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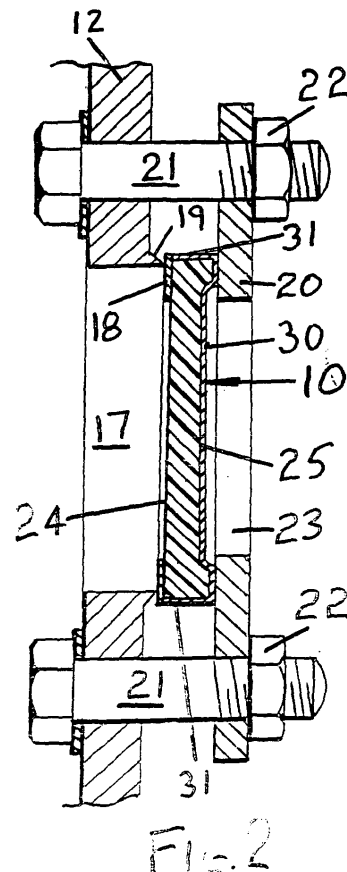
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(54) **Charged particle window, window assembly, and particle gun**

(57) A passivation layer (30) protects an electron beam window (2) from chemical damage by plasma formed by an electron beam (15) entering a chamber (14). The passivation layer (3) additionally protects the electron beam window (2) from arc-discharge damage by providing an electrical path to structures (12)



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## Description

**[0001]** This invention relates to an improved window for transmitting charged particles to a particle gun, a window assembly, and to a particle gun provided therewith. The term "charged particle" is used to include high-energy electrons, other charged particles and ionised neutrals. The invention is particularly, but not exclusively, concerned with an electron gun window for transmitting an intense electron beam, an electron window assembly, and an electron gun provided therewith.

**[0002]** It is desirable to transmit high energy electrons from an electron source in a high vacuum chamber, through an electron beam window, into a higher pressure environment. The electron beam window needs to be mechanically robust to withstand the force generated by the pressure difference between the high vacuum chamber and the higher pressure environment, whilst being thin enough to prevent too much attenuation of the electron beam. It is also desirable to transmit charged particles through a gas tight interface.

**[0003]** The unique properties of chemical vapour deposition (CVD) diamond, particularly its relative transparency to electrons, its high strength, and its high thermal conductivity, make it an ideal material to form a window for transmitting charged particles into a chamber containing a gas in which a plasma may be generated.

**[0004]** Diamond has many attractive properties for the formation of an electron beam window, but we have discovered that it is damaged when a plasma is produced by the interaction of the transmitted electron beam and gas. The plasma reacts chemically with the diamond which is progressively ablated, or etched, thereby thinning the window which will eventually fail mechanically under the pressure difference across it. We have also discovered that plasma can generate a significant electrical charge on the downstream face of the window. This electrical charge can cause an arc-discharge which can punch a hole through the window. In our co-pending patent application number (reference XA2047 the content of which is incorporated herein by reference), we have identified another cause of damage to windows formed from an insulating material, such as diamond, by arc-discharge caused by the transmission of an intense electron beam. The electrical charge which is generated by a plasma on the downstream face of the window will, of course, interact with any electrical charge generated on the window by the passage of an intense electron beam.

**[0005]** Although we are particularly concerned with windows formed of CVD diamond, we believe that this invention could also be useful with any window formed from an appropriate insulating material, or of material having low conductivity. In addition to the transmission of an electron beam, the window may be used in any system requiring an electron or ion interface between two media, for instance the interface between an ion source and the experimental chamber in an ion beam system, or between an electron source and workpiece for non-

vacuum electron beam welding.

**[0006]** According to one aspect of the invention a window, for transmitting charged particles into a chamber where a plasma will be generated, has a passivation coating on a window surface to protect it from etching by the plasma, the passivation coating being sufficiently thin that it will not significantly impede the passage of charged particles through the window.

**[0007]** In the case where the window is formed from an insulating material, the passivation coating is preferably electrically conductive to dissipate any electrical charge generated by the passage of the charged particles through the window or by the plasma. The window is preferably made of diamond which may be formed by chemical vapour deposition.

**[0008]** The passivation coating may have a thickness of between 5 nm and 100 nm. Preferably the passivation layer has a thickness of approximately 8 nm to 20 nm. The passivation layer is preferably formed from a highly inert metal or compound having a high atomic number. The passivation layer may include a material chosen from the group comprising indium tin oxide, aluminium, magnesium, titanium, platinum, gold and silicon dioxide doped to make it electrically conductive, more preferably aluminium. The layer may be formed by vacuum deposition.

