April 25, 1967 C. W. HANKS 3,316,468

VIEWING METHOD AND APPARATUS FOR HIGH VACUUM SYSTEMS

Filed May 3, 1963 2 Sheets-Sheet 1

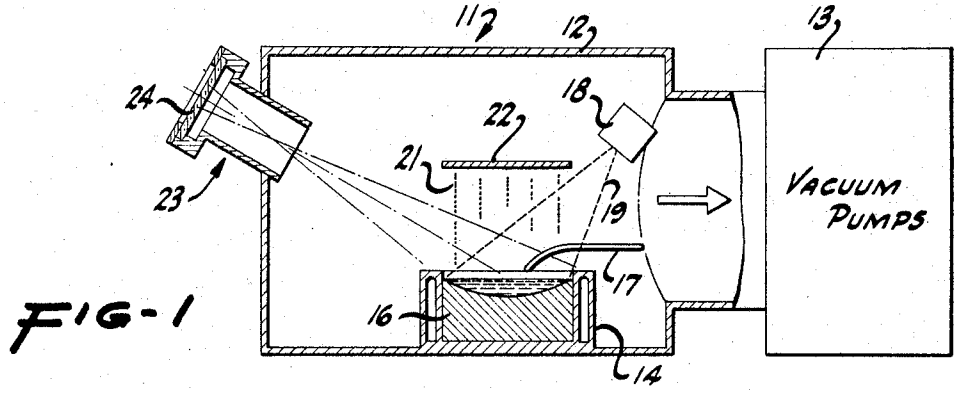


FIG-1

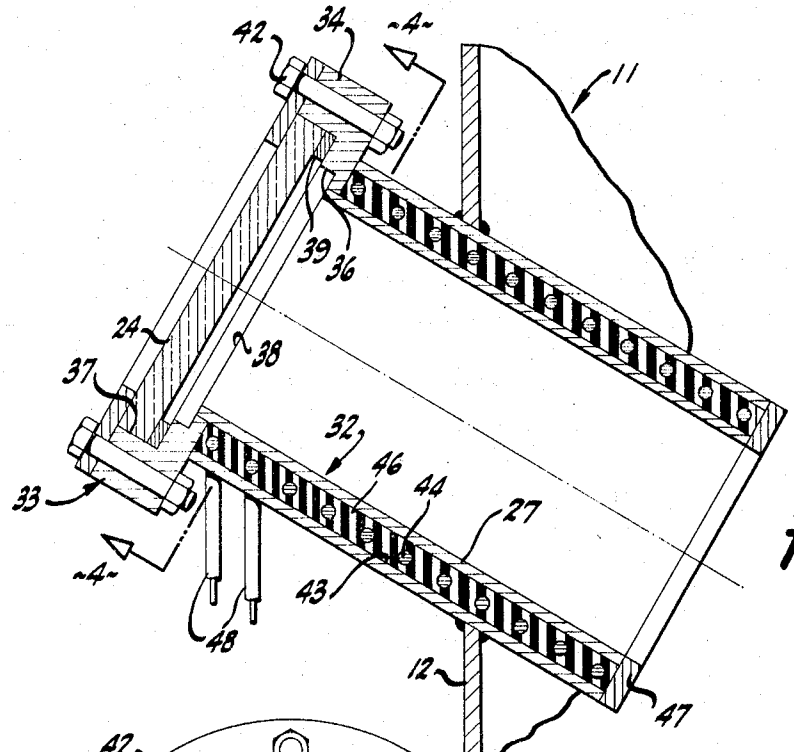


FIG-3

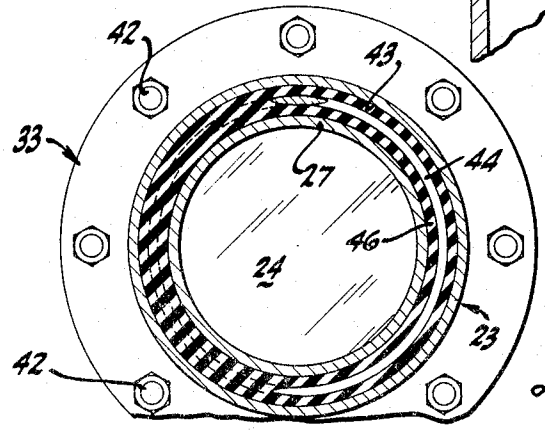


FIG-4

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VIEWING METHOD AND APPARATUS FOR HIGH VACUUM SYSTEMS

Filed May 3, 1963 2 Sheets-Sheet 2

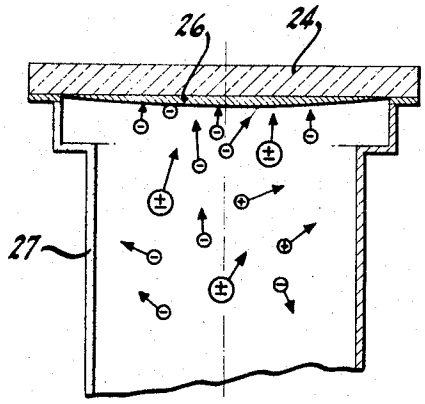


FIG-2a

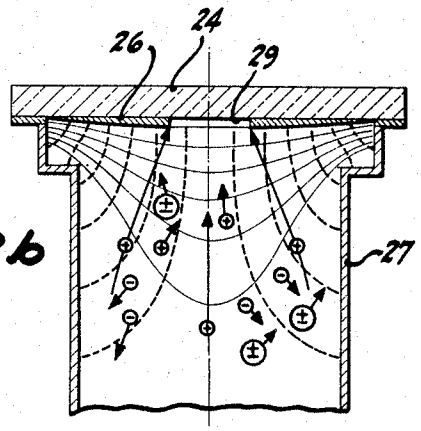


FIG-2b

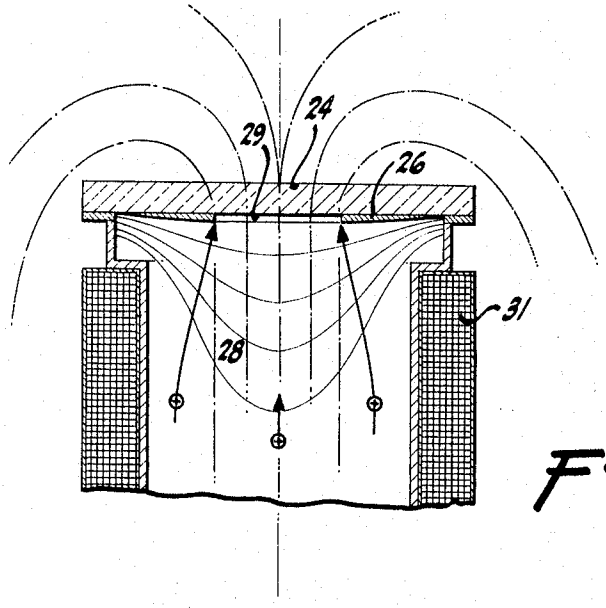


FIG-2c

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VIEWING METHOD AND APPARATUS FOR HIGH VACUUM SYSTEMS

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7 Claims. (Cl. 317—262)

The present invention relates generally to the unobscured viewing of high vacuum system interiors wherein substantial quantities of condensable vapor are present which would normally tend to deposit upon and cloud interior surfaces of viewing ports or the like provided in the walls of the system. The invention is more particularly directed to a viewing method and apparatus for cleaning deposited vapor from a viewing port with constituents inherently existing in the vacuum system whereby observation of the system interior through the port is facilitated without introduction of extraneous matter into the system which might adversely affect the completion of various processes therein.

It is well known that considerable difficulty is normally encountered in satisfactorily viewing the interior of high vacuum chambers wherein condensable material is evolved. This is due to the unavoidable dispersion of vapor molecules in a vacuum system and the consequent condensation of the vapor upon the interior walls, and the like, of the vacuum system. Windows or other viewing apparatus installed in the walls of such systems are consequently likewise subjected to the deposition of vapor molecules thereon and become clouded in a relatively short time with the result that vision through the viewing apparatus is obscured. The foregoing problem is particularly prevalent in high vacuum furnaces for the melting and casting of metals, or the like, under high vacuum, and wherein various high vacuum vapor deposition processes are advantageously conducted. It will be appreciated that where, for example, a light metal such as aluminum is heated in a high vacuum furnace to temperatures commensurate with vaporization of the metal in copious quantities for coating a substrate of another material therewith, any viewing windows in the vacuum system in very short order are coated to the extent that they become mirrors in effect and are thus wholly unsuited to viewing purposes. Although the effect may not be quite as extensive where other materials are processed or other operations are conducted in a high vacuum furnace, vapor deposition on viewing apparatus is still sufficiently great as to prevent adequate observation of the interior of the vacuum chamber.

