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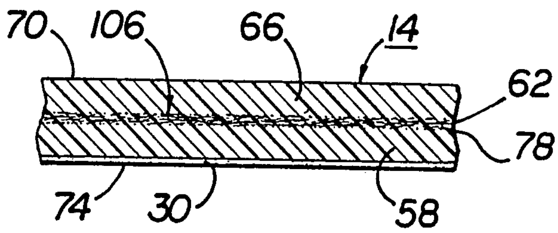

(57) Abstract

Electrically conductive and static dissipative materials (14), and methods of manufacturing the materials, are disclosed. Unlike existing conductive films or webs, the present invention includes discrete electrically conductive fibers (62) dispensed to form a network principally at or near the surface of a polyvinyl chloride (PVC) or other substrate (58). The fibers are typically, but need not be, copper sulfide dyed acrylics. Forming such a conductive network in situ permits the resulting material to have improved electrical characteristics.

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ELECTRICALLY CONDUCTIVE/STATIC DISSIPATIVE MATERIAL AND METHODS OF MANUFACTURE

This invention relates to materials that include a layer of discrete electrically conductive fibers dispensed to form a network.

Background of the Invention

Excessive amounts of static electricity can easily and sometimes insidiously destroy or damage integrated circuit and other electronic devices. Arcs and sparks produced by static discharge can also create dangerous disturbances in a variety of hazardous environments. For charged individuals, such static discharges can also be uncomfortable. Having recognized the need to control static charge in many areas, various industries currently use preventive measures including providing workers and work stations with grounding straps and neutralizing static charge through ion emission. Workers in some cases may also utilize conductive or static dissipative work surfaces or flooring products.

U.S. Patent No. 4,208,696 to Lindsay, et al. discloses a pre-formed, electrically conductive web for use as such a static dissipative work surface or floor mat. The web consists of a foraminous material such as scrim or open-cell foam coated with latex or other carbon-containing binder resin to make it electrically conductive. The pre-formed, coated material may then be bonded to a layer of plasticized vinyl. According to the Lindsay patent, because the plasticized vinyl penetrates the scrim, it forms a good electrical and mechanical bond when scrim is used.

U.S. Patent Nos. 4,414,260 and 4,363,071 to Rzepecki, et al., illustrate alternative static dissipative mats and fabrics. The multi-layer webs include upper and lower vinyl layers between which a continuous, pre-formed conductive film is placed. The conductive film is similarly made of vinyl, although pre-processed to contain an electrically conductive ingredient such as carbon black. Figure 3 of U.S. Patent No. 4,307,144 to Sanders, et al., shows another static dissipative fabric including a continuous conductive film painted into the underside of an unsupported polyvinyl chloride (PVC) sheet. Other static dissipative mats include as a conductive film a non-woven, aluminized polyester fleece. Commercially available aluminized fleeces are relatively expensive, however, in many cases reducing the cost-effectiveness of the resulting product. Some aluminized fleeces may also lack sufficient metal to ensure that the resulting product can be adequately grounded.

U.S. Patent No. 4,590,120 to Klein, incorporated herein in its entirety by this reference, describes a transparent static reducing chair mat including electrostatically conductive fibers deposited onto a rigid plastic base. According to the Klein patent, these fibers chemically bond to the rigid base in a partially conductive polymeric matrix and are typically covered with a transparent film. By choosing appropriately rigid materials, moreover, the fibers remain more or less in the same horizontal plane. Although Figure 5 of the Klein patent illustrates fibers oriented in both horizontal and vertical planes, they have not descended or diffused into the rigid base. As a result, the amount of activity in the vertical dimension is relatively small.