**[0009]** According to another aspect of the invention, a window assembly is formed by attaching a window, having any of the features detailed above, over an aperture defined by an electrically conductive mounting plate such that the window covers the aperture, and an hermetic seal is positioned between the window and the plate. Preferably the passivation layer is connected to the plate thereby providing an electrical connection between them.

**[0010]** According to another aspect of the invention, a particle gun, arranged to produce charged particles within a vacuum chamber and to direct the charged particles through a window into a region of higher pressure where a plasma will be generated, has a surface of the window facing the region of higher pressure which is protected from etching by the plasma by a passivation layer which is sufficiently thin that it will not significantly impede the passage of the charged particles through the window.

**[0011]** The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a diagrammatic longitudinal section through an electron gun illustrating the position of its electron beam window;

Figure 2 is an enlarged section illustrating the mounting of one form of electron beam window to a support structure within the electron gun shown in Figure 1, and

Figure 3 is an enlarged section, similar to Figure 2, illustrating the mounting of another form electron beam window to a support structure within the elec-

tron gun shown in Figure 1.

**[0012]** With reference to Figure 1, an electron beam window 10 is positioned inside a typical electron gun 11 with its periphery supported by a structure 12 which connects a vacuum chamber 13 to a chamber 14 that is to receive an electron beam 15 from an electron beam generator 16. The vacuum chamber 13 is evacuated to generate a vacuum of typically  $10^{-6}$  mbar. The chamber 14 defines a region of higher pressure, as is well known in the art, the electron beam window 10 serving as a physical barrier to preserve the pressure difference between the chambers 13 and 14. Consequently, the electron beam window 10 must withstand a force equal to its cross sectional area multiplied by the pressure difference between chambers 13 and 14, this force being transmitted to the structure 12.

**[0013]** Figures 2 and 3 illustrate the mounting of the electron beam window 10 to the structure 12 in much greater detail. The structure 12 is a cast web of stainless steel formed with a cylindrical orifice 17 through which the electron beam will pass towards the electron beam window 10. An annular copper sealing gasket 18 is trapped between the electron beam window 10 and an annular edge 19 formed integral of the structure 12.

**[0014]** In order to withstand the force created by the differential pressure across the electron beam window 10, a bracket 20 is slidably mounted on an array of stainless steel bolts 21 and is urged against the electron beam window 10 by corresponding lock-nuts 22. The arrangement illustrated is diagrammatic and the actual mounting of the window would generally include a compliant member positioned between the bracket 20 and the electron beam window 10. The bracket 20 is formed with a central aperture 23 to allow free passage of the electron beam. As the heads of the bolts 21 are within the vacuum chamber 13, they are provided with respective copper sealing washers as shown. If desired, the bolts could instead engage blind threaded bores in the structure 12. In both Figure 2 and Figure 3, the electron beam window 10 is formed from diamond by chemical vapour deposition as this is much less costly than using natural diamond. Various methods are known for the synthetic production and shaping of the diamond. For instance, US Patents 5,264,071 and 5,349,922 teach the production of monolithic diamond sheet by passing a mixture of hydrogen and a hydrocarbon at a high temperature over a cooled substrate on which diamond is deposited. The CVD diamond may be single crystal or polycrystalline, the latter being more available.

**[0015]** The electron beam window 10 comprises a cylindrical disk of polycrystalline diamond which has been ion beam etched to define a thinner pane, as shown, for the passage of the electron beam 15. The thickness of the pane is sufficient to withstand a predetermined pressure differential across it and is typically between 25 microns and 5 microns, and is preferably about 10 microns. In this manner, the electron beam window 10 defines a

first surface 24 for receiving a high energy electron beam 15, and a second surface 25 for transmitting the electron beam into the higher pressure chamber 14.

**[0016]** As previously stated, the passage of the high energy electron beam 15, through the electron beam window 10, into the higher pressure chamber 14 will develop a plasma in chamber 14 dependent on the nature of the environment within the chamber 14. A plasma produced by the interaction of the electron beam 15 with gas in the chamber 14 will react chemically with the diamond electron beam window 10. As a result, the surface 25, together with associated diamond surfaces exposed to the plasma, will be etched, or ablated, with the result that the electron beam window 10 will become progressively thinner until such time as the window 10 will fail mechanically under the pressure difference across it. Furthermore, the plasma in the higher pressure chamber 14 can also generate a significant electrical charge on the surface 25, and this charge can increase until it attains a value that will generate an arc discharge either through the electron beam window 10, or from the electron beam window 10 to the structure 12.

**[0017]** As shown in Figure 2, the diamond electron beam window 10 is protected, from erosion or ablation by the plasma, by the provision of a passivation coating 30 which extends over the surface 25 thereby forming a physical barrier preventing chemical interaction between the plasma in chamber 14 and the diamond forming the electron beam window 10. Preferably, the passivation coating 30 includes a cylindrical portion 31 which also protects the exposed circumference of the electron beam window 10.

