

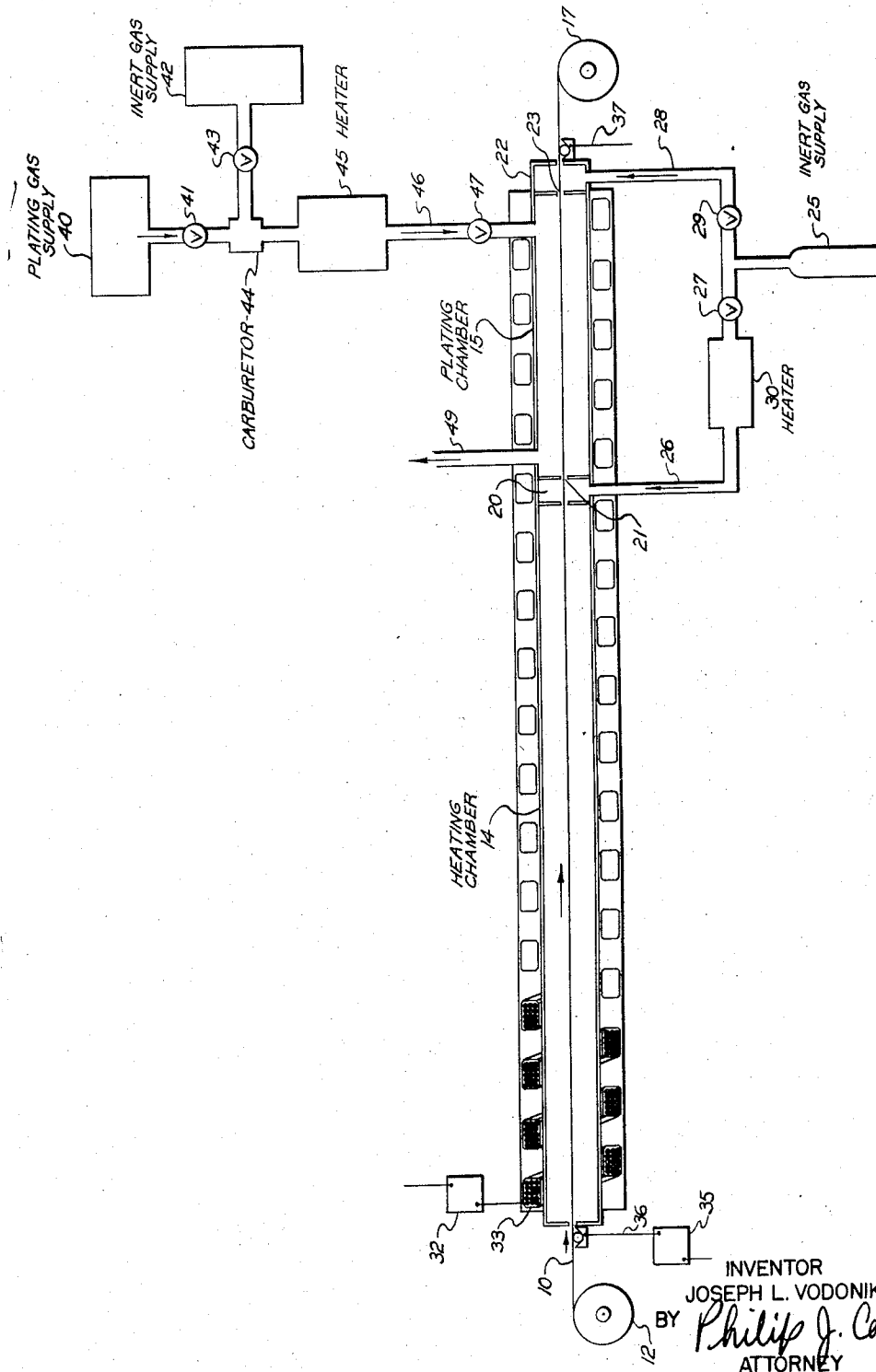
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METHOD OF HEATING A FILAMENT TO PRODUCE A METAL COATING
IN A DECOMPOSABLE GAS PLATING PROCESS
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METHOD OF HEATING A FILAMENT TO PRODUCE A METAL COATING IN A DECOMPOSABLE GAS PLATING PROCESS

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This invention relates to the vapor coating or plating of shaped articles with solid materials such as metals and the like. More particularly it relates to the coating of shaped articles of the nonmetallic type such as, for example, organic fibers, filaments, films, plastics and the like by a vapor coating method hereinafter referred to as the "chemical vapor decomposition process" or, more briefly, as the "vapor decomposition" process.

