electrical charges, thereby breaking the emulsion and depositing as a coating on the electrode.

Electrophoretic deposition of composition coatings is old in the art. United States Patent 2,507,018 discloses one method of forming an insulating coating on an anode by submerging it in a bath of finely divided insulating organic particles in a liquid medium. When a potential is applied between the anode and a cathode, which is also submerged in the bath, a coating is deposited on the anode.

Electrophoretic coating of natural and synthetic resins is further discussed in the May 1944 issue of Metal Finishing Magazine, volume 42, page 313 by Edward J. Roehl in an article entitled “A Discussion on Electrophoretic Finishing.”

The electrolyte solution utilized in the electrophoretic coating process of this invention comprises emulsified paint particles in a colloidal state dispersed in a suspended conducting liquid medium.

The paint emulsion particles are prepared so that each dispersed paint droplet when suspended in an aqueous bath is uniform in composition and consists of all film forming materials that are required for a practical paint coating. Each emulsion paint droplet is charged with either a positive or negative electrical charge so that they will migrate in an electrical field that is deposited on an electrode. An example illustrating the formulation and preparation of one paint composition to be utilized for electrophoretic coating is hereinafter described.

Current electrophoretic coatings of paint film have not proven satisfactory due to the nature of the electrophoretic coating process. Charged colloidal particles suspended in the electrolyte solution migrate towards the article being coated if the surface of the article has an electrical charge opposite in polarity to the charge of the colloidal material. When the charged particles come into contact with the oppositely charged surface, they lose their electrical charge and deposit as a coating. The deposition of this coating is irreversible in the sense that the deposited particles lose their tendency to return to colloidal dispersion. Since some of the dispersed colloidal materials in the solution have migrated toward the article while an electrical field is applied, a relatively high concentration of such colloidal particles is present near the surface of the submerged article being coated. Upon the removal of the article from the solution, many of the colloidal particles which have not been deposited but remain in the vicinity of the submerged article, adhere to the already deposited film. Upon the drying or curing of the deposited paint film, the nondeposited colloidal material adhering to the surface will bring about an uneven coating which is very unsightly.

Rinsing of the excess undeposited colloidal material has resulted in damaging the deposited paint film and therefore, has not proven satisfactory for removing the excess colloidal material. Also, during the rinsing operation large amounts of the undeposited colloidal materials are washed away with the rinsing solution.

The improvement of the electrophoretic coating process of this invention comprises the reversal of the direction of the electrical field after an article is electrophoretically coated by changing the polarity of the electrical charge applied to the electrolytic cell during the electrophoretic coating process, i.e. changing the direction of flow of direct electrical current between the electrodes of such cell. Upon reversal of the electrical field, the colloidal material which has been previously migrating towards the surface of the article now migrates away from the surface of the article. After a reverse field is applied for a limited time, the depletion of the colloidal material in the solution in the immediate vicinity of the submerged article is achieved. The article can then be removed from the solution without having an undeposited colloidal material adhering to its coated surface.

In U.S. Patent 1,769,659 it has been disclosed that in the electrophoretic coating process the direction of the current may be reversed after each complete deposition to prevent pitting of the electrodes. In this patent, the potential applied during the deposition and reversal is limited to a value below the decomposition potential of tap water, which ranges between 1.2 and 1.9 volts, to prevent the formation of hydrogen and oxygen at the electrodes.

The electrical potential applied in the process of this
The rinse solution 15 may be mixed with a detergent, such as soap, to reduce its surface tension in order to avoid any damage to the deposited paint film. Very little or no agitation is required since no mechanical action is necessary to remove the undeposited excess colloidal material.

In a second embodiment of our invention, an article 11 is electrophoretically coated in the coating bath 12 contained in the tank 13 similar to the first embodiment as illustrated in FIGURE 2a. After the article 11 is coated, it is not lifted from the bath 12 but remains submerged in the same tank 13 while the direction of the electrical field between the article 11 and the electrode 14 is reversed as shown in FIGURE 2b. The reversal of the electrical field is achieved by connecting the article 11 to the negative terminal of the power source 17 and electrically grounding the electrode. This reversal of the electrical field will result in the migration of the undeposited colloidal material in the immediate vicinity of the submerged article 11 away from its coated surface. The article 11 is then lifted from the coating bath 12—the resulting surface film being uniform and relatively free from undeposited material.