**[0018]** The passivation coating 30, 31 is preferably also made electrically conductive so that any electrical charge from the plasma is dissipated to the structure 12, thereby preventing the build up of any destructive electrical charge on the electron beam window 10.

**[0019]** It is important that the passivation coating 30, 31 is sufficiently thin that it will not significantly impede the passage of electrons through the electron beam window 10. We have found that a passivation coating with a thickness of between 5 nm and 100 nm gives good results, the preferred thickness being between 8 nm and 20 nm. We have also found that the passivation coating 30, 31 is best formed from a highly inert metal, or compound, having a high atomic number, our preferences being aluminium, magnesium, titanium, platinum, gold, silicon dioxide (if desired, doped to make it electrically conductive), and indium tin oxide.

**[0020]** The passivation coating 30, 31 is desirably multi-layered, for example, with a titanium layer adhered to the window 10 to enhance adhesion and electrical contact, and covered by an aluminium layer to provide the bulk of the electrical conductivity. Each layer may be adhered to the surface 25 by any process known in the art. With an aluminium layer, vacuum deposition or sputtering is convenient.

**[0021]** The material used for forming the passivation

layer 30, 31 should have a low attenuation coefficient for high energy electrons (that is ideally to have a low atomic number), a high electrical conductivity when less than 1000 nm thick, be capable of deposition onto diamond with a minimal amount of stress but with adequate adhesion, be realisable onto planar and non-planar diamond surfaces, and be compatible with mounting of the diamond electron beam window 10 to a suitable frame or support 12 such that the passivation coating 30, 31 is electrically grounded. From Figure 2 it will be noted that the passivation coating 30 is in direct electrical contact with the bracket 20.

**[0022]** With reference to Figure 3, it will be noted that the passivation layer surrounds the electron beam window 10, the surface 25 being covered by the portion 30, the periphery by the portion 31 and the surface 24 by a portion 32. In this manner the surfaces 24 and 25 are simultaneously grounded to the structure 12, thereby preventing the build up of any electrical charge between the surfaces 24 and 25.

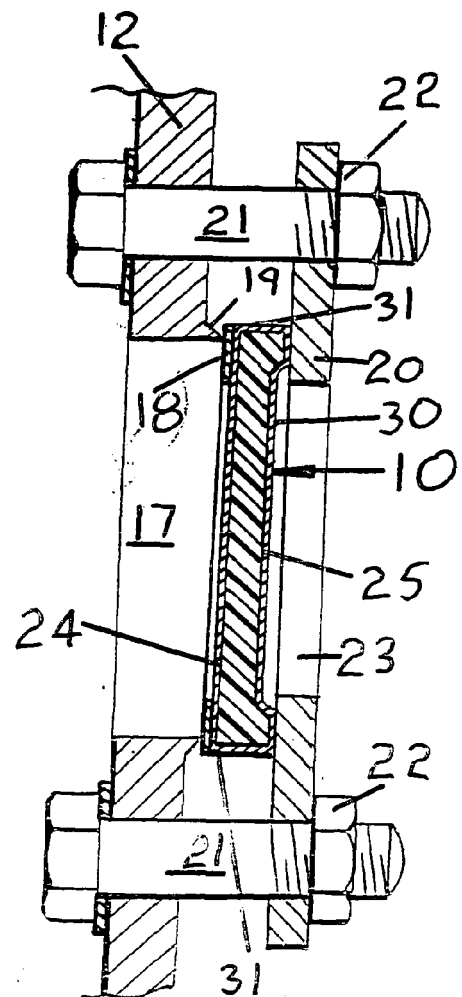
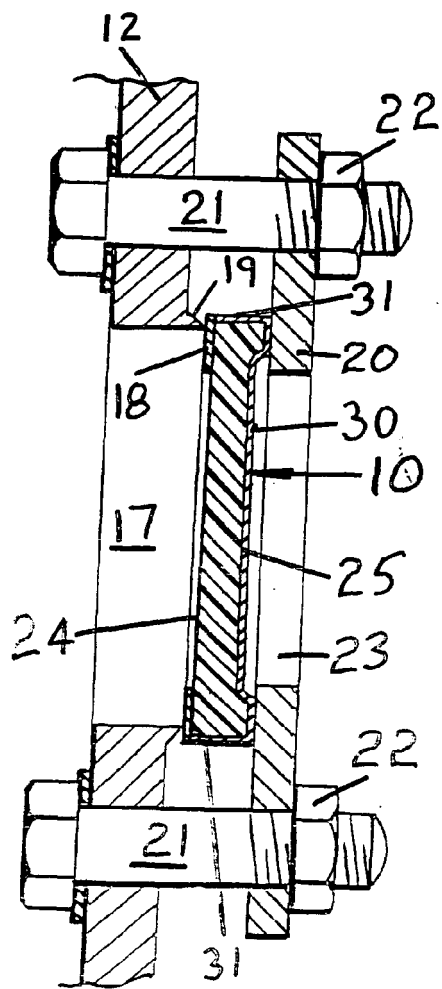
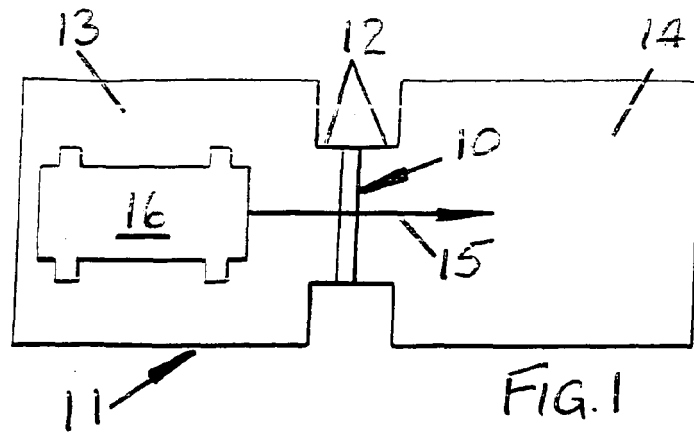
**[0023]** Reference is again made to our co-pending patent application number (reference XA2047) which teaches the protection of an electron beam window from damage by an electrical field that can be generated across the thickness of the window by the transmission of the electron beam 15. The embodiment shown in Figure 3 provides similar protection but additionally protects the electron beam window 10 from chemical attack by plasma in chamber 14, and prevents the build up of an electrical charge on the surface 25 by the plasma.