Summary of the Invention

The present invention provides another electrically conductive or static dissipative material for use in a wide variety of industries. Unlike many of those described above, the present invention does not use a pre-formed conductive web or continuous film such as coated scrim or carbon-impregnated vinyl. Instead, the invention provides a layer of discrete, electrically conductive fibers dispensed to form a network at or near the surface of a PVC or other substrate. The initial viscosity characteristic of the substrate permits fibers to diffuse and descend into it, however, providing substantial fiber activity in the vertical dimension. The resulting product, moreover, optionally can include a second layer (which may be chemically-blown foam for cushioning), is relatively flexible, and can be bent without fracturing the material or disrupting its electrical characteristics. Alternatively, the fibers may be blown or otherwise placed in the backings of carpet tiles (or carpets) substantially normal to the backing surface to establish electrical continuity with, for example, conductive face yarns of the carpet tiles.

Materials made according to the present invention possess significant advantages over prior mats in which conductivity is achieved by means of a discrete conductive layer. Because the discrete layers of prior mats are physically different from the primary constituents of the products, the mats are subject to curling and delamination. In materials of the present invention, however, the relatively dense conductive layer is nonetheless composed volumetrically primarily of the PVC of the body of the material. Thus, while the material acts electrically like one having a discrete conductive layer, its mechanical performance is essentially that of a homogeneous product. For practical purposes, the material may be said to be electrically heterogeneous, but mechanically homogeneous.

In one embodiment of the invention, acrylic fibers coated with copper sulfide are dispensed onto a PVC plastisol substrate and covered to form a multi-layer material. If sufficient numbers of discrete fibers are dispensed along the substrate surface, they will link physically to form a dense network of electrically contacting fibers in that plane. Because of the viscosity characteristic of the substrate, however, a substantial number of fibers penetrate into the surface and a diffused, three-dimensional network of conductive fibers typically results.

Dispensing of the fibers in some embodiments of the invention may be accomplished using a hopper having a perforated bottom and a dispensing brush positioned above a traveling substrate. The dispensing brush forces fibers through the perforated hopper bottom to dispense them approximately uniformly with a generally random orientation along the substrate surface. As some fibers begin to descend into the substrate, the composite is heated to gel, or partially harden, the substrate. An optional second layer of, e.g., chemically-blown foam may then be applied over the dispensed fibers to form a three-layer material. The material subsequently is heated (and cooled) to cure and bond the various layers and, if appropriate for its ultimate use, cut, rolled, or embossed. A metal grommet or similar structure additionally may be forced through the material to permit connection of a grounding wire and create an improved electrical path from the material surface to ground.

It is therefore an object of the present invention to provide a material containing discrete electrically conducting fibers.

It is another object of the present invention to provide a multi-layer conductive or static dissipative material that may be said to be electrically heterogeneous, but mechanically homogeneous.

It is an additional object of the present invention to provide a material formed, at least in part, by dispensing quantities of conductive fibers along the surface of a substrate.

It is yet another object of the present invention to provide a flexible material capable of supplying an improved electrical path from the material surface to ground.

It is an additional object of the present invention to provide methods for forming a multi-layer conductive or static dissipative material that is flexible.

Other objects, features, and advantages of the present invention will become apparent with reference to the remainder of the written portion and the drawings of this application.

Brief Description of the Drawings

FIG. 1 is a partially schematicized, side elevational view of equipment which can be used to manufacture the material of the present invention.

FIG. 2 is a perspective view of an embodiment of the material of FIG. 1 shown partially cut away.

FIG. 3 is a cross-sectional view of the embodiment of the material of FIG. 2 shown together with a carrier.

FIG. 4 is a cross-sectional view of an embossed embodiment of the material of FIG. 2 shown together with a carrier.