In the vapor decomposition process as proposed, for example, in U. S. Patents 2,576,289 and 2,656,283, the vapor of a volatile metal compound, e. g. nickel carbonyl, contacts a metal article such as a steel wire which is heated to a temperature at which the nickel carbonyl vapor decomposes to form an adherent coating of pure nickel on the surface of the heated metal article. This method of plating is distinguished from the vacuum metal-gasification method of plating by the characteristics, among others, that the vapor of this process comprises a metal compound instead of a pure metal, vacuum is not usually required to vaporize the coating material, and deposition is not a condensation phenomenon but a chemical decomposition of the vapor occurring at an elevated temperature to which the article is raised. Upon contact of the heated article with the decomposable vapor employed in this process, the vapor undergoes a chemical change such as thermochemical decomposition, thermochemical reduction or the like whereby the elemental metal is regenerated from the vapor on the surface of the shaped article.

The vapor decomposition process relies heavily upon proper heating of the shaped article up to the required vapor decomposition temperature and the maintenance of this temperature throughout the reaction. Shaped articles made of metals are particularly suited for this method because they withstand heating to relatively high temperatures and have high heat capacities. On the other hand, the nonmetallic shaped articles with which this invention is concerned, due to their characteristic heat sensitivity and low heat capacity, are not as advantageously adapted to being plated by this process. That is, nonmetallic articles are usually very poor heat conductors and must be heated much longer in order that the whole article be raised to the proper temperature. Even then, when the heat is dissipated from the surfaces where it is required in this process, it is not readily replaced from the interior of the article. If the article is heated only briefly, merely a thin skin on the surface of the article is raised to the required temperature and this heat is quickly exhausted by the vapor; i. e., by the heat absorbed to bring the vapor up to the reaction temperature and by the heat absorbed because of the endothermic nature of the decomposition reaction. Also, the heating of nonmetallic shaped articles to be plated such as fibers, films,

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plastic parts, etc., must be very carefully controlled since excessively high temperatures, especially for prolonged periods, result in discoloration or loss in physical characteristics such as strength, flexibility and the like. Moreover, high temperatures, resulting from heating by poorly controlled means, cause poor adherence of the coating to the article, undesirable side reactions during the vapor decomposition, and premature decomposition of the vapor. These difficulties have presented serious obstacles in the acceptance of the vapor decomposition method for plating nonmetallic articles.

Heating means which would provide improved temperature controls would overcome many of these difficulties and render this process more widely applicable to nonmetallic articles. Moreover, precise and uniform temperature maintenance would result in improved plated products. The present invention is one method of accomplishing such results as hereinafter described.

In accordance with this invention the coating or plating operation is performed on a substantially nonmetallic shaped article which has been combined with a relatively small amount of an electrical conducting material. This article is subjected to the action of an electrical current to heat it to an elevated temperature. The heated article, upon contact with a vapor compound that decomposes at the elevated temperature of the article, causes a solid coating or plating material to be released from the vapor thereby plating the surface of the article uniformly and with improved adherence. The solid coating material released by the vapor in this manner may be a metal, a nonmetal, or combinations thereof as will be described more fully later in the specification.

The presence of a very small amount of an electrical conducting material such as carbon or metal on or in the nonmetallic article to be plated renders the article susceptible to heating by electrical means. The electrical conducting material is advantageously employed in the form of fine discrete particles or flakes. Although the particles may be combined with shaped articles either by incorporating them within the article or by applying them to the surface of the article, it has been found particularly advantageous to disperse them throughout the article. Thus, for example, artificial or synthetic material could have the electrical conducting particles dispersed within it before it is extruded or shaped. Or, composite articles, such as paper or spun thread which are made up of small discrete pieces of material mechanically held together in the shape of the article, could have the electrical conducting particles mixed therethrough with the particles both on the small discrete pieces making up the article and in the article itself. In this manner heat could be produced evenly throughout the material of the shaped article and excessive temperatures in localized areas avoided. Also, the effect of the inherently low heat conductivity of the nonmetallic article in retarding the distribution of heat is minimized and a uniform temperature throughout the article is more quickly attained and maintained.

