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[54] **TRANSPARENT ANTI-STATIC DEVICE**

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[52] **U.S. Cl.** **161/43,** 161/44, 161/45, 117/211, 117/217, 52/171, 102/105

[51] **Int. Cl.** **B32b 1/04,** H05b 33/28

[58] **Field of Search** .... 117/211, 217, 71 R; 52/171; 102/105; 161/44, 45, 41, 43

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[57] **ABSTRACT**

A transparent anti-static device having a generally transparent electrically conductive metal film on a substrate with a silicon monoxide film superimposed on the conductive film to eliminate buildup of static electricity. The coating can be deposited on a transparent substrate such as glass or plastic on, as an example, a window or safety shield, thereby permitting observation through the substrate of a tool or explosive being processed.

2 Claims, 6 Drawing Figures

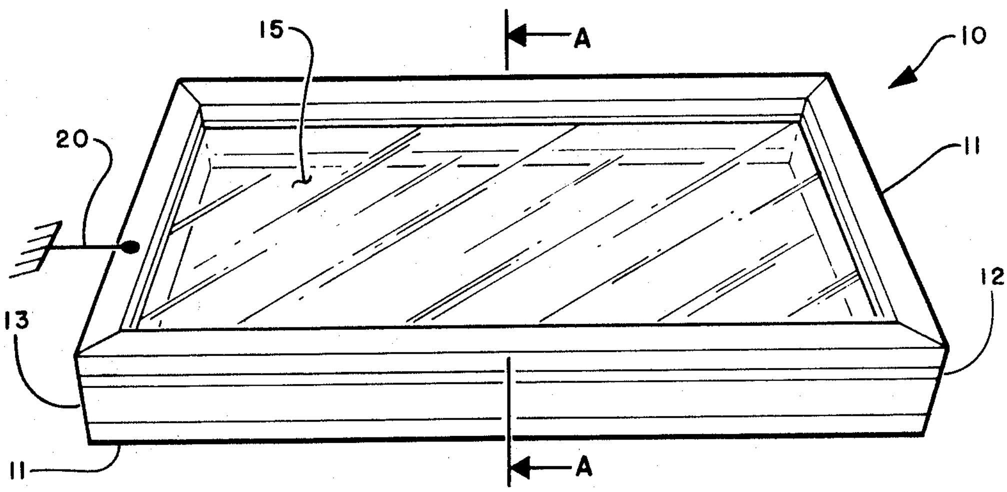


FIG. 1

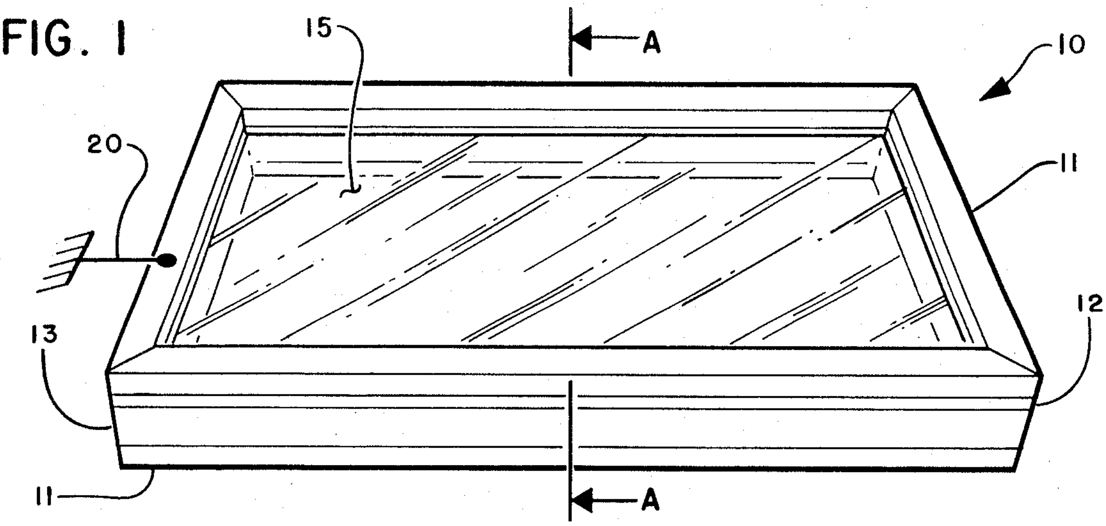


FIG. 2

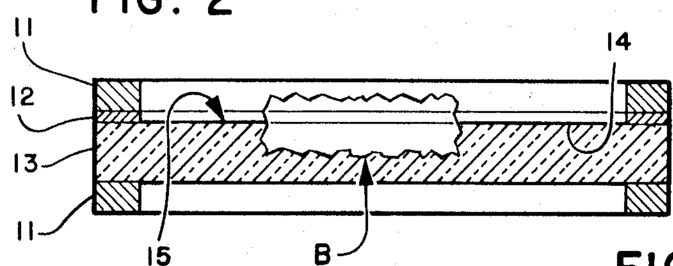


FIG. 3

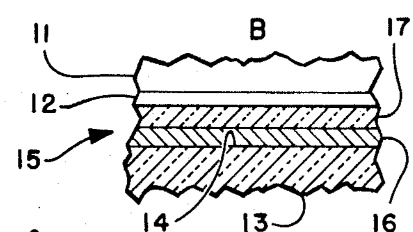


FIG. 4

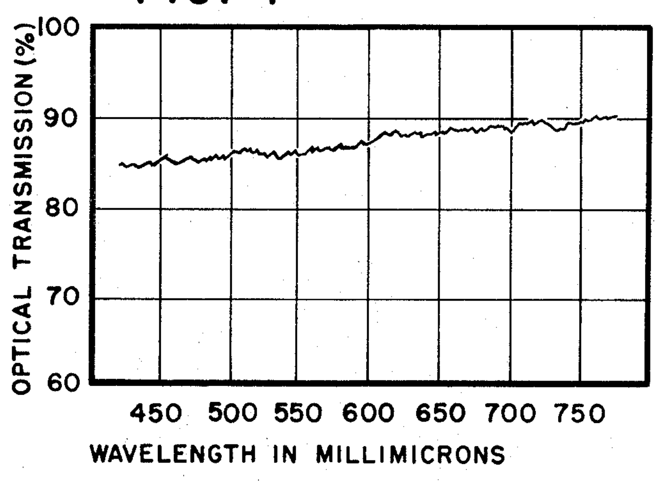


FIG. 6

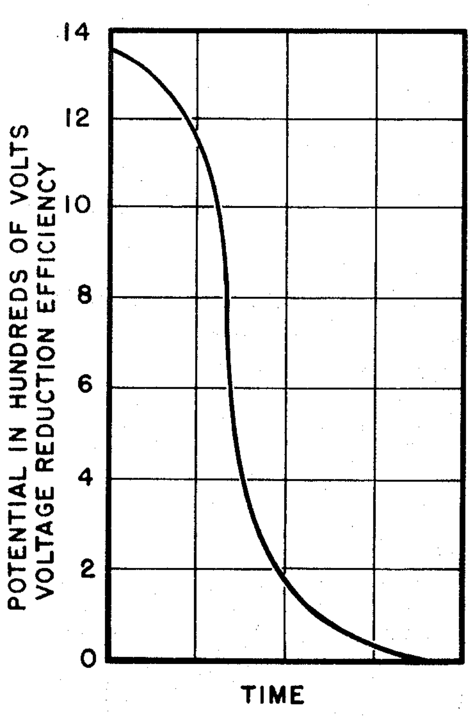
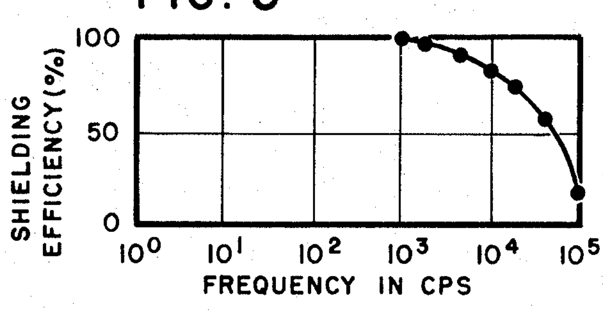


