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FIBROUS COMPOSITIONS

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This invention relates generally to electrically-conductive fibrous compositions for use in making felted products such as paper and mats. More particularly it relates to improved electrically-conductive compositions and felted products utilizing carbon in a particular fibrous form. It further relates to a novel method of making these fibrous carbon-containing compositions and products.

Conductive felted products of various types are generally well known. One of the most common kinds utilizes a base felt of cellulosic-type fibers impregnated or filled with particulate carbon or graphite. Although such conductive products, e.g., paper, have found some measure of use, the presence of fine particle carbon or graphite results in certain disadvantages which heretofore have seriously curtailed their use. Some of these disadvantages are degradation of other materials, e.g., natural and synthetic resins, within the conductive product; impairment of the coloring of the final product, particularly when a light color is desired; a decrease in the web strength of the paper; etc. These problems are particularly acute when large amounts of fine particle carbon necessary for high conductivity are utilized.

It is the object of this invention to provide new and improved electrically-conductive compositions and products utilizing carbon in a fibrous form.

Another object of this invention is to provide a new and improved method for making the electrically-conductive compositions and products.

Other objects, advantages and features of this invention will become apparent from the following detailed description.

Broadly speaking, our invention comprises a mixture of electrically-conductive carbon fibers, preferably in the form of individual, unitary fibrils or filaments, and electrically-nonconductive fibers which can be either natural or synthetic. Our invention is further directed to a method of making the compositions which utilizes the preferred form of the fibrous carbon, that is, a fibril or filament. Broadly, this process comprises dispersing the carbon fibers in a liquid slurry and agitating the slurry, preferably under high shearing stresses to disperse the fiber in the form of individual filaments, adding the nonconductive fibers, felting the resultant mixture, and finally drying to form the final fibrous product. As is well known, any desired number of the resultant mats may be fused together under elevated temperature and pressure.

The utilization of electrically-conductive carbon fibers along with nonconductive synthetic or natural fibers such as are normally employed in making fibrous compositions and products, imparts many advantageous properties not heretofore available. The use of the fibrous form of carbon results in a super-multiplicity of conductive paths thus effecting much higher electrical conductivities than was possible with an equal weight of the fine particle carbons hitherto used. This results in such advantageous benefits as little or no degradation of other materials, e.g., synthetic polymers, present in the final product; little impairment of the overall color of the conductive products, particularly beneficial when light coloring is desired; improved web strength of the final product; and a considerable reduction in the loss of conductive carbon in fine particle form in the mixing water. The advantages are most apparent when high electrical conductivities are desired. Since the carbon itself is fibrous, and possesses some flexibility and tensile strength of its own, it becomes enmeshed in the mat, and has a lesser deleterious effect on the overall strength of the web than does equivalent amounts of fine particle carbon. The fibrous carbon also eliminates the hitherto expensive and time-consuming operation of supercalendering, necessary in many instances when fine particle conductive carbon has been employed. Other advantages such as reduced weight and size of the final product for comparable conductivity are also obtained.

Fibrous, electrically-conductive carbon as employed herein includes carbon in any of its forms, e.g., crystalline or graphite, differentiated by their dimensional structure. The process of making the fibrous carbon forms no part of this invention and can be any method well known to the prior art, for example, pyrolizing synthetic fibers, such as nylon, at an appropriate temperature such that the carbon to carbon bonds are not cleaved but rather the side substituents, e.g., hydrogen and nitrogen, are removed until a substantially pure chain of fibrous carbon remains. Other methods of producing the fibrous carbon from other materials, for example, those of vegetable origin, such as disclosed in the patent to Soltes, No. 3,011,981, can be employed also.

Preferably, the fibrous carbon reduced to individual filaments or fibrils is employed in making the electrically-conductive mats. In this form, the carbon is more easily and homogeneously dispersed among the nonconductive fibers. The individual fibrils or filaments, in their dispersed state, also provide more numerous conductive paths in the final product than are available with bunched fibers or filaments.

The fibrous products resulting from our improved composition and process can vary greatly in their final properties. The desired conductivity determines the ratio of fibrous carbon to nonconductive fibers. As little as 1%, or even less, carbon based on the total weight of the final product improves conductivity substantially. Obviously, as the amount of fibrous carbon increases, the conductivity increases proportionately. Generally, the amount of fibrous carbon which can be added is limited only by its adverse effect on the properties of the final composition such as web strength, etc. Because of the flexibility and tensile strength present in the fibrous form of the carbon, amounts as high as 75% by weight of the final composition can be employed. Products such as mats can be paper-thin or can be built up to greater thicknesses by laying down large quantities of the mixture of fibrous carbon and the electrically-nonconductive fibers or fusing many thin layers of the mixture together. Such properties as electrical conductivity, flexibility, tensile strength, etc., can be prescheduled for each final product depending upon the stresses experienced and the ultimate use of the product.