As previously mentioned, only relatively small amounts of electrical conducting particles are combined with the article to be plated. Generally, however, the amount of such particles used must be sufficient to allow the flow of an electrical current through the article but not enough to alter its original appearance and character. Although the amount of particles employed may vary depending upon the nature of the particles, the size of the particles, the distribution of the particles, etc., it has been found

that greater advantages are obtained by combining no more than about 8% by weight of the uncoated article. However, concentrations of from 0.5% to 5% by weight of suitable particles have been found to be more advantageous, and amounts in the range of from 0.5% to 3% have been found to be particularly advantageous.

With regard to heating by electrical means, it has been found that particular advantages are derived from the use of electrical heating means in which the production of heat is effected within the material of the article to be heated. Of the various electrical heating means of this type, greater advantages are derived by employing electrical induction heating means and high frequency dielectric heating means. However, the selection of the method of electrical heating means to be employed depends to a great extent upon the application; that is, broad classes of metals are better adapted to each specific electrical heating means and the metal particles utilizable with any particular article must be compatible with the chemical nature of the article so that the particles will not adversely effect the characteristics or appearance of the finished product. For example, greater advantages are obtained when electrical resistance heating means are used with particles of a highly conductive material such as, for example, dispersed particles of aluminum, copper, silver and the like which are incorporated in the article to be plated. Induction heating means may be particularly advantageously utilized where particles of metals such as ferromagnetic metals are used. The group of metals referred to as "ferromagnetic metals" is meant to include not only ferrous metals such as, for example, iron and steel, but also those nonferrous metals which exhibit some ferromagnetic characteristics. Among these may be mentioned, for example, nickel, silver, brass and the like. Particular advantages have been found to accrue in the use of induction heating means when these ferromagnetic particles are dispersed throughout the article thereby heating the article uniformly and in a shorter time. High frequency dielectric heating means may be especially advantageously utilized with metals which exhibit low electrical conductivity, such as, for example, Nichrome, manganin, Chromel, carbon and the like. Very small particles of low conductivity metals and alloys such as those mentioned, when evenly distributed, appear to act as heat concentrating nuclei for the heat generated within the article by its being subjected to the action of the high frequency electrostatic field.

By the foregoing heating means the shaped articles to be plated are heated to an elevated temperature. Necessarily the temperature of the article must be above the practical decomposition temperature of the vapor compound but also it must be below the degradation temperature of the article. By the term "practical decomposition temperature" it is meant the temperature at which the vapor decomposes at a practical and economical rate. The actual temperature to which the article is heated therefore is dependent upon, among other things, the nature of the vapor compound and the nature of the article as will be hereinafter more fully described.

Articles which may be coated or plated in accordance with this invention may be of any shape. Shapes which readily lend the article to continuous operations are particularly advantageously employed such as for example, sheeting material like films, tapes, ribbons, felts, nonwoven fabrics, webs, and the like or filamentary articles such as filaments, fibers, threads, strands and the like, especially where these articles to be plated have the particles uniformly dispersed throughout. It is with such continuous length articles of a relatively low ratio of cross section to length dimensions that the process of this invention has its greatest advantages.

The invention will be further described in connection with the accompanying drawing which illustrates schematically the general process of the present invention.

Briefly, a shaped article 10 such as a thread, strand, filament, sheet, film, tape, or the like from the supply source 12 is passed through a heating chamber 14 thence through a plating chamber 15 and finally taken up on a collecting device 17.

More specifically, the article 10 passes through the heating chamber 14 and then enters and leaves the plating chamber 15 through two small openings 21, 23 which are surrounded by sealing chambers 20, 22. Hinged access sides (not shown) permit the opening of the apparatus to facilitate threading the article therethrough. An inert gas such as carbon dioxide is supplied under pressure to the sealing chambers 20, 22 to minimize the escape of plating vapors and exclude air from the plating chamber. Two valves 27, 29 positioned in the conduits 26, 28 to the sealing chambers, regulate the flow of carbon dioxide from the storage tank 25. A heater 30 raises the temperature of the carbon dioxide gas supplied to the sealing chamber 20 so that it does not cool the shaped article 10 before it enters the plating chamber 15. Since the gas in this sealing chamber 20 is at a slightly raised pressure, it flows both into the plating chamber 15 and into the heating chamber 14. The gas that flows into heating chamber 14 maintains an inert atmosphere around the shaped article during its initial heating and thus aids in preventing oxidative degradation of the article. Carbon dioxide gas supplied to the sealing chamber 22 is supplied cold to aid in cooling the article after it is plated and before it is collected.