FIG. 5



TRANSPARENT ANTI-STATIC DEVICE

BACKGROUND OF INVENTION

A cause of many accidental detonations of primary explosives has been proven to be high sensitivity to static electricity. A source of static hazard is the highly nonconductive plastic and otherwise transparent materials used in operational shields in explosive handling processes. These materials, such as copolymers of polymethacrylate and ethylacrylate, i.e., arcylic plastics, and also polycarbonate plastics, can accumulate up to 15,000 volts on their surface and can easily supply enough energy to cause detonations of explosive agents such as lead azide or lead styphnate. Surface conductivity of present transparent anti-static coatings generally range between a few million ohms to several hundred million ohms per square. Although some of these anti-static materials are presently in use, the desired requirements of optimum safety in a hazardous area, coupled with minimum maintenance, minimum design change requirements and maximum protection are not entirely met and therefore these anti-static materials are not satisfactory. The greatest disadvantage of commercially available transparent anti-static coatings is that they are removed by light wear and abrasion to the treated surface such that the user is never entirely sure if they remain in effect or not, i.e., their use is unreliable unless frequent testing is conducted. Required are permanent, reliable generally transparent anti-static means which permit application to transparent, electrically nonconductive surfaces of windows, shields, or other devices.

SUMMARY OF INVENTION

In view of the above requirements, it is an object of this invention to provide a generally transparent, electrically conductive, permanent coating which may be deposited on an electrically nonconductive material.

It is a further object of this invention to provide a permanent electrically conductive coating which may be applied to devices such as windows, safety or operational shields and still retain transparency for viewing the product being processed.

It is a further object of this invention to provide a permanent anti-static coating which may be applied to various substrates and which will provide an electrostatic field attenuation of better than 99 percent.

It is a further object of this invention to provide a permanent anti-static coating which provides an attenuation of alternating electrostatic fields or electrostatic fields changing in magnitude or polarity with time which exceeds 99 percent up to an equivalent frequency of at least 60 cycles per second.

It is a further object of this invention to provide a coating with an outer protective layer of good scratch or abrasion resistance, and which coating provides a visual indication of coating effectiveness based upon the color of the coating.

Various other objects and advantages will appear from the following description of the invention, and the most novel features will be particularly pointed out hereinafter in connection with the appended claims. It will be understood that various changes in the details, materials and arrangement of the parts which are herein described and illustrated in order to explain the nature of the invention may be made by those skilled in the art without departing from the principles and scope of this invention.

The invention comprises an electrically conductive, transparent, permanent coating of conductive and silicon monoxide layers which may be applied to nonconductors for anti-static electrical protection.

DESCRIPTION OF DRAWING

The present invention is illustrated in the accompanying drawings wherein;

FIG. **1** is a perspective view of an embodiment of this invention.

FIG. **2** is a cross sectional view along line AA of FIG. **1.**

FIG. **3** is an exploded view of an area B of FIG. **2** showing details of this invention.

FIG. **4** illustrates the optical transmission properties of the anti-static coating.

FIG. **5** illustrates the percent shielding efficiency of this invention as a function of the frequency of the applied electrostatic field.

FIG. **6** illustrates the voltage reduction efficiency of a DC or steady static electrostatic field.

DETAILED DESCRIPTION

FIG. **1** illustrates one embodiment of this invention. In FIG. **1,** a window, shield, or other appropriate device **10** is shown which may include a suitable mounting or supporting frame front and rear portions **11,** an electrically conductive gasket **12,** an electrically nonconductive, and preferably optically transparent sheet or substrate **13** which may commonly be of plastic or glass as described below. One of the transmissive surfaces of substrate **13,** such as surface **14** shown in FIG. **2,** may have disposed thereon a generally transparent coating **15** formed in accordance with this invention. The coating **15** and its placement is better shown in FIG. **2** which also better describes or displays the method of assembling the window or other appropriate device **10.** FIG. **3** is an amplified or enlarged view of area B in FIG. **2.** FIG. **3** shows, in exaggerated proportions for the sake of illustration, the surface **14** of the substrate **13** and the positioning of the coating **15** which comprises an electrically conductive metal film **16** and a protective coating **17** which may be a silicon monoxide film thereagainst to provide the desired electrical shielding of substrate **13.**

It has been found that the conductive metal film **16** may be formed from a material taken from the group consisting of nickel and nickel-chromium alloys such as 80% Ni-20% Cr and other alloys thereof to provide the desired conductivity levels to achieve highly effective electrostatic shielding with high levels of optical transmission for the normally nonconductive substrate **13.** The protective thin film **17** may be made of a material which provides an outer protective coating of good durability resistant to abrasion and wear and chemical attack such as to impart permanent characteristics, to the coating **15** and which is substantially optically transparent and of good optical quality. A protective thin film material which exhibits these desired properties has been found to be silicon monoxide at a thickness of from about 500 to about 600 angstroms. Gasket **12** may be made of any suitable conductive rubber material, such as polyethylene plastic filled with carbon black or any type of flexible plastic filled with carbon black or other suitable conductive particles, such as silver particles, which can make electrical contact between film **16** and frame portion **11**, if frame portion **11** is conductive, or directly with grounding means **20**.