Heretofore, various types of viewing apparatus and methods have been proposed to cope with the foregoing problem. Past approaches to the problem, however, have generally entailed the provision of streams of air or gas flowing across the interior surface of viewing ports or the like to prevent the vapor molecules from impinging upon the surface through collision processes therewith. Where the gas streams are heavy, such a mechanism cannot be satisfactorily employed in a high vacuum system inasmuch as the introduction of gas thereto is quite incompatible with the maintenance of a high vacuum. In distinction to these types of prior art approaches, there has also been advanced the novel method of viewing the interior of vacuum chambers disclosed and claimed in the copending patent application of Charles d'A. Hunt, Ser. No. 140,750, entitled, "High Vacuum Observation Method," now Patent No. 3,170,383, and assigned to the same assignee as the present application. As regards this method of viewing, it is briefly noted that an elongated viewing tube is provided extending from a viewing window into a vacuum system interior, and gas is introduced

into the tube to establish molecular collisions whereby vapor molecules are condensed upon the walls of such tube and are thus prevented from impinging the surface of the window. The tube is of limited cross-section in proportion to its length to insure sufficient gas concentration for the requisite collision processes while at the same time limiting the flow of the gas into the vacuum system. The introduction of extraneous gas to the vacuum system is thereby of relatively low order, and can be tolerated in most metal melting, casting and coating processes, or the like, conducted under high vacuum conditions. However, there are still other processes where the introduction of even an extremely minute amount of gas to the vacuum system is detrimental. This is particularly so in various vapor plating processes where the efficiency thereof is dependent upon the maintainment of a very long mean free path of the vapor molecules to be deposited upon the material to be coated. The existence of even a minute quantity of extraneous gas in the vacuum system may sufficiently reduce the mean free path that an untenable number of vapor molecules experience collisions before depositing upon the material to be coated and are thereby deflected from the material and lost to the vacuum system. In other words, the efficiency with which the vapor is desirably deposited is reduced and under some circumstances cannot be tolerated. Accordingly, under the foregoing, as well as other vacuum system operations, advantages are to be gained where viewing of the vacuum system interior can be accomplished without the introduction of extraneous gas to the system, even in minute quantities.

In accordance with the present invention, viewing of the interior of a vacuum system through a viewing port or window is facilitated without the use of gas or any other matter not already inherently existing within the vacuum system. In this regard, it will be appreciated that in addition to neutral vapor molecules being present in a vacuum system, particularly one wherein vapor deposition processes or other metal melting or casting operations are performed, some of the vapor is in an ionized state; that is, in the form of ions and free electrons. Thus, vapor molecules, ions and free electrons are coexistent in vacuum systems of the type with which viewing in accordance with the invention hereof is contemplated. According to the invention, these inherently existing ions are employed to bombard the interior surface of a viewing window, or the like, to thereby evaporate and hence clean vapor molecules therefrom, and provide an unobscured field of view through the window of the interior of the vacuum chamber. In the accomplishment of the foregoing, a method is provided according to which there is established an electrostatic field emanating from a viewing window which serves to accelerate ions inherently existing in the vacuum system upon the interior surface of the window. The accelerated ions bombardment clean deposited vapor molecules from the window. The field is generated by establishing a negative charge at the interior surface of the window, preferably by impinging upon the window free electrons inherently existing in the vacuum system. The electrostatic field of the present invention is advantageously of a configuration to convergently focus the accelerated ions upon the window and thereby provide a concentration of ions at a central region of the window which is sufficiently great to insure complete cleaning of vapor molecules therefrom. The method further contemplates, however, the controlled defocusing of the accelerated ions to effect enlargement of the area of window surface cleaned commensurate with the concentration of ions existing in the vacuum system. In this regard, there may be further provided as a step of the method, the ionization of vapor molecules in a confined region adjacent the interior surface of the viewing window, and in-