In the drawing there are shown two means either of which can be used in heating the article; namely, resistance heating means and induction heating means. When resistance heating means are used, a resistance controller 35 varies the electrical current supplied to two mercury contacts 36, 37 or other similarly acting contacts located at the entrance and exit of the apparatus. This current passes through the article located between the contacts 36, 37 and thus heats it. When induction heating means are used, a resistance controller 32 varies the alternating current supplied to energize a coil 33 positioned around the apparatus. This coil thus induces a flow of electricity in the article 10 and thereby heats it.

Into the plating chamber 15 there is introduced through conduit 46 a vaporized compound of the plating material. This plating vapor from supply source 40 is mixed in a carburetor 44 with an inert gas, such as carbon dioxide, from supply tank 42 using proportioning valves 41, 43 to obtain the desired mixture. A preheater 45 heats the gas mixture to a temperature below the decomposition point of the plating compound as it flows to the plating chamber 15. A control valve 47 controls the rate of addition of gas to the plating chamber 15, and a conduit 49 conducts away the spent gases from the plating chamber 15.

This invention will be more fully described by the following examples although it is understood that the invention is not to be limited by these examples. In these examples, "parts" and "percent" of materials is intended to mean parts and percent by weight.

Example I

A melt comprised of 1000 parts of polycaprolactam of a relative viscosity of about 2.5 having dispersed therein 50 parts of an aluminum powder having an average particle size of about 170 mesh is extruded under pressure and at a temperature of about 260° C. into a monofilament approximately $\frac{1}{32}$ of an inch in diameter. The apparatus and general procedure used in forming and collecting the formed filament is essentially the same as that used commercially to produce nylon fibers. The resultant composite monofilament is then washed with water, stretched, dried and collected ready for plating.

The composite monofilament is passed through an apparatus substantially as shown in the accompanying drawing in which the resistance heating means is utilized.

The monofilament is removed from a supply bobbin 12 and passed continuously as a single-end through the apparatus at about 4 meters per minute. The amount of current passing through the monofilament is varied by means of the resistance controller 35 to maintain the temperature of the monofilament at about 275° F. The carbon dioxide which is admitted to the sealing chambers 20, 22 is maintained at about 2 p. s. i. pressure, and that portion of the gas supplied to the sealing chamber 20 is heated by means of heater 30 to about 150° F.

As the monofilament passes through the plating chamber 14 it is contacted by a vapor composed of gaseous nickel carbonyl and carbon dioxide in the proportion of approximately 5 ounces of carbonyl per cubic foot of carbon dioxide. This gas mixture is preheated to approximately 150° F. and then admitted to the plating chamber 15 at a rate of between 1 and 5 cubic feet per hour. The nickel carbonyl vapor, upon being raised to its decomposition temperature by coming in contact with the electrically heated monofil, breaks down to form elemental nickel which deposits on the monofil and carbon monoxide gas which is flushed from the plating zone through exhaust conduit 49 by the continuous addition of fresh carbonyl-rich vapors. The elemental nickel deposited on the heated monofil forms a bright, lustrous tenacious coating without degrading the polycaprolactam monofilament.

This bright, lustrous, nickel coated monofilament may be used as a decorative thread in fabrics woven of other textile materials or may be woven alone into a heat reflectant cloth. Also, by reason of the enhanced control now made possible by this invention, the coated monofilaments may be used as electrical conductors of very uniform resistivity.