**[0024]** The electron beam window 10 is preferably part of an electron beam assembly (not illustrated) which incorporates an electrically conductive mounting plate defining an aperture, the electron beam window being positioned over this aperture, and an hermetic seal being formed between the electron beam window and the mounting plate. In use, this electron beam assembly would be positioned over the orifice 17 and secured to the structure 12 by any convenient means, such as the bolts 21 and lock-nuts 22. The mounting plate would, of course, need to be sealed to the structure 12 and this can be achieved by arranging a copper gasket between them. The hermetic seal must be electrically conducting and can take the form of a mechanical seal, an adhesive, solder, or brazing securing the window 10 to the mounting plate. The passivation coating 30, 31, 32 is preferably formed over at least part of a surface of the mounting plate to provide electrical continuity.

**[0025]** This invention enables diamond electron beam windows to be used for transmitting electron beams having a significantly higher intensity than hitherto. The electron beam windows may be of any convenient shape or geometry, for instance curved or part of a spherical shell presenting a convex face towards the higher pressure domain so that the diamond is always subjected to a compressive force. The electron beam window may incorporate supports and/or coolant means as are already known in the art.

## Claims

1. A window, for transmitting charged particles into a chamber where a plasma will be generated, having a passivation coating on a window surface to protect it from etching by the plasma, the passivation coating being sufficiently thin that it will not significantly impede the passage of charged particles through the window.
2. A window, according to Claim 1 and formed from an insulating material, in which the passivation coating is electrically conductive to dissipate any electrical charge generated by the passage of the charged particles through the window or by the plasma.
3. A window, according to Claim 2, made of diamond.
4. A window, according to any preceding claim, in which the passivation layer has a thickness of between 5 nm and 100 nm.
5. A window, according to Claim 4, in which the passivation layer has a thickness of between 8 nm and 20 nm.
6. A window, according to any preceding claim, in which the passivation coating is formed from a highly inert metal or compound having a high atomic number.
7. A window, according to any of Claims 1 to 5, in which the passivation layer includes a material chosen from the group comprising indium tin oxide, aluminium, magnesium, titanium, platinum, gold and silicon dioxide doped to make it electrically conductive.
8. A window assembly formed by attaching a window, according to any one of the preceding claims, over an aperture defined by an electrically conductive mounting plate such that the window covers the aperture, and an hermetic seal is positioned between the window and the plate.
9. A window assembly, according to Claim 8, in which the passivation layer is connected to the plate.
10. A particle gun, arranged to produce charged particles within a vacuum chamber and to direct the charged particles through a window into a region of higher pressure where a plasma will be generated, in which a surface of the window facing the region of higher pressure is protected from etching by the plasma by a passivation layer which is sufficiently thin that it will not significantly impede the passage of the charged particles through the window.





| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                   |                                                   |                                             |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                   |                                                   |                                             |
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| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                                                                   |                                                   |                                             |

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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