cluding the field, by collisions between the molecules and free electrons and ions in such region. For each collision, an additional ion and free electron are produced and accordingly the ionization action becomes to some extent cumulative. The concentration of ions in the region of the accelerating field is thus increased and moreover, the molecules which were ionized in producing the ions are no longer potentially condensable upon the viewing window surface. The invention also provides preferred apparatus with which the method may be conducted; however, various alternative apparatus may be likewise employed in the conduct of said method. In the preferred apparatus, a transparent viewing port is secured in closing relationship to one end of a metallic viewing tube which encompasses and defines a viewing path extending from the window into the interior of a vacuum chamber. In order to facilitate generation of an electrostatic field of the type contemplated by the method for accelerating and focusing the ions, means are provided for insulating the interior surface of the window from the adjacent end of the viewing tube, and such tube is maintained at ground potential, for example. Such structural configuration in addition to facilitating the establishment of an electrostatic field of the desired configuration, also defines a confined region adjacent the interior surface of the window within which cumulative ionization may be accomplished to optimize the window cleaning process. The apparatus may further include a solenoid concentrically disposed about the viewing tube, or equivalent means for generating a magnetic field which may be employed to controllably defocus the accelerated ions in accordance with the method.

The present invention is illustrated as to the method and a particular embodiment of the apparatus thereof in the accompanying drawings, wherein:

FIGURE 1 is a schematic illustration in sectional view of a high vacuum plating furnace having viewing apparatus in accordance with the present invention mounted therein,

FIGURE 2, portions *a*, *b*, *c*, illustrate various steps of the method of the invention as conducted in the environment of the furnace of FIGURE 1 to facilitate unobscured viewing of the furnace interior through the viewing apparatus employed therewith,

FIGURE 3 is a diametric sectional view on an enlarged scale through the viewing apparatus, and illustrating the structural details thereof, and

FIGURE 4 is a sectional view taken at line 4—4 of FIGURE 3.

Referring now to FIGURE 1, there will be seen to be provided a vacuum plating furnace **11** which is herein presented as an exemplary setting with respect to which the present invention may be conveniently described. It is to be noted, however, that the present invention is in no way limited to use in this form of physical embodiment, inasmuch as equivalent environmental conditions exist in vacuum furnaces for other purposes, and elsewhere, which are suited to employment of the present invention therewith.

As regards the plating furnace **11**, same will be seen to include a vacuum chamber **12** communicated with vacuum pumps **13** for evacuating the chamber to high vacuum, for example, of the order of one micron of mercury or less. Within the chamber there may be provided a water-cooled crucible **14** containing an ingot **16** of refractory metal, for example, and adapted to be heated at the top thereof to raise the temperature of this upper surface to a sufficient level for the melting and vaporization surface of the ingot **16** may be accomplished as by means thereon as in the form of a wire **17**. Heating of the upper surface of the ingot **16** may be accomplished as by means of an electron gun **18** directing one or more high energy electron beams **19** thereon. The vaporized material rises from the crucible as indicated by the arrows **21**, with the major portion thereof being deposited upon the under surface of a suitable substrate **22** appropriately positioned in overlying relation to the crucible. Such vapor condenses on the under surface of the substrate to thus form a coating thereon in accordance with known practices, and moreover the substrate may be moved over the crucible if desired to accomplish a continuous plating process.

It is frequently desirable to observe areas of interest within the vacuum chamber **12**, for example, the top of the crucible **14**, from the outside of the chamber. To this end, it is the common practice to provide viewing apparatus mounted in a wall of the chamber **12** including a viewing window or port for providing a field of vision extending from the exterior of the chamber to the area of interest interiorly thereof. As depicted in FIGURE 1, viewing apparatus **23** is provided for this purpose, and such apparatus is adaptable to the conduct of the method of the present invention. For present purposes, it suffices to state that such apparatus includes a viewing window or port **24** which has an interior surface exposed to the interior of the vacuum chamber **12** and accordingly which is subjected to the environmental conditions existing therein. In this regard, it will be appreciated that not all of the vapor molecules rising from the top of crucible **14** impinge the overlying substrate **22** as indicated by the arrows **21**, many of these molecules bypassing the substrate and randomly moving throughout the interior of the chamber. These molecules, of course, condense upon interior surfaces of the vacuum chamber **12**, including the exposed interior surface of the viewing port **24**. As a result, such interior surface of the viewing window is coated by the vaporized material deposited and condensed thereon, and observation of the interior of the chamber through the window is consequently obscured.