Example II

Ten parts of a stainless steel (A. I. S. I. Type 316) powder having an average particle size of about 270 mesh is mixed with 1,250 parts of fully ripened viscose spinning solution comprised of about 8% cellulose and 6.5% sodium hydroxide which has been prepared by the method well-known in the rayon industry. This composite viscose solution is extruded through a rhodium-platinum spinneret having 720 holes of 0.0025 inch diameter into a coagulating bath of the Mueller type formulation, i. e., 10% sulfuric acid, 22% sodium sulfate and 1% zinc sulfate, to produce a yarn of 1650 denier. The yarn is neutralized, washed, lubricated, and dried and collected with about one turn per inch twist into a wound package ready for plating.

The above rayon yarn is then plated with a nickel coating by being passed through the apparatus as shown in the accompanying drawing and as described above wherein the induction heating means is utilized. The yarn is removed from a supply bobbin 12 and passed continuously as a single-end through the apparatus at approximately 4.5 meters per minute. The amount of current passing through the coil 33 is varied by means of the resistance controller 32 to produce and maintain the temperature of the rayon yarn at about 325° F. Carbon dioxide is admitted to the sealing chambers 20, 22 and controlled at about 1.5 to 2 p. s. i. pressure. The carbon dioxide supplied to the entrance sealing chamber 20 is heated by means of a heater 30 to within the range of 140 to 150° F.

On entering the plating chamber 15, the yarn is contacted by a vapor composed of gaseous nickel carbonyl and carbon dioxide in the proportion of approximately 5 ounces of carbonyl per cubic foot of carbon dioxide. This gas mixture is preheated to approximately 160° F. and introduced into the plating chamber 15 at a rate of between 3 and 5 cubic feet per hour. The plated yarn produced exhibits a bright, lustrous appearance with a tenacious metal coating and with no degradation of the cellulose.

This coated heavy denier rayon yarn may be used in the construction of reinforced rubber products such as tires, power transmission belts, conveyor belts and the like to aid in dissipating the excess heat which is generated within the article. Also, higher heat resistant industrial fabrics made from such metal coated yarns may be utilized for the handling of hot materials in chutes and conveyor belts. This metal coated yarn may be employed to eliminate static electricity by being incorporated in small percentages in fabrics and tufted materials such as carpeting made from nylon, acrylic or wool fibers.

Example III

A composite stainless steel-viscose spinning solution is prepared as described in Example II and converted to a cellophane type film. This viscose containing dispersed stainless steel is extruded through a narrow slot onto a rotating drum the lower end of which is submerged in an acid coagulating bath of substantially the same composition as that described in Example II. The viscose film formed on the periphery of the drum is continuously removed from the drum and washed, desulphurized, bleached, dried and collected in the form of a two mil film. The film is then nickel plated by passing it through an apparatus of the type described in Example II while being heated by induction means. All of the conditions of the process are the same as in Example II; that is, the rate of passage of the film is approximately five meters per minute, and its temperature is controlled at 325° F.; the carbon dioxide sealing gas is maintained at 2 p. s. i. pressure, and the gas admitted to sealing chamber 20 is heated to about 150° F.; and, finally, the plating gas mixture is mixed in the proportion of 5 ounces of carbonyl per cubic foot of carbon dioxide and preheated to 160° F. before being admitted to the plating chamber 15 at a rate of between 3 and 5 cubic feet per hour.

This plated film has greatly improved water vapor impermeability over films without the coating and may be advantageously used as a wrapping material. Also this product, because of its reflective quality, might be employed in disposable packaging as a thermobarrier to retain heat or maintain lower temperatures. For textile uses, this film can be slit into strips of approximately 1/4 inch width and used as highly decorative threads in fabric.

Example IV

The following example describes a method of making plated paper products. In the processing line in the manufacture of paper, i. e. to the cellulose pulp slurry in the Hollander, there is added aluminum powder of an average particle size of 100 mesh in an amount of 3% by weight of the pulp. This mixture is sent to the head box of a Fourdrinier machine and processed through the machine to produce a composite aluminum-paper sheet of approximately four mils thickness. This sheet is then plated with a nickel coating in substantially the same manner and under the same conditions as those described in Example II with the exceptions that the temperature of the article is maintained at about 275° F., and the rate of passage through the plating apparatus is maintained at eight feet per minute.

This nickel plated paper has an attractive metallic luster making it highly desirable as a decorative wrapping. The nickel coating also greatly enhances the impermeability of the paper to water vapor and along with its high reflectance makes it particularly useful as an inexpensive insulating material.