In a third embodiment of this invention, as illustrated in FIGURE 3, the articles 11 to be coated are transported by a conveyor 18 to an insulated tank 19 containing the electrophoretic coating bath 12. The articles 11 are hung from the conveyor 18 by a paint hook 19 which has an electrically insulated portion 20 to isolate the article 11 from ground. A contact plate 21 is attached to the paint hook 19 below its insulated portion 20. Article 11, about to be coated, is grounded when the contact plate 21 makes an electrical connection with a grounded bus bar 22. Article 11b, already coated, after having been submerged in the coating bath 12, becomes negatively charged when the contact plate 21 contacts a second bus bar 23 which is connected to the negative terminal of the power source 17.

Colloidal paint particles in the coating bath 12 are repelled from the vicinity of the article 11b which serves as a cathode of the electrolytic cell. The charged particles are propelled towards the article 11 which is grounded and are irreversibly deposited on its surface. Articles 11a and 11b remain submerged in the coating bath 12 until a sufficient paint film is deposited on the surface of article 11a. Article 11b becomes a cathode after being coated by being electrically connected to the negative terminal of the power source 17 through the contact plate 21 and the bus bar 23. The uncoated article 11a, which is conveyed to the tank 13, becomes submerged in the coating bath 12 where it is grounded by the bus bar 22 to become the anode of the electrolytic cell.

Upon the removal of the coated article 11b from the coating bath 12, substantially no excess undeposited material will adhere to its coated surface due to the depletion of the colloidal material in the vicinity of the submerged coated article 11b during the coating of article 11a. The coated article 11b is then conveyed to an oven 24 to cure the deposited paint film. To keep the colloidal material uniformly dispersed in the coating bath 12, a mixer 25 is placed into the tank 13 to slightly agitate the coating bath 12.

This embodiment of our invention readily lends itself to a continuous high volume coating of articles by electrophoretic means which will result in a high quality paint film without requiring a rinsing operation.

A further embodiment of this invention is illustrated in FIGURE 4. A second electrode 26 having a large surface area is placed into the coating bath 12 contained in the tank 13 and is then electrically connected to the negative terminal of the power source 17. Upon the application of the electrical field, particles of the paint migration from the vicinity of the coated article 11b and from the electrode 26 to deposit a film on the electrically grounded article 11a.

The potential required to sufficiently propel particles...
away from the coated surface 11b does not have to be as great as that required to deposit charged particles on an uncoated surface 11a. By utilizing the second electrode 26 as a cathode, the required total potential between the coated article 11b and the uncoated article 11a may be reduced since the coated article 11b, serving as the only cathode in the embodiment illustrated in FIGURE 3, has a relatively high resistance due to its built up insulating paint coat. Otherwise, a relatively high potential would be necessary to deposit the paint particles on the uncoated article 11a.

It is to be understood that for certain formulations of the coating bath, in which the dispersed colloidal materials are positively charged, deposition can also be initiated on the surface of an article when the article serves as a cathode of the electrolytic cell.

One red primer which may be electrophoretically deposited as a prime coating on an electrically grounded steel panel is formulated as follows:

A film forming material consisting of a styrene-acryl alcohol copolymer 63 percent by weight is mixed with linseed fatty acid 37 percent by weight. This mixture is emulsified at 300° F. to an Acid Number of 5 and a maximum viscosity of 2.5 poises measured when the copolymer is reduced to 60 percent of the volatiles with xylene. A portion of this film forming mixture 51 percent by weight is intimately blended in a roller mill with red oxide pigment 45 percent by weight and linseed fatty acid 4 percent by weight. This blend 38 percent by weight is then let down by further blending it with an additional portion of the film forming material of the above composition 50 percent by weight, malamine formalddehyde 11.8 percent by weight, and cobalt naphthenate 0.2 percent by weight.

This paint mixture is then emulsified by the addition of an emulsifying agent, which consists of chemically pure concentrated ammonium hydroxide (28 percent strength) 3.5 percent by weight and demineralized water 96.5 percent by weight. This diluted ammonium hydroxide solution is gradually added until the so-called inversion point is reached at which time the viscosity of the paint mixture drops suddenly after reaching a high peak. The balance of the diluted ammonium hydroxide is then added. The resulting emulsion is then further refined in a colloid mill until a more stable emulsion is reached.

The paint composition of the above example is then utilized to prepare an aqueous coating bath for electrophoretically coating a metallic article. One example of the electrophoretic coating process utilizing this paint composition is as follows:

**Example 1**

Two parts of the automotive primer paint composition described above are thoroughly mixed with 6 parts of water and 1/4 part of concentrated ammonia to form a colloidal dispersion to be used as a coating bath. This coating bath has a specific resistance of approximately 5.0 x 10^6 ohm centimeter.

