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CONDUCTIVE PLASTIC COMPOSITION AND METHOD OF MAKING THE SAME

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This invention relates to the production of electrically conductive plastics and more particularly to molded plastic articles having improved electrical and physical properties and to molding powders for making such articles. The conductive plastics of the present invention are especially adapted to be used in forming the contact elements of multi-contact switch devices such as are used in information sampling and similar instruments and will be illustratively described as used for this application, although as the description proceeds it will become apparent that these plastics may also be used in other applications wherein their improved electrical and physical properties are advantageous.

Multi-contact switch devices commonly comprise a series of contact elements which may be made of metal or conductive plastic and at least one contactor that is movably mounted in such manner as to permit it to be brought into contact with a selected one of the contact elements to complete an electrical circuit. In some cases the contactor is stationary and the contact elements are moved with respect thereto. The relative movement of the contactor and the contact elements tends to cause the contactor to wear a groove in the surface of the contact elements, and accordingly it is desirable that the contact elements be made of a relatively hard material so that they will resist this wear. It is further desirable that the contact elements have a static and dynamic contact resistance that is as low as possible. Also the contact resistance should be as nearly uniform as possible, that is to say, it is undesirable that the contact resistance vary as a function of the particular point on the surface of the contact element over which the contactor is passing.

In general the previously proposed electrically conductive plastics are incapable of satisfying these varied requirements. In accordance with one previously proposed process for producing conductive plastics, a solvent solution of a resin or plastic is prepared, and a finely divided conductive material, such as finely divided carbon, is uniformly dispersed in the solvent solution. The solvent is then evaporated to produce a solid product having a degree of electrical conductivity. In this type of product a relatively large amount of conductive material must be employed to achieve a significant degree of electrical conductivity. The use of such a large amount of conductive material impairs the physical properties of the plastic composition, and even if a large proportion of conductive powder is used, the resistivity of the material is still substantially greater than that of a metal. If a product of this type having acceptable wear-resistance is employed in the contact elements of a multi-contact switch, the contact resistance is undesirably high, especially for those applications that involve a low voltage and a small current.

In another method of making electrically conductive plastics disclosed in U.S. Patent 2,761,854, the surfaces of a plastic material in granular form are coated with finely divided metal powder and the metal-coated granules of plastic are then molded to produce a product having a reticulate conductive metal structure therein. Such products have exceptionally low resistance in relation to the amount of conductive powder employed in their production, and have good molding properties. When products of this type are employed in the contact elements of a multi-contact switch they are capable of exhibiting low

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contact resistance. However, because such products are not completely homogeneous they tend to exhibit a widely variant contact resistance at different points on their surface. If, for example, the contactor passes over a portion of the surface of the contact element that is composed of metal forming part of the reticulated metal structure of the plastic, the contact resistance is substantially zero. If on the other hand, the contactor of the switch passes over a portion of the surface of the contact element that is composed of plastic, the contact resistance is very high. Hence products of this type are not entirely satisfactory as contact elements.

It is accordingly an object of the present invention to provide molded plastic articles having improved electrical properties and wear-resistance. It is another object of the invention to provide a material adapted to be used in forming switch contacts that exhibit low static and dynamic resistance. It is still another object of the invention to provide an electrically conductive plastic having improved wear-resistance. It is a still further object of the invention to provide an electrically conductive plastic which when used as a contact element of a switch exhibits more nearly uniform contact resistance than has heretofore been achieved. Other objects of the invention will be in part obvious and in part pointed out hereafter.

The objects of the invention may be achieved in general by forming an electrically conductive molded article having a reticulate skeletal structure of an electrically conductive substance with the spaces in said skeletal structure being filled with a conductive composition that is essentially a substantially uniform dispersion of finely divided electrically conductive material in an organic molding plastic. The term "plastic" as used herein embraces any one of a large and varied group of materials commonly referred to as plastics and resins characterized by the fact that they are organic substances of high molecular weight that may be readily molded into desired shapes under conventional molding conditions. Plastics that may be employed in carrying out the process of the present invention may be chosen from the large group of molding substances that includes thermo-setting materials such as phenolic and ureaformaldehyde plastics and thermoplastic materials such as polystyrene, polyethylene, polymethylmethacrylate, vinyl polymers and copolymers, cellulose acetate, silicone, polymonochlorotrifluoroethylene, polytetrafluorethylene and the like. The plastic material used as a starting material in the present process may already contain compounding ingredients such as lubricants, plasticizers, dyes, pigments, fillers and the like.

In carrying out the process of the present invention a dispersion of finely divided conductive material in a plastic of the type described above is prepared. The dispersed phase may be, for example, an electrically conductive carbon powder or a conductive compound or metal powder. Dispersion of the conductive powder in the plastic may be effected by any of several known procedures. For example, the plastic may be dissolved in a suitable solvent and the conductive powder thoroughly mixed with the solvent solution to form a homogeneous dispersion therein. The solvent is then evaporated to provide a solid product having the conductive powder uniformly dispersed therein. Alternatively, in the case of thermoplastic materials, the plastic may be dispersed on a mill and the conductive powder incorporated in the plastic by milling. The quantity of conductive powder dispersed in the plastic may be such that it comprises from 20% to 50% by weight of the conductive plastic product. Preferably the conductive powder is a finely divided carbon such as acetylene black or a furnace black and it is preferably present in the conductive plastic to the extent of 30% to 40% by weight.