Detailed Description

FIG. 1 details an embodiment of the present invention illustrating equipment 10 which can be used to manufacture material 14. As shown in FIG. 1, equipment 10 includes substrate, or primary dispenser 18, hopper 22, and conveyor 26. Also illustrated in FIG. 1 are material carrier 30, secondary dispenser 34, doctor blades 38 and 42, oven 46, and, in phantom lines, opposed embossing rollers 50 and 54, each of which may be included as part of equipment 10 as appropriate. Together, these components assist in forming a multi-layer material 14 and conveying the material 14 through various curing and finishing stations. Material 14, an improved electrically conductive or static dissipative substance, comprises a network of discrete, electrically conductive fibers dispensed between, typically, PVC or other layers, one optionally being foamed to provide a cushioning effect for the resulting product. The result in any event is a material 14 having a conductive layer composed volumetrically primarily of PVC and which may be said to be electrically heterogeneous, but mechanically homogeneous.

In an embodiment consistent with FIG. 1, primary dispenser 18 distributes a substrate 58 onto a paper or other carrier 30. The height of substrate 58 may be made more uniform, if desired, by passing substrate 58 underneath doctor blade 38 (or, alternatively, an air knife or similar device). Substrate 58 subsequently passes beneath hopper 22, receiving from the hopper 22 discrete fibers 62, and is heated before advancing to secondary dispenser 34. Heating substrate 58 partially gels it, substantially reducing diffusion of the fibers 62 throughout the depth of the substrate 58 from that time forward. Secondary dispenser 34 may be used to supply a layer 66 of viscous material over fibers 62, or chemically-blown foam may be applied as layer 66, effectively forming a three-layer material 14 in which fibers 62 are sandwiched between portions of substrate 58 and layer 66. Doctor blade 42 may then smooth exposed surface 70 of layer 66. Oven 46, in turn, cures material 14, bonding layer 66 to substrate 58 and fibers 62.

Because fibers 62 do not form a continuous film, substrate 58 and layer 66 can encompass the fibers 62 and interact with each other, forming a strong mechanical bond among the various components of material 14. Material 14 may then be passed through opposed embossing rollers 50 and 54, if appropriate, to texture either or both of exposed surface 70 and the exterior surface 74 of substrate 58. Typically, the exterior surface 74 of substrate 58 will be embossed by roller 54 and ultimately form the upper surface, or face, of (finished) material 14. Material 14 may also be cut into sections or rolled for further processing or transport.

Hopper 22 is designed to supply fibers 62 approximately uniformly along the interior surface 78 of substrate 58 and in sufficiently quantities to ensure electrical continuity throughout the surface 78. Although any appropriate means may be used, in the embodiment of FIG. 1 hopper 22 includes multiple spaced perforations 82, as in a screen, through which fibers 62 descend. A rotating brush 86, powered by motor 90, separates and fluffs fibers 62 before forcing the fibers 14 through perforations 82. If electrostatic dispensing is desired, charger 94 may be used to assign fibers 62 and substrate 58 unequal potentials. Alternatively, gravity or other means may supply the force necessary to cause fibers 62 to contact interior surface 78.

FIGS. 2-4 illustrate a three-layer embodiment of material 14 formed of substrate 58, fibers 62, and layer 66. FIG. 2 also shows ground clip 98, which penetrates each of the three layers of material 14, and its associated ground wire 102. Clip 98 and wire 102 permit material 14 to be connected directly to electrical ground.

FIG. 2 further details the electrical continuity achieved by dispensing discrete fibers 62 throughout interior surface 78. If suitably dispensed, the longitudinal axes of many of the fibers 62 tend to remain adjacent surface 78, with fibers 62 contacting neighboring fibers 62 to form a continuous, linked network 106 along surface 78. Depending on the viscosity of substrate 58 and weight of fibers 62, some fibers 62 may penetrate into the substrate 58. Other fibers 62, moreover, will fail to lie flat along the interior surface 78, effectively forming a three-dimensional network of electrically conductive fibers 62 diffused throughout much of the flexible material 14 (but diminishing in quantity as the distance from interior surface 78 increases). As described in the accompanying EXAMPLE, forming in situ an electrically conductive network 106 of discrete fibers 62 can result in material 14 having excellent static dissipation characteristics.