The terms "gas plating," "vapor plating," or "vapor decomposition" as used herein are meant to refer to the deposition of a solid material from a vapor by a chemical process at an elevated temperature such as, for example, thermal reduction or thermal decomposition and are not to be confused with the purely physical processes, such as, for example, vacuum metallizing. By thermal de-

composition is meant that process in which the gaseous solid bearing compound decomposes at the high temperature of the article being plated into a solid material which deposits on the article and gaseous by-products which are exhausted from the plating zone. The term "thermal reduction" refers to the process in which the gaseous solid-bearing compound is mixed with hydrogen gas or any other suitable reducing agent and, at the elevated temperature of the article to be coated, is reduced into the solid material which deposits on the article and the gaseous reduction products which are exhausted from the plating zone.

In the practice of this art the vapor of a volatile compound of the solid coating material is placed in contact with the article to be coated, which is heated to a temperature at which the compound decomposes or is reduced at the surface of the article to form an adherent coating. The solid-bearing vapors are continuously replenished and the by-products formed by the decomposition or reduction are simultaneously pumped off or flushed off by a stream of carrier or diluent gas.

Solid materials which form volatile compounds suitable for use in the gas plating process include not only pure metals but also alloys of metals and mixed compounds of metals and nonmetals. Among the metals which may be applied as coatings are nickel, aluminum, tin, iron, chromium, molybdenum, tungsten and the like. Alloys of metals such as chromium-molybdenum, titanium-tantalum, nickel-tin, and the like, and mixed compounds of metals and nonmetals such as those generally referred to as carbides, nitrides, borides, silicides, oxides and mixed oxides may also be applied by the vapor-decomposition process. A more complete listing of the solid materials which may be applied by vapor-decomposition can be found in the book "Vapor Plating" by C. F. Powell, I. E. Campbell and B. W. Gonser (John Wiley & Sons, Inc., 1955) on pages 5 through 7.

The volatile compounds of these solid materials which may be employed in the chemical vapor deposition process may be classified in accordance with the reaction that occurs in effecting deposition. In the class of thermal reduction reactions there are: (1) halide compounds reduced by hydrogen or metals at an elevated temperature, (2) compounds containing carbon, nitrogen, boron, silicon or oxygen which are reacted at an elevated temperature with halides, and (3) compounds which react at an elevated temperature in the gas phase with the base material being coated. In the class of thermal decomposition reactions there are: (1) halide and oxygen-containing compounds which decompose at high temperatures, and (2) carbonyl and hydride compounds which decompose at relatively low though elevated temperatures.

The most generally used compounds are those deposited by the relatively low-temperature thermal decomposition process. Solid materials deposited by this method may be introduced as volatile compounds such as gaseous carbonyls, nitroxyl compounds, nitrosyl carbonyls, metal hydrides, metal alkyls, halides of the coating material, and the like. Illustrative metal constituents of the carbonyl type compounds are nickel, iron, chromium, molybdenum, tungsten, and the like. Illustrative compounds of the other groups mentioned above are: the nitroxyls, such as copper nitroxyl; the nitrosyl carbonyls, such as cobalt nitrosyl carbonyl; the hydrides such as antimony hydride, tin hydride; the metal alkyls, such as the carbonyl halogens like osmium carbonyl bromide, ruthenium carbonyl chloride, and the like.

Each of these compounds or mixtures from which a solid material may be deposited has a temperature at which a practical rate of decomposition or reduction occurs. The rate of reduction or decomposition of the compound increases with increases of temperature so that the plating takes place slowly at a lower temperature and while the vapors are being raised in temperature to the practical plating temperature range. For example, nickel

carbonyl starts to decompose slowly at about 175° F. and as the temperature rises it decomposes at an increasingly faster rate until about 275° to 400° F. it reaches a practical decomposition rate which is sufficiently high enough to be advantageously utilized in the process of this invention. The practical utilization of this process relies upon the solid coating material having a decomposable volatile compound with a practical plating temperature range below the heat sensitive temperature or degradation point of the article being plated. Thus, if a refractory or ceramic article is to be coated, compounds whose practical plating temperature range is above about 1000 to 1200° C. could be utilized whereas if artificial materials, such as cellulose which degrades at about 450° F., or synthetic materials, such as polyamides which melt at about 200° C., are to be plated, compounds with somewhat lower practical plating temperature ranges would have to be utilized.