The dispersion of the conductive powder in the plastic is broken up into granular form. Although the extent to which the conductive plastic is comminuted does not appear to be particularly critical, in general it is desirable that the granules be smaller than 40 mesh and that particles that pass through a 325 mesh screen be removed. The preferred particle size range is 80-140 mesh.

In the next step of the process the surfaces of the granular material are coated with a conductive powder of smaller particle size than the plastic granules. The average diameter of the particles of coating powder should be less than one-third the average diameter of the plastic granules. Coating or cladding of the plastic granules with the conductive powder is facilitated if the powder is composed of flake-like particles. Especially good results have been achieved when using silver powder as the coating powder, although other conductive powders such as nickel powder, an electrically conductive carbon powder or the like may also be used. Oxidation-resistant powders composed of the noble metals are especially useful. The amount of coating powder used may be from 15% to 40% by weight of the plastic granules, the preferred quantity being from 25% to 35% of the weight of the granules. The desired conductive coating on the plastic granules may be achieved by tumbling the granular plastic and finely divided conductive material as described in the specific examples given below or, alternatively, the coating of metal on the plastic granules may be obtained by chemical deposition of the metal on the granules or by vaporization of the metal under reduced pressure and condensation of the metal on the plastic granule surfaces.

In cases where the plastic particles are to be coated with a conductive metal powder, it has been found advantageous to apply a sub-coating of an adhesion-promoting material. Suitable adhesion-promoting materials are molybdenum sulfide and graphite. By applying a preliminary coating of such an adhesion-promoting agent to the plastic granules, it has been found that more effective cladding of the plastic granules with the metal powder is achieved and the lubricity of the contact surface is increased.

In order to point out more fully the nature of the present invention the following specific examples are given of illustrative embodiments of the invention:

Example 1

A resin solution is prepared by dissolving 140 grams of an alcohol-soluble phenolic resin (Bakelite BRP 57772) in 500 grams of ethyl alcohol using a mechanical stirrer. This solution is added to 60 grams of acetylene black of approximately 1 micron particle size with stirring and thereafter an additional 300 grams of ethyl alcohol is added and mixed with the suspension. The suspension is then placed in a one-gallon porcelain mill with porcelain balls and milled for two hours.

The milled suspension is put in a tray and dried in an oven at 65° C. for 3 hours to evaporate the solvent therefrom and leave a homogeneous dispersion of the carbon powder in the plastic mass. The solid plastic composition is removed from the tray and comminuted in a hammer-mill (A Mikro-pulverizer) to reduce it to granular form. The granular product is separated by sieving to segregate the 80-mesh to 140-mesh fraction, and 25.2 grams of this fraction of the granules, together with 4.2 grams of finely divided molybdenum sulfide, is put in a one-liter bottle provided with tumbling blades. The bottle is turned about its axis for two hours at about 120 r.p.m. At the end of this time 12.6 grams of finely divided silver in flake form and having an average particle size of the order of 300-mesh, together with 40 grams of 1/8" stainless steel balls, is introduced into the 1-liter bottle, and the entire mixture within the bottle is milled for an additional 8 hours.

The coated granular product obtained by following the foregoing procedure was molded into contact elements

that were tested for electrical properties and wear-resistance. These elements exhibited a static contact resistance of as little as 0.1 ohm as compared with about 25 ohms for the prior art dispersion-type conductive plastics. In order to test the wear resistance of the composition, the surface of a contact element made therefrom was wiped with a hooked-shaped wiper made of 0.04" diameter palladium alloy wire using a bearing force of 55 grams and rotating the wiper at 600 r.p.m. The direction of rotation of the wiper was reversed every 15 minutes and the test was continued for 24 hours. At the end of the test the depth of the groove was measured and found to be 200 micro-inches, which compares with a groove depth of 700 micro-inches for a prior art composition containing a comparable amount of conductive material.

Example 2

The procedure of Example 1 is followed except that the phenolic resin is replaced by an alcohol-soluble grade of ureaformaldehyde resin manufactured and sold under the trade name "Amorite," the step of coating with molybdenum sulfide is omitted, and the quantity of acetylene black used is increased from 60 to 70 grams. Contact elements molded from granules as thus prepared exhibit improved electrical properties and wear resistance.

Example 3

The procedure of Example 1 is followed except that the phenolic resin is replaced by an alcohol-soluble grade of melamine-formaldehyde resin and the 60 grams of acetylene black is replaced by 80 grams of a conductive oil furnace black sold under the trade name "Vulcan XC72R." Also the flake silver powder is replaced by 15 grams of finely divided nickel.