In accordance with the present invention, cognizance is taken of the fact that the interior of the vacuum chamber **12**, or equivalent vacuum system, contains, in addition to the aforementioned vapor molecules, ions and free electrons in substantial quantities which are produced, for the most part, by some of the vapor molecules in the crucible being heated to the extent that they are ionized. In accordance with the method of the invention, the ions inherently existing within the vacuum chamber **12** or equivalent environment, are utilized to good advantage to facilitate cleaning of vapor deposits from the interior surface of a viewing window through bombardment therewith. Such method is now described with reference to FIGURE 2, which depicts a viewing window, for example window **24** of the viewing apparatus **23**, which is exposed to the interior of a high vacuum system. The window may be of a boro-silicate glass, plexiglass or equivalent transparent insulating material, the method being applicable in all cases. It will be noted from portion *a* of FIGURE 2 that the interior surface of the window **24** is covered in the usual manner by a coating **26** of vapor molecules, denoted by the symbol ⊕, randomly moving within the chamber and condensing upon the window surface. To facilitate removal of this coating **26** in accordance with the method, an electrostatic field is established emanating from the coating **26** and of progressively negatively decreasing potential in directions away therefrom. Preferably, the field is established by impinging free electrons, as denoted by the symbol ⊖, existing within the vacuum chamber upon the coating **26** to thus charge same negatively. More particularly, the electrons being of relatively small mass compared to that of an ion, denoted by the symbol ⊕, or a molecule, have substantially greater mobility in their random movement throughout the vacuum chamber. Thus, the number of electrons impinging the coating **26** in any given interval of time is materially greater than that of the ions during the initial stages of the method. Consequently, a substantial negative charge is accumulated on the coating **26** such that same becomes relatively negative with respect to adjacent metallic surfaces, such as the walls of the vacuum enclosure, which are typically

at ground potential. Consequently, an electrostatic field is established therebetween and the lines of force emanate from the coating **26** at the interior surface of the window **24**, the field can be readily established as having a potential that is negatively decreasing in directions away from the coated surface **26**. It should be noted that alternatives are possible in the establishment of a negative charge adjacent the interior surface of window **24**; however, same are somewhat undesirable in that they involve increased complexity of apparatus. For example, the negative charge may be alternatively provided by disposing negatively biased electrode structure adjacent the interior surface of the window. In any event, irrespective of the particular manner in which the negative potential is established at the interior surface of the window, an electrostatic field of the foregoing type is established in accordance with the method of the invention, which field, upon the random movement of ions thereinto, accelerates the ions upon the coating **26**. Substantial heating is produced by the ion bombardment of the coating which in turn evaporates the deposited vapor molecules and cleans same from the interior surface of the window.

The electrostatic field established in accordance with the method of the invention, is preferably of a configuration which is conducive to convergent focusing of the ions accelerated therein. As a result, the density of ions bombarding a predetermined area of the coating **26** may be increased to enhance the cleaning action therein and insure complete removal of the coating. In addition, the cleaning action may be further enhanced by ionizing vapor molecules in a confined region adjacent the coating **26** and including the electrostatic field. Thus, vapor molecules potentially condensable upon the interior surface of the window are reduced and, moreover, additional ions are formed which are accelerated by the field and contribute to the bombardment cleaning process. Additional electrons are likewise produced in the ionization of molecules; and these electrons may serve to ionize additional molecules approaching the interior surface of the window, such that the ionization process becomes cumulative whereby fewer and fewer molecules impinge the window surface and more and more ions are available to bombardment clean the same.