In one embodiment of the present invention, substrate 58 constitutes a layer of PVC approximately thirty mils high and layer 66 is made of PVC foam approximately sixty mils high. Fibers

62 are copper sulfide dyed acrylic fibers, each approximately two denier and four to five millimeters long. Hopper 22 dispenses approximately one-half gram of fibers 62 per square foot of substrate 58. Those skilled in the art will recognize, however, that silver-coated fiber (such as Sanquoit X-Static fiber), metal-coated polyacrylonitrile fibers (such as TEXMET copper/nickel-plated fibers) or other sufficiently electrically conductive fibers of various base and coating materials and physical dimensions may be used as fibers 62, and that substrate 58 and layer 66 may be formed of materials other than PVC. Layer 66, furthermore, need not be present.

The following EXAMPLE may additionally be used to illustrate (but not limit) characteristics of selected components which may be used in connection with the present invention.

EXAMPLE

A PVC substrate 58 approximately twenty-eight mils high is formed and heated using a first plate (600°F) and a second plate (250°F) positioned opposite carrier 30 from the substrate 58. The substrate 58 travels on carrier 30 at approximately eight to nine feet per minute. Hopper 22 dispenses two denier, five millimeter copper sulfide dyed acrylic fibers 62 onto substrate 58. Such fibers 62 are sold by Sanmo under the brand name "Thunderon." A second PVC foam layer 66, approximately sixty-seven mils high, covers substrate 58 and fibers 62 on the first three (of four) trials. One surface of the resulting material 14 is then embossed by rollers 50 and 54.

Using EOS/ESD Association Standard "Work Surfaces, EOS/ESD S-4" at 100 volts, electrical resistance of material 14 (in ohms) produced during these trials is as follows:

Trial 1	embossed surface	1.8×10^8
	back surface	4×10^8
Trial 2	embossed surface	9×10^7 to 2.2×10^8
	back surface	---
Trial 3	embossed surface	1.2×10^8 to 1.9×10^8
	back surface	1.6×10^8
Trial 4	embossed surface	4×10^7
	back surface	1.6×10^5

At higher brush 86 rotation speeds, some clumping of fibers 62 occurs.

The foregoing is provided for the purposes of illustration, explanation, and description of embodiments of the present invention. Modifications and adaptations to these embodiments will be apparent to those of ordinary skill in the art and may be made without departing from the scope and spirit of the invention.

What is claimed is:

1. A method of manufacturing material comprising the steps of:

a. providing a substrate having a surface and a depth;

b. dispensing a plurality of discrete, electrically conductive fibers along the surface, thereby forming an electrically conductive fiber network along substantially all of the surface as a portion of the plurality of fibers descends into and partially diffuses through the depth of the substrate; and

c. bonding the fibers to the substrate to produce an electrically substantially heterogeneous, but mechanically substantially homogeneous, material.

2. A method according to claim 1 in which the dispensing step comprises dispensing a plurality of copper sulfide dyed acrylic fibers substantially uniformly along the surface.

3. A method according to claim 2 in which the dispensing step further comprises:

a. feeding the fibers into a hopper having a perforated section;

b. separating and fluffing the fibers by contacting them with a moving brush; and

c. forcing the fibers through the perforated section of the hopper.

4. A method according to claim 3 in which the providing step comprises providing a substrate made of polyvinyl chloride at least approximately thirty mils thick.

5. A method according to claim 4 in which the bonding step comprises heating the fibers and substrate.

6. A method according to claim 5 further comprising the step of embossing the substrate.

7. A method according to claim 6 further comprising the steps of:

a. smoothing the surface of the substrate before dispensing the plurality of fibers;

b. heating the surface of the substrate after dispensing the plurality of fibers; and

c. smoothing the foam before heating the fibers and substrate.

8. A method according to claim 7 further comprising the step of penetrating the fibers and substrate with a means for grounding the material.