The metallic article to be coated is immersed in the bath and electrically grounded. A negative charge is applied to the electrode also immersed in the bath as described in the second embodiment of this invention illustrated in FIGURE 2a. This negative charge is gradually increased until the potential difference between the electrode and the article reaches 150 volts in an approximately 20 second time period and is then maintained at 150 volts for an additional 40 seconds in order to obtain a uniform paint film of approximately 1 mil thickness on the surface of the article after the paint film is cured. The specific resistivity of the uncured deposited paint film is approximately 3.0 x 10^6 ohm centimeter and the final current density measures approximately 1.7 amperes per square foot.

After the desired film thickness is achieved, the article is lifted from the electrophoretic coating bath and immersed in a conductive rinse bath containing a grounded electrode as illustrated in FIGURE 2b. While the article is being rinsed, an electrical potential of approximately 45 volts at a current density of ½ ampere per square foot is applied directly to the coated article for about a 30 second period. After the rinsing operation, the article is removed from the bath and baked in an oven at a temperature of approximately 350° F. for 10 minutes to cure the electrophoretically deposited prime coating.

**Example 2**

One part of the automotive primer paint composition heretofore described is mixed with 6 parts of water and 1/4 part of concentrated ammonia and 1/4 part of a soap detergent to form a colloidal dispersion to be used as a coating bath. The specific resistance of this coating bath is approximately 1.0 x 10^6 ohm centimeter. The metallic article to be prime coated is immersed in the coating bath and electrically grounded. An electrode, which is also immersed in the bath, has an electrical charge applied which is gradually increased to 200 volts in 30 seconds. This potential is maintained between the electrode and the article for approximately an additional 60 seconds in order to obtain a paint film of approximately 1 mil thickness on the surface of the article and after the film is cured. The specific resistivity of this paint film on the coated article measures approximately 2.1 x 10^6 ohm centimeter, and the final current density measures approximately 3.5 amperes per square foot.

After the desired film thickness is achieved, the electrode is grounded and an electrical potential of 200 volts is applied directly to the coated article for 20 seconds to remove the excess colloidal material from the vicinity of the immersed coated article. The article is then removed from the bath and baked in an oven at an approximate temperature of 375° F. for about 10 minutes to cure the deposited prime paint coating on the surface of the metallic article.

The power source 17 utilized in Examples 1 and 2 is a rectifier having a range of 0 and 1,000 volts and 0 and 90 amperes.

We claim:

1. In a method of applying a coating to a conducting surface of an article comprising the steps of causing the surface of said article to contact an aqueous bath having organic film-forming material dispersed therein, said article serving as a first electrode, causing a second electrode to contact said aqueous bath and causing a direct electric current to flow between said first and said second electrodes and through said aqueous bath at an electrical potential substantially above the value at which the electrolysis of water occurs until a coating of said film-forming material is electrically deposited upon said article from said aqueous bath, the step of causing the direction of flow of the direct electric current between said article and said bath to be reversed for a time sufficient to remove from the surface of said electricaly deposited coating film-forming material from said bath that has not been electrically deposited.

2. In a method of applying a coating to a metallic article comprising the steps of immersing said article in an aqueous bath having charged particles of organic coated material dispersed therein, said article serving as a first electrode, causing a second electrode to contact said aqueous bath, and causing a direct electric current to flow between said first and said second electrodes and through said aqueous bath at an electrical potential between 50 and 1000 volts until a water insoluble coating of said coating material is electrophoretically deposited upon said article from said aqueous bath, the step of causing the direction of flow of direct electric current between said article and said bath to be reversed for a time sufficient to remove charged particles of coating material from said water insoluble coating.

3. In a method of applying paint to a metallic article...
comprising the steps of causing the surface of said article to be immersed in an aqueous bath having a paint formulation comprising a film-forming organic resin dispersed therein, said article serving as a first electrode, causing a second electrode to contact said aqueous bath, and causing a direct electric current to flow between said first and said second electrodes and through said aqueous bath at an electric potential substantially above the value at which the electrolysis of water occurs until a water-insoluble film of paint is electrically deposited upon said article from said aqueous bath, the step of causing the direction of flow of direct electric current between said article and said bath to be reversed for a time sufficient to remove adhered paint particles from the electrically deposited paint film.

4. In a method of applying paint to a metallic article comprising the steps of causing the surface of said article to be immersed in an aqueous bath having charged particles of a paint formulation comprising a film-forming organic resin dispersed therein, said article serving as a first electrode, causing a second electrode to contact said aqueous bath, and causing a direct electric current to flow between said first and said second electrodes and through said aqueous bath at an electric potential in the range of about 50 to about 1000 volts until a water-insoluble film of paint is electrophoretically deposited upon said article from said aqueous bath, the step of causing the direction of flow of direct electric current between said article and said bath to be reversed for a time sufficient to remove charged paint particles from the electrophoretically deposited paint film at a voltage in the range of about 5 to about 1000 volts.

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