Gasket **12** may be eliminated if frame **11** is machined flat to achieve maximum contact with the applied coating **15**. This may be impractical and consequently a soft, compressible and conductive gasket may be used to establish an intimate contact area. Frame portion **11** may also be a conductor or be formed from conductive portions and, since in contact with gasket **12**, may provide the means for charge dissipation to some suitable grounding means **20**. A typical embodiment which has been successfully used with this invention has device **11** being an explosive or operational shield wherein means **20** is electrically connected with said electrical thin film for removing electrical charges therefrom. The substrate **13** may be a suitable plastic such as a copolymer of polymethacrylate and ethylacrylate, i.e., acrylic plastics or also polycarbonate plastics, or a suitable glass. The method of depositing coating **15** on the substrate **13** may vary but vacuum deposition may be used with success. Process parameters are determined by the skill of the operators and the type of equipment available. A typical process for vacuum deposition of the conductive film **16** involves cleaning the substrate **13** used as a target with a suitable alcohol, such as isopropyl alcohol, placing the dried sheet in an appropriate size chamber, evacuating the chamber to a suitable low pressure such as about 5×10^{-4} microns, and vaporizing the material to be deposited (using a tungsten filament or the like) to a thin film thickness of from about 30 to about 40 angstroms on the target substrate **13**. Preferably the thin film coating thickness and feed rate may be selected such as by typical automatic or the like controls, to achieve the desired coating properties of electrical conductivity, optical transmission, strength and reliability without being severely affected by outgassing of substrate **13** during application of the coatings.

The protective thin film **17**, such as silicon monoxide film, may then be vacuum deposited using granular silicon monoxide suitably disposed in the deposition chamber. Preferably, the thin film thickness **17** may be deposited over electrically conductive thin film **16**, such as by automatically controlling the process in a manner known in the art, to a thickness between about 500 and about 600 angstroms of silicon monoxide. Total coating **15** thickness may therefore typically vary between 530 and 640 angstroms. It has been found that 35 angstroms of vaporized 80% Nickel—20% Chromium material produces a film which will attenuate a steady state electrostatic field by at least 99.99 percent while transmitting between 75 and 90 percent light in the optical spectrum (400 to 800 millimicrons). This typical film exhibits a surface resistivity of about 100,000 ohms per square. Surface resistivity is a constant for all systems of measurement of area where the width and length of the area being measured are equal, i.e., a square. Consequently, a unit of area is not specified since surface resistance will be identical for a given material regardless of the designation as ohms/per square inch, per square foot, etc.

The surface resistivity figure of 100,000 ohms per square applies to the finished coating which includes an overlay of silicon monoxide which itself is nonconductive. The actual metal film may have a surface resistivity much lower than 100,000 ohms per square. If a heavy layer of silicon monoxide were used, the surface resistivity value may be well above the 100,000 ohms per square. The 500 to 600 angstrom thick silicon monoxide film provides a highly transparent overlay for protection of the metallic film and possesses excellent optical properties with no detectable aberration. FIG. **4** illustrates the optical transmission properties of a typical coating of these materials and thicknesses for which there was an optical transmission average of approximately 87%.

The normal outgassing of the nonconductive plastic substrate (passage of gas molecules from the plastic to air) does not interfere with the coating which is of sufficient thinness not to inhibit the slow leakage of gas therethrough and, consequently, virtually preventing formation of gas bubbles or disbonds at the coating substrate interface. Any desired substrate materials, as enumerated above and others, may be used with this invention except for those materials having such a high outgassing rate which may raise problems in achieving the required vacuum to vacuum deposit the desired layers and with subsequent degradation of deposited layers.

The use of protective coating **17** imparts permanent characteristics to the coating **15** such as to resist abrasion, wear, chemical attack, etc. Further, the protective coating generally has a tinge or hue such that cursory visual examination quickly reveals if the coating has been damaged. This is especially critical when working with explosives and reduces prior extensive inspection requirements. If the coating has been damaged, the color or hue of the thin film **17** will be different and be visually evident.