9. A method according to claim 8 further comprising the steps of:

a. charging the fibers to an electrical potential having a first value; and

b. charging the substrate to an electrical potential having a second value not equal to the first value.

10. A method according to claim 1 further comprising the step of covering the fibers and substrate with a foam to form a flexible, cushioned composite.

11. A method of manufacturing an electrically substantially heterogeneous, but mechanically substantially homogeneous, material comprising the steps of:

a. providing a substrate made of polyvinyl chloride having interior and exterior surfaces;

b. charging the substrate to an electrical potential having a first value;

c. smoothing the interior surface of the substrate using a doctor blade;

d. conveying, on a paper carrier, the substrate to a location adjacent a hopper having a perforated section;

e. dispensing from the hopper a plurality of discrete acrylic fibers dyed with copper sulfide substantially uniformly along the interior surface, thereby forming an electrically conductive fiber network along substantially all of the interior surface, which dispensing step comprises:

   i. feeding the fibers into the hopper;

   ii. separating and fluffing the fibers by contacting them with a rotating brush; and

   iii. forcing the fibers through the perforated section of the hopper;

f. charging the fibers to an electrical potential having a second value not equal to the first value;

g. dispensing a layer of polyvinyl chloride foam having an exterior surface onto the fibers and the interior surface of the substrate, thereby contacting both the fibers and the interior surface and securing the fibers between the layer and the substrate;

h. smoothing the exterior surface of the layer;

i. heating and then cooling the fibers, substrate, and layer to bond the fibers to the substrate and layer after smoothing the exterior surface of the layer;

j. embossing the substrate and exterior surface of the layer; and

k. penetrating the fibers, substrate, and layer with a metal grommet for grounding the material.

12. A flexible material adapted to dissipate static, comprising:

a. a substrate having a surface; and

b. a plurality of discrete, electrically conductive fibers (1) dispensed substantially uniformly along the surface to form an electrically conductive fiber network along substantially all of the surface and (2) bonded to the substrate so that the electrically conductive fiber network will not be disrupted if the material is bent.

13. A material according to claim 12 in which (a) the surface of the substrate defines a plane, (b) the fibers define respective longitudinal axes, and (c) most of the longitudinal axes lie in the plane defined by the surface.

14. A material according to claim 12 in which the material is electrically substantially heterogeneous, but mechanically substantially homogeneous.

15. A material according to claim 12 further comprising a layer of chemically-blown foam covering the substrate and fibers to provide a cushioning effect.

16. A material according to claim 13 in which the substrate has depth and the fibers whose longitudinal axes do not lie in the plane defined by the surface are diffused through the depth of the substrate, with the fiber density approximately inversely proportional to the distance within the substrate from the plane defined by the surface.

17. A material according to claim 16 further comprising means, penetrating the fibers and substrate, for connecting the material to electrical ground.

18. A material according to claim 17 having an electrical resistance of between approximately 10^5 and approximately 10^9 ohms.