To facilitate the foregoing optimization of the ion bombardment cleaning action, the electrostatic field is preferably of a configuration commensurate with the establishment of equipotential surfaces outwardly bulging from the coating **26** at the interior surface of window **24** in coaxial relation thereto, and of progressively negatively decreasing potential in directions away from the coating. In addition, the field is preferably confined to a spatial region immediately adjacent the inner surface of the window. Such a field is depicted in FIGURE 2*b*, wherein the dashed lines depict electrostatic lines of force, and the full lines depict equipotential surfaces. Such field may be variously provided such as by defining a viewing path, extending away from the window, with an encompassing metallic surface **27**, preferably of tubular or cylindrical form, disposed in perpendicular relationship to the interior surface of the window and insulated therefrom. Inasmuch as charged particles tend to move perpendicularly to the equipotential surfaces, the ions in the confined region **28** of the field are convergently focused in being accelerated by the field to thus impinge a central area **29** of the coating **26** and clean same of vapor molecules. Moreover, electrons are accelerated in the opposite direction by such field in a divergently focused pattern; in other words, in directions away from the window **24** and outwardly towards the metallic surface **27**. Thus, a relatively large cross-section of accelerated electrons moving in directions away from the window is produced, which tends to intercept vapor molecules moving towards the window and accordingly ionize same by collisions therewith. A substantially cumulative ionization process thus results in the region **28** which, as noted hereinbefore, is effective in preventing a substantial number of the vapor molecules from reaching the interior surface of the window and enhances the ion bombardment cleannig action occurring thereat. Although the method as described to this point is effective in cleaning a relatively small central area of the viewing port, in certain instances this is desired over cleaning of the entire surface thereof. For example, where a closed circuit television camera is employed to view the interior of the vacuum chamber, the light emitted from the material heated during processing is so intense that the camera lens must normally be stopped way down. Accordingly, with the lens serving as the viewing port, the method of the invention facilitates cleaning of a small central area of the lens and the surrounding coating serves as the stop.

Where larger areas of cleaned surface of a viewing port or the like are desired, the area of focus of the bombarding ions should be optimumly selected commensurate with the density of ions existing within the region **28** of the electrostatic field and the rate of sputtering which can be produced thereby at the coating. In other words, it is desirable that the area of focus be increased for increased ion densities and/or increased sputtering capabilities thereof such that the area of the cleaned surface **29** can be made as large as possible. Thus, the method of the present invention may advantageously include the further step of controllably defocusing the accelerated ions to produce a focal area at the coated surface of the window **24** of a size commensurate with the maximum area of cleaned surface that can be effected with the available density of ions. Such defocusing of the bombarding ion beam may be variously accomplished; however, a magnetic defocusing is preferred. More particularly, a magnetic field is generated which has lines of force, as depicted by the phantom lines in FIGURE 2*c*, extending through the region **28** in substantially normal relation to the coating **26** at the interior of window **24**. As is well known, charged particles moving in a magnetic field with components of motion both parallel and perpendicular to magnetic lines of force tend to spiral about such lines and, in effect, are bound thereto to some extent. Thus, inasmuch as the magnetic lines of force intersect the coating **26** in substantially perpendicular relation, the convergent focusing action of the electrostatic field is to some extent offset by the tendency of the ions to follow the magnetic field lines. Moreover, the extent to which the ions follow the magnetic lines of force, or are bound thereto, is dependent upon the strength of the magnetic field. Hence, the amount of defocusing of the accelerated ions may be controlled through variation of the strength of the magnetic field as desired to facilitate "matching" of the cleaned surface area **29** of coating **26** to the ion density existing within the region **28**. It is assumed in FIGURE 2*c* that the density of ions in region **28** is somewhat greater than exists in FIGURE 2*b*, and that the strength of the magnetic field is appropriately adjusted in accordance therewith, whereby the area of clean surface shown in FIGURE 2*c* is enlarged over that depicted in FIGURE 2*b*. The generation of the magnetic field, in accordance with the method of invention, may be variously accomplished, as by means of a solenoid **31** concentrically disposed about the metallic surface **27**, and thus about the confined region **28** of the electrostatic field. energized with variable direct current.