Coating thickness may affect the final electrical conductivity of the deposited metal film and the protective effects of the silicon overlay. Nickel, or an 80% Nickel 20% Chromium alloy, may be selected as a suitable metal because its function of thickness versus conductivity is more linear than many other metals having practical boiling points. The temperature of the target during and after the vacuum deposition process may also be important as affecting electrical conductivity properties. Since high temperatures may tend to agglomerate the metal grains, thereby reducing the conductivity but not significantly altering the optical properties, all possible steps to minimize temperature elevation should be taken.

A major advantage of this invention is the Faraday Cage action provided by the coating around the solid substrate to which it is applied. Faraday action is the shielding effect which attenuates or reduces the strength of an electrostatic or electromagnetic field through the material. Since the coating conductive, excellent anti-static properties are present also. FIG. **5** shows that the frequency response of a safety shield using this coating is high enough to provide adequate protection against 60 cycle radiation and also against changes in field strength arising from mechanical movement.

The electrostatic shielding efficiency is measured by placing the coated plastic or coated glass between a source of static electricity, such as a metal plate charged to the indicated voltage, and the probe of an electrostatic voltmeter. The drop in potential, which is the result of the invention herein described being placed in front of the metal plate, is recorded on a chart and the efficiency is determined. As an example, metal screen with 14 wires per inch will typically attenuate an electrostatic field by 99.6%. Further testing using this invention, at equal and higher voltages showed the electrostatic shielding efficiency to be in excess of 99.99%. The results of this testing are shown in FIG. **5.** This means that a source of static electricity representing 1,000 volts on the operator side of the shield will be reduced to less than 0.1 volt on the other side of the shield. FIG. **6** illustrates the drop in steady static field strength when the invention is used, or shielding efficiency in regard to nonchanging fields.

The coating may be readily checked visually by noting the uniformity of the light brown tint of coating **15,** and also electrically with a volt-ohmeter. If the coating should be removed on some areas of the operational shield due to excessive friction, abrasion, etc., it will show up as a light patch which can be confirmed by a volt-ohmeter. The coated side may be placed facing the explosive or other material being protected from static electricity. Friction on the uncoated side will produce static electricity but this cannot penetrate the coating due to its Faraday effect.

Although the primary description throughout the specification has been of a transparent substrate, with a transparent anti-static coating, this invention is not limited to transparent substrates and may be used wherever an anti-static coating is required and to which this invention may be suitable. As such, this invention could also be used on opaque materials as well as transparent substrates. Although a coating may be used on both sides of the substrate, the optical qualities would be reduced, i.e., less visibility, greater light reflections, etc. Further a coating on both sides would form an excellent capacitor, i.e., two conductive surfaces separated by an insulator. If the ground connection on one side were to be accidentally disrupted, a large quantity of energy could be stored in the "capacitor" producing a great hazard. A one sided coating cannot produce this effect.

A particularly successful application of this invention has been its usage on operational shields in explosive handling processes. This use has effectively eliminated premature detonation of explosive agents such as lead azide or lead styphnate due to static electricity discharges resulting from charge buildup on nonconductive surfaces.

What is claimed is:

1. A generally transparent, anti-static window shield for explosive handling apparatus comprising an electrically conductive annular support frame; a planar optically transparent electrically insulative substrate encircled and supported by said support frame; an annular electrically conductive gasket intermediate said frame and substrate; a permanent, optically transparent, electrically conductive film of uniform thickness between about 30 and about 40 angstroms and of about 80% nickel-20% chromium disposed directly on and coextensive with said substrate and intermediate said substrate and said gasket; a permanent, optically transparent, abrasion resistant silicon monoxide film being of uniform thickness of from about 500 angstroms to about 600 angstroms superimposed directly on and coextensive with said electrically conductive thin film intermediate said first mentioned film and said gasket, to protect said electrically conductive film from wear and to provide a visual indication of film state and anti-static properties; and a grounding connector electrically connected with said gasket and with said electrically conductive film for removing electrical charges therefrom.

2. The window shield of claim **1** wherein said films together have between about 75% and about 90% optical transmission, a surface resistivity of about 100,000 ohms per square and an electrostatic field attenuation better than about 99.99%.

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