The choice of nonconductive fibers employed herein also can vary widely and is largely determined again by the conditions of ultimate use of the final product. For example, among the suitable nonconductive fibers are such natural fibers as jute, hemp, cellulosic materials, e.g., those commonly termed "kraft" fibers and alpha cellulose; wool, cotton, silk, etc. Synthetic nonconductive fibers such as polyvinyl chloride, polytetrafluoroethylene, polyamide fibers, e.g., nylon, polyester fibers, e.g., Dacron, and polyethylene can also be employed. Inorganic fibers such as asbestos or glass, etc., are also included within the group of nonconductive fibers suitable for the purposes of this invention. Obviously, any desirable mixture of fibers either synthetic or natural, organic or inorganic, can also be used. If a fiber of relatively low water resistance, e.g., kraft cellulose, is employed, water resistant coatings such as polyethylene, etc., are preferably used.

Other ingredients conventionally employed in the papermaking art can also be added to the conductive products. Thus, materials such as fire retardants, e.g., ammonium acid phosphate, adhesive binders, e.g., casein, neoprene (polymerized polychloroprene), and the like.

In order to illustrate the electrical conductivity of the fibrous products of this invention, the following illustration is presented, but, it is understood, is in no way limiting.

Conductive mats having an average thickness ranging from 0.022 to 0.040 inch were fabricated by the following process. Pyrolized carbon fibers were dispersed in a water slurry subjected to agitation by a Waring blender to produce a high rate of shear. Polyethylene coated kraft cellulose fibers were then added to the slurry and dispersed until the mixture of fibers was substantially homogeneous. The resulting slurry was felted on a screen mold and some of the water removed by application of a vacuum. The semi-dried sheets were then placed in a press between platens maintained at approximately 350° F. and fused under several hundred p.s.i. pressure. The pressed sheet was then cooled. The mats fabricated in this manner have excellent water resistance and electrical conductivity, the latter of which is a function of the amount of carbon fiber initially introduced. The electrical conductivities of several of these mats containing varying percentages by weight of carbon are presented in the following table.

Carbon, percent by weight:	Conductivity mhos
1	.000005 to .000002
2	.0004
5	.0125
10	.0333
15	.050
20	.100

As can readily be seen from these figures, the conductivity is a function of and can be predetermined by the amount of carbon originally added.

The electrically-conductive mats find particular application in the fabrication of dielectric type absorbers for attenuating incident ultra high frequency energy, e.g., radar waves. If the radar absorptive material is fabricated with a tapered impedance in which the conductivity varies continuously, or in discrete steps, from essentially zero on the incidient surface to the greatest electrical-conductivity on the rearward surface, little or no radar energy is reflected.

The new and improved radar absorbers can be fabricated in several ways. A plurality of felted mats in which the proportions of the fibrous carbon and nonconductive fibers are varied to effect an appropriate tapered impedance, are laid down upon a wire screen form and fused at elevated

temperatures. The final product thus appears as a single mat or sheet having a continuously increasing conductivity from the incident surface to the opposite surface. The same effect can also be obtained by laminating the paper-thin individual mats between layers of a foam, e.g., polyurethane, to provide composite structures of the required conductivity gradients. The flexibility of the fibrous carbon and the nonconductive fibers permits the shaping of the final conductive sheet to any substructure which it is desired to protect from rader detection.

The electrically-conductive compositions can also be employed in other uses, conventional in the art, such as laminated conductive panels, the conducting base of an electrosensitive recording blank, non-sparking surfaces, etc.

Although this invention has been described with reference to illustrative embodiments thereof, it will be apparent to those skilled in the art that it may be embodied in other forms within the scope of the appended claims.

We claim:

1. A process for making an electrically conductive felted, fibrous composition, said process comprising the steps of dispersing electrically conductive fibrous carbon in a liquid slurry, subjecting said fibers to agitation in order to reduce the fibers to individual filaments of carbon, dispersing electrically nonconductive cellulose fibers coated with a water-resistant synthetic resin in the fibrous carbon liquid slurry and forming a felted product therefrom, wherein said filaments of carbon provide electrically conductive paths.

2. A process for making an electrically conductive felted, fibrous composition comprising the steps of dispersing electrically conductive fibrous carbon in a liquid slurry, subjecting said fibers to agitation in order to reduce the fibers to individual filaments of carbon, dispersing electrically nonconductive polyethylene-coated cellulose fibers in the fibrous carbon liquid slurry and forming a felted product therefrom, wherein said filaments of carbon provide electrically conductive paths.

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