Considering now apparatus with which the method outlined hereinbefore may be conducted, and in particular the viewing device **23** of the invention which was briefly noted hereinbefore as being mounted in a wall of the vacuum chamber **12** of the plating furnace **11** and including the viewing window **24** exposed to the vacuum chamber interior, reference is made to FIGURE 3 wherein the viewing device is depicted in detail on an enlarged scale. The device includes a generally cylindrical, metal-

lic viewing tube 32 which extends through a wall of the vacuum chamber 12 in the direction of an area of interest therein, which it is desired to observe. The outer end of the viewing tube 32 is provided with flange structure, as generally indicated at 33, to facilitate mounting of the viewing window 24 in closing relation thereto. Such flange structure 33 preferably includes an annular flange 34 outwardly flared from the outer end of the viewing tube 32 and having an internal doubly-stepped shoulder arrangement terminating the outer end of the viewing tube bore. In this regard, there is a first enlarged bore portion 38 coaxially of the flange 34 and outwardly stepped from the viewing tube bore proper. In addition, a second enlarged bore portion 37 is outwardly stepped from the bore portion 38 and extends through the exterior end face of the flange to define an intermediate support shoulder 36. The diameter of bore portion 37 is conformed to that of the window 24, whereby the latter may be concentrically mounted within such bore region and supported by the shoulder 36. It is particularly important to note in this regard, that an annular seal ring 39, of rubber or equivalent resilient insulating material, is interposed between the viewing window and shoulder. A backing ring is disposed upon the outer faces of the window and flange in radial bridging relation thereto, and the backing ring is secured to the flange as by means of a plurality of circumferentially-spaced flange bolts 42 extending therethrough. It will thus be appreciated that the foregoing structure facilitates mounting of the window in sealed closing relation to the viewing tube bore. Moreover, the seal ring 39 performs the additional function, in conjunction with the longitudinal gap afforded by bore portion 38, of insulating the interior face of the window from the viewing tube surfaces. Thus, the viewing tube 32 establishes the metallic surface 27 previously mentioned relative to the method, which defines a viewing path extending normally from the window 24 and which is insulated from the window in order to terminate electrostatic lines of force emanating therefrom. The tube thus facilitates establishment of an electrostatic field having a converging focusing action upon ions, and which is disposed within a confined region equivalent to region 28 discussed hereinbefore.

Where it is desired to defocus the bombarding ion beam, in accordance with the method of the invention outlined hereinbefore, the viewing device 23 may include means for generating a magnetic field to this end. More particularly, there is preferably provided an annular recess 43 extending coaxially into the viewing tube 32 from the inner end face thereof. A solenoidal winding 44 encased within insulating material 46 is in turn coaxially disposed within the recess 43, and the end of such recess is capped by an annular closure plate 47 coaxially secured to the inner end face of the viewing tube. Input leads 48 to the winding 44 are extended through the outer wall of the viewing tube in insulated relation thereto for connection to an auxiliary D.-C. power supply (not shown). The winding 44 is thus equivalent to the coil 31 of previous mention for generating the magnetic field in the conduct of the method of the invention.

Thus, with the viewing device 23 provided as just described, the method of the invention may be conducted therewith in the manner set forth hereinbefore. The interior face of the window 24 being exposed to the interior of the vacuum chamber 12 is coated by randomly-moving vapor molecules therein. An ion-accelerating electrostatic field is established with lines of force emanating from the coated interior surface of the window by establishment of a negative charge adjacent same. Preferably, the charge is established by impingement of free electrons within the vacuum chamber 12 upon the coating of vapor at the interior surface of the window. However, it should be noted that the viewing device 23 may be modified at the cost of complexity of structure to include a screen grid or equivalent electrode structure disposed adjacent the interior surface of the window and arranged for connection to a source of negative voltage bias. Such a modified structure provides an alternative means for accomplishing the step of establishing a negative charge at the interior surface of the window to in turn facilitate generation of the electrostatic ion-accelerating field. In any event, electrostatic lines of force emanating from the interior coated surface of the window terminate upon adjacent metallic surfaces of relatively less negative, or more positive potential; in the present case upon the interior bore surface of the viewing tube 32, which it should be noted is grounded through its attachment to the walls of the vacuum chamber 12. Further to the foregoing, the electrostatic field that is generated by the viewing device 23 has the desired configuration noted hereinbefore wherein equipotential surfaces of progressively negatively decreasing potential in directions away from the window bulge coaxially outward therefrom and are disposed within a confined region. Ions randomly moving into the confined region from the interior of the vacuum chamber are hence accelerated and focused by the electrostatic field upon the interior coated surface of the window to bombardment clean same. Furthermore, the confined region of the field facilitated by the viewing tube 32 facilitates cumulative ionization processes, as noted hereinbefore, which serve to enhance the cleaning action in accordance with the method of the invention. Also, the viewing device 23 facilitates defocusing of the bombarding ions if desired in a controlled manner upon connection of the input leads 48 of winding 44 to a variable D.-C. power supply.