Example 4

A water emulsion of polytrifluoro-monochloroethylene containing 140 grams of the polymer is added to 60 grams of acetylene black with stirring and the suspension is placed in a one-gallon porcelain jar mill with porcelain balls and milled for 2 hours. The resulting suspension is dried in an oven at 65° C. for three days to evaporate the water therefrom and yield a homogeneous dispersion of the acetylene black in the plastic mass. Thereafter the plastic is comminuted to form granules that are treated with molybdenum sulfide and silver powder in accordance with the procedure described in Example 1.

Example 5

The procedure of Example 4 is followed except that the emulsion of polytrifluoro-monochloro-ethylene is replaced by an emulsion of polytetrafluoro-ethylene.

Example 6

The procedure of Example 1 is followed except that the phenolic resin solution is replaced by a solution of 140 grams of nylon in 500 grams of dimethyl-formamide and gold powder is used instead of silver powder.

Example 7

The procedure of Example 1 is followed except that the phenolic resin solution is replaced by a solution of 140 grams of allylphthalate in acetone.

Example 8

The procedure of Example 1 is followed except that the phenolic resin solution is replaced by 280 grams of a melamine-formaldehyde formulation containing 50% solids manufactured under the trade name "Cymel 245-8." The contact resistance measured against a conductive segment of a switch element made from the resulting conductive plastic was one ohm.

From the foregoing description it should be apparent that the present invention provides a molding composition and molded articles capable of meeting the objec-

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tives set forth in the beginning of the specification. By employing a homogeneous dispersion of conductive material in a plastic to fill the interstices of a reticulate conductive skeletal structure, a molded electrically conductive plastic article is achieved which exhibits superior electrical and physical properties as compared with the previously available conductive plastics. It is, of course, to be understood that the foregoing examples are intended to be illustrative only and that numerous changes can be made in the ingredients, proportions and conditions specifically disclosed without departing from the spirit of the invention as defined in the appended claims.

I claim:

1. An electrically conductive molded article comprising a finely reticular three-dimensional network composed of an electrically conductive substance selected from the group consisting of carbon and conductive metals, the spaces in said network being filled with a conductive composition which is essentially a uniform dispersion in a synthetic organic plastic of finely divided electrically conductive powder selected from the group consisting of carbon and metal powders, said conductive powder constituting 20% to 50% by weight of said dispersion, the interstices of said network being not substantially greater than 0.02 inch.

2. A granular product adapted to be used in molding conductive plastic articles, said product consisting of granules of an electrically conductive material, said granules having their surfaces coated with a thin layer of an electrically conductive substance selected from the group consisting of carbon and conductive metals, said conductive material being essentially composed of a substantially uniform dispersion in a synthetic organic molding plastic of finely divided electrically conductive particles selected from the group consisting of carbon and metal powders, said dispersion containing from 20% to 50% by weight of said conductive particles.

3. A granular product according to claim 2 and wherein said conductive particles are carbon particles and said conductive substance is a conductive metal powder.

4. A granular product according to claim 3 and wherein said conductive metal is silver, said finely divided carbon is acetylene black and said molding plastic is a phenolic resin.

5. A granular product adapted to be used in molding conductive plastic articles, said product consisting of granules of an electrically conductive material, said granules having their surfaces covered with a thin layer of an electrically conductive substance selected from the group consisting of carbon and conductive metals, said layer of conductive substance being attached to the surfaces of said granules through an adhesion-promoting layer, and said conductive material being essentially composed of a substantially uniform dispersion in a synthetic

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organic molding plastic of finely divided electrically conductive particles selected from the group consisting of carbon and metal powders, said dispersion containing from 20% to 50% by weight of said conductive particles.

6. A granular product according to claim 5 and wherein said adhesion-promoting layer is composed of a substance selected from the group consisting of molybdenum sulfide and graphite.

7. The method of making a molding powder for molding electrically conductive articles which comprises preparing an organic solvent solution of a synthetic organic plastic, dispersing uniformly in said solvent solution of said plastic a finely divided conductive material selected from the group consisting of carbon and metal powders in an amount constituting from 25% to 100% of the weight of the plastic in said solvent solution, evaporating the solvent of said solution to produce a solid plastic composition having said conductive material uniformly dispersed therethrough, comminuting the plastic composition to form granules thereof, and applying a thin coating of an electrically conductive substance selected from the group consisting of carbon and conductive metals to the surfaces of said granules.

8. A method of making a molding powder for molding electrically conductive articles which comprises, dissolving a synthetic organic plastic in an organic solvent, dispersing in the resulting solution finely divided conductive material selected from the group consisting of carbon and metal powders in an amount constituting from 25% to 100% by weight of said plastic, evaporating the solvent from said solution to produce a solid plastic having said conductive material uniformly dispersed therein, comminuting the plastic composition to form granules, tumbling said granules with an adhesion-promoting agent selected from the group consisting of molybdenum sulfide and graphite to form an adhesion-promoting layer on the surfaces of said granules, and thereafter tumbling said granules with an electrically conductive metal powder to form a coating of said powder on the surfaces of said granules.

9. A method according to claim 8 and wherein said conductive material is acetylene black, said conductive metal is silver and said plastic is a phenolic resin.

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