The process of this invention is applicable to articles made of materials which are essentially nonmetallic or nonconductors of an electrical current. The material need not necessarily be entirely nonmetallic since many compounds, such as, for example, refractory and ceramic materials which are composed of metallic elements in combination with nonmetallic or other metallic elements, exhibit the property of non-conductivity of electricity. Materials which will not readily conduct electricity will also not readily conduct heat and these are the materials which, heretofore, have been difficult to heat with the requisite control for the vapor decomposition process and upon which this invention may be advantageously used. The material may be a natural occurring material such as refractory ceramics, asbestos, glasses, woods, natural textiles like wool, cotton, ramie, jute, hemp and the like, or it may be an artificially formed material such as regenerated or altered natural materials like regenerated cellulose, cellulose esters, cellulose ethers, hydrolyzed cellulose, carboxymethyl cellulose, and the like, or a synthetic polymeric or plastic material such as polyamide, polyester, polyacrylic, vinyl, polyurethane, and the like. This invention is particularly advantageously utilized with heat sensitive materials, that is, materials which discolor and/or degrade at relatively low though elevated temperatures.

The only restrictions on the shape of the article are those imposed by the practical necessities of heating it and enclosing it to prevent the escape of the solid bearing vapors, many of which are toxic. Although examples have been given of this process which describe the coating of articles in a continuous manner, the scope of this invention is not to be restricted to articles of such a shape that the process can only be operated continuously. In fact, the form of the article may just as well be such that intermittent operation of the process is required. However, the process of this invention has particular applicability to natural, artificial and synthetic material formed in the shape of sheeting and filamentary articles. By filamentary articles it is meant articles in the form of filaments, fibers, strands, threads, tows and the like. The term "sheeting" is meant to refer to long, broad, thin shaped articles such as films, tapes, ribbons, webs, felts, and the like, whether the material is unitary as is cellulose film or made up of contiguous particles as is paper, nonwoven textile cloth, felt, and the like.

The type of electrical conductive particles which may be added to the nonconductive article to make it susceptible to heating by electrical means is determined by the type of electrical heating means employed. Induction heating, high frequency heating and resistance heating may be used in the practice of this invention but such electrical heating means in which production of heat is effected within the material of the article to be heated, such as induction heating and high frequency heating, are particularly well adapted for use in this process, and conductive materials selected from the group

consisting of metals and carbon are advantageously used with these methods of heating. By the term "resistance heating" it is meant heating by passing an electric current through the article so that the heat is generated by the resistance of the material to the flow of the electrical current. High conductive materials are advantageously used when resistance heating means are employed since they need to be used in much lower concentrations than materials with higher resistances to attain the same results, such as, for example, aluminum, copper, silver, Phosphor-bronze, Duralumin, and the like. The term "induction heating" refers to that means of heating in which the article cuts the electromagnetic lines of force emanating from an electrical conductor to induce an electrical current in the article and thus produce heat by virtue of the resistance of the material to the flow of the electrical current. Induced currents are most readily produced in ferromagnetic materials. Those materials in which induced currents are most easily produced are advantageously utilized since much smaller amounts are therefore required. The term "ferromagnetic materials" are previously stated is not to be restricted to only ferrous metals but is to be extended to include nonferrous metals which exhibit the ability to have an induced current generated within them. High-frequency or dielectric heating means as herein used refers to heating by subjecting the article to a field of high-frequency electrostatic or electromagnetic oscillations. Such high-frequency electrical oscillations or radiations of electrical energy induce electrical potential and current in the material of the article whereby eddy currents are formed of sufficient intensity to elevate the temperature of the material. Metallic particles included within the article have a higher electrical conductivity than the material of the article itself and are therefore more easily heated and result in heating of the article more readily than the article could be heated without them. However, in order to prevent excessive localization of heating, it is preferred to use metallic particles of rather low electrical conductivity approaching the conductivity of the material or the article. These particles, when thoroughly dispersed throughout the article, produce rapid and uniform heating.