Although the present invention has been described hereinbefore with respect to specific steps in the method thereof and as to particular structural embodiment, it is believed apparent that various modifications and variations may be made therein without departing from the concepts hereof; and accordingly, no limitations are intended nor to be implied therefrom, reference being made to the following claims for a precise delineation of the true scope of this invention.

What is claimed is:

1. An apparatus for viewing the interior of a vacuum chamber which contains condensible vapor molecules, ions and free electrons comprising, a viewing tube adapted to be supported in a position extending through a wall of a vacuum chamber, a window disposed across the outer end of said viewing tube, and means for generating a negative electrostatic field at the interior surface of said window whereby positive ions entering said field are accelerated onto said window for cleaning thereof.

2. An apparatus for viewing the interior of a vacuum chamber which contains condensible vapor molecules, ions and free electrons comprising, a metallic viewing tube adapted to be supported in a position extending through a wall of a vacuum chamber, a window disposed across the outer end of said viewing tube in sealed relationship thereto, means for generating a negative electrostatic field at the interior surface of said window, and means for generating a magnetic field within said viewing tube having lines of force substantially normal to said window.

3. An apparatus for viewing the interior of a vacuum chamber which contains condensible vapor molecules, ions and free electrons comprising, a metallic viewing tube adapted to be supported in a position extending through a wall of a vacuum chamber, a nonconductive window disposed across the outer end of said viewing tube in sealed relationship thereto, and means for insulating the interior surface of said window from said viewing tube, whereby a negative charge accumulates on the interior surface of said window by impingement thereon of the free electrons present in the vacuum chamber thereby producing an electrostatic field at the interior surface of said window, which accelerates and focuses the ions present in the vacuum chamber onto said window.

4. An apparatus for viewing the interior of a vacuum

chamber which contains condensible vapor molecules, ions and free electrons comprising, a metallic viewing tube adapted to be supported in a position extending through a wall of a vacuum chamber, a nonconductive window disposed across the outer end of said viewing tube in sealed relationship thereto, means for insulating the interior surface of said window from said viewing tube, and means for generating a magnetic field within said viewing tube having lines of force substantially normal to said window.

5. An apparatus for viewing the interior of a vacuum chamber which contains condensible vapor molecules, ions and free electrons comprising, a cylindrical metallic viewing tube adapted to be supported in a position extending through a wall of a vacuum chamber, said viewing tube being provided with a counterbore at its outer end, a nonconductive window supported within said counterbore so that the interior surface of the window is insulated from said viewing tube, and means for generating a magnetic field within said viewing tube having lines of force substantially normal to said window.

6. A method of cleaning a viewing window disposed across the outer end of a viewing tube supported in a position extending through a wall of a vacuum chamber which contains condensible vapor molecules, ions and free electrons, which method comprises generating a negative electrostatic field at the interior surface of the window, accelerating and focusing the positive ions entering the viewing tube onto the window by means of the electrostatic field, whereby condensed vapor molecules deposited upon the interior surface of the window are bombarded by the accelerated and focused ions.

7. A method of cleaning a viewing window disposed in sealing relationship across the outer end of a metallic viewing tube supported in a position extending through a wall of a vacuum chamber which contains condensible vapor molecules, ions and free electrons, which method comprises generating an electrostatic field between the interior surface of the window and the viewing tube, said electrostatic field having a decreasing negative potential in a direction away from the window, accelerating and focusing the positive ions entering the viewing tube onto the surface of the window by means of the electrostatic field, and generating a magnetic field within the viewing tube having lines of force substantially normal to the window for defocusing the ions to thereby bombard a larger area of the window.

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