19. A material formed by the method of claim 1.

20. A material formed by the method of claim 11.

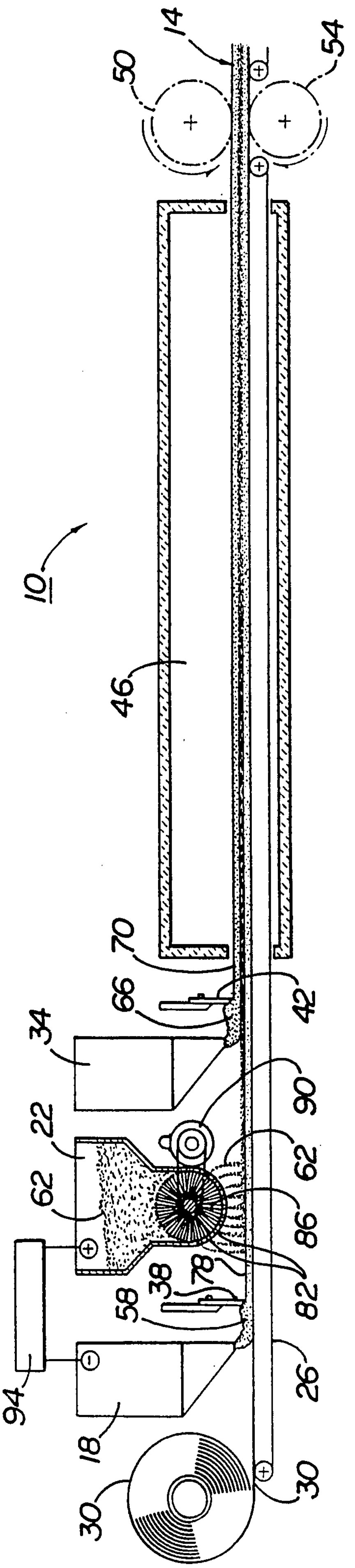

FIG 1

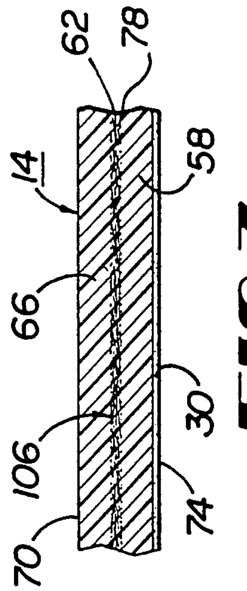

FIG 3

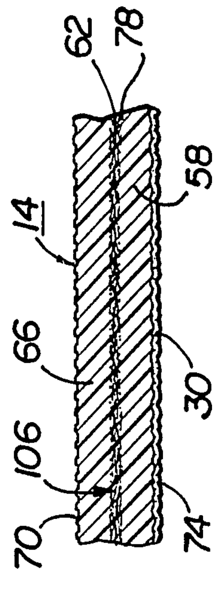

FIG 4

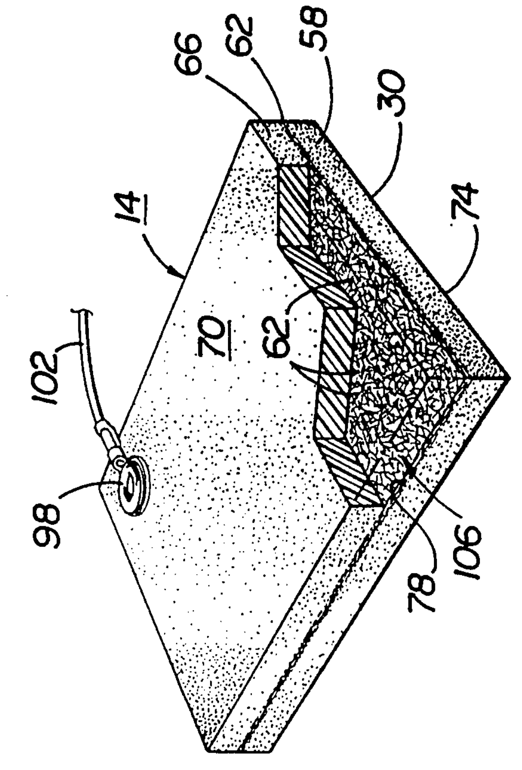

FIG 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/10783

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B05D 1/12; B32B 27/12, 27/14, 31/26
US CL :156/276, 308.2; 427/180, 203; 428/285, 319.1, 522, 922
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,590,120 (KLEIN) 20 MAY 1986. See entire document.	1-20
Y	US, A, 4,891,264 (DAIMON) 02 JANUARY 1990. See entire document.	1-20
Y	US, A, 4,208,696 (LINDSAY) 17 JUNE 1980. See column 2, lines 58-68.	7, 10 and 15

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 DECEMBER 1993	24 FEB 1994

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