It is advantageous to utilize the electrical conducting material in the form of fine particles when combining it with the article to be plated. Although there are many things to be considered in determining the size of particles to be used, the optimum particle size depends principally upon the dielectric characteristics of the material from which the article is made. Articles made of materials with high dielectric characteristics require very fine mesh particle sizes to minimize the amount of dielectric material between the electrical conducting particles. At points in the article, where a relatively large amount of dielectric material separates the particles, excessive resistance to the flow of electrical current is apt to develop resulting in uneven heating. The use of very fine particles substantially prevents this from occurring. Also, the use of very small particles results in more effective utilization of the electrical conducting material so that the weight, appearance and general character of the original article is not substantially altered by its having been added. Generally speaking though, it has been found that although larger size particles may be used in some cases greater advantages are derived in carrying out this invention when particles of a size no larger than about 100 mesh are used; and it has been further found that particles of about 325 mesh are particularly advantageous in fulfilling the requirements of this process.

The amount of electrical conducting material which need be combined with the article to make it susceptible to heating by electrical means yet not alter its original appearance and character has been found to be relatively small. Greater amounts, of course, could be used but

this would be economically disadvantageous and would deleteriously affect the original appearance of the article. Generally, the amount of electrical conducting material need only be sufficient to allow the flow of an electrical current through the article but the amount necessary to produce this result varies depending upon the nature of the material of the article, the nature of the conducting material, the particle size if particles are used, etc. As a practical upper limit, however, it has been found advantageous to use in the practice of this invention no more than about 8% by weight of the uncoated article. It has been found, however, more advantageous to use concentrations of from 0.5% to 5% and particularly advantageous to employ amounts within the range of 0.5% to 3%.

It will be understood that while there have been given herein certain specific examples of the practice of this invention, it is not intended thereby to have this invention limited to or circumscribed by the specific details herein specified, in view of the fact that this invention may be modified according to individual preference or condition without necessarily departing from the spirit of this disclosure and the scope of the appended claims.

I claim:

1. In the gas plating of a solid coating material on shaped articles the steps comprising, subjecting a substantially nonmetallic, heat sensitive filamentary article to the action of an electric current, said article having been combined with a relatively small amount of an electrical conducting material; heating said article by the action of said electric current to an elevated temperature; contacting said article, while maintaining it at an elevated temperature, with a vapor of a compound that decomposes at an elevated temperature to release a solid coating material; thereby depositing said released solid material on said heated shaped article.

2. In a gas plating of a metallic coating on shaped articles the steps comprising, subjecting a substantially nonmetallic, heat sensitive filamentary article to the action of an electric current, said article having mixed therethrough a relatively small amount of fine particles of an electrical conducting material selected from the group consisting of metal and carbon, heating said article by the action of said electric current to an elevated temperature; contacting said article, while maintaining it at an elevated temperature, with a vapor of a metallic compound that decomposes at an elevated temperature to release a metallic coating material; thereby depositing said released metal on said heated filamentary article.

3. A process in accordance with claim 2 in which the amount of said mixed particles is no more than about 8% by weight of the uncoated article.

4. In a gas plating of a metallic coating on shaped articles the steps comprising, subjecting a substantially nonmetallic, heat sensitive filamentary article to the action of an electric current, said article having mixed therethrough a relatively small amount of fine particles of an electrical conducting material selected from the group consisting of metal and carbon, heating said article by the action of said electric current to an elevated temperature; contacting said article, while maintaining it at an elevated temperature, with a vapor of a metallic compound that decomposes at an elevated temperature to release a metal selected from the group consisting of nickel, tin, aluminum, iron and chromium; thereby depositing said released metal on said heated shaped article.

5. In the gas plating of a metallic coating on shaped articles the steps comprising, subjecting a substantially nonmetallic, heat sensitive filamentary article to the action of an electric current, said article having mixed therethrough a relatively small amount of metal particles of an average size of about 100 mesh; heating said article by said electric current to an elevated temperature below about 450° F.; contacting said article while maintaining

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it at said temperature with a vapor of a metal compound that decomposes at said temperature to release the pure metal of said compound; thereby depositing a coating of said released metal on said heated article.

6. A process in accordance with claim 5 in which the substantially nonmetallic, heat sensitive filamentary article consists of fibers of a material selected from the group consisting of cellulose, polyamides, polyacrylics, polyesters and glass.

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