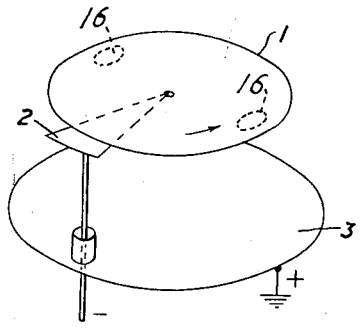
May 23, 1961 L. A. HOLLAND 2,985,756

IONIC BOMBARDMENT CLEANING APPARATUS

Filed Dec. 5, 1958

FIG. 1.



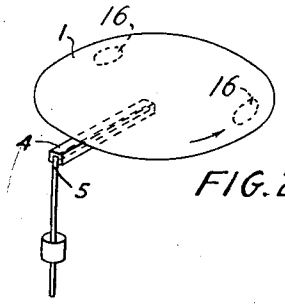


FIG. 2.

FIG. 3.

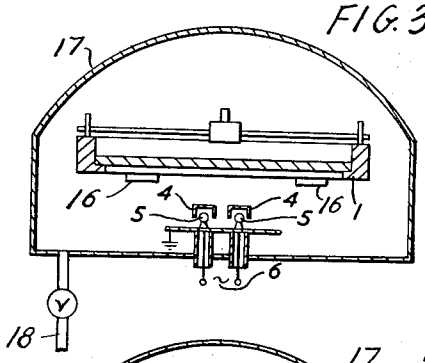
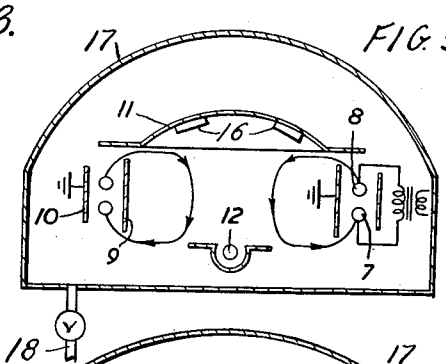


FIG. 5.



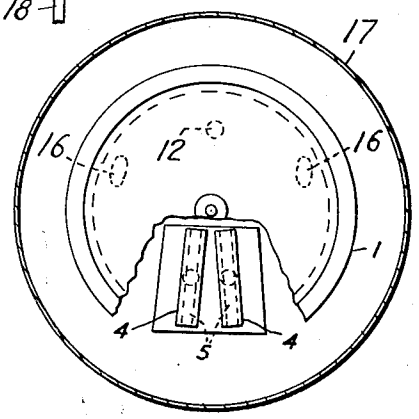


FIG. 4.

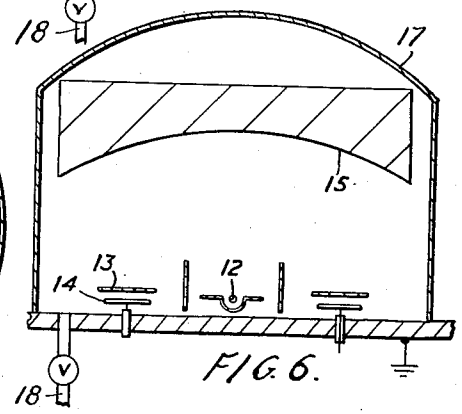


FIG. 6.

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IONIC BOMBARDMENT CLEANING APPARATUS

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3 Claims. (Cl. 250—49.5)

This invention relates to ionic bombardment cleaning apparatus, more particularly for use in the preliminary cleaning of, for example, optical surfaces to be coated in a vacuum coating chamber. The technique of producing mirror surfaces for example, by deposition of a metal film under vacuum is well established and it has been recognised for some time that the glass surface to be coated must be free from any contaminants in order that a closely adherent film may be produced.

It has been found that the known methods of cleaning by ionic bombardment in which a glass surface to be cleaned is exposed to a glow discharge at a low pressure, may, in some circumstances, result in actual contamination of the surface intended to be cleaned or the formation of optically absorbing films upon that surface. Both contamination of the surface and the formation of optically absorbing films may in fact occur. These highly detrimental effects occur if the surface is placed facing a cathode electrode and while the contaminating layers may result from a variety of causes, it is believed that they are due to decomposition under electron bombardment from the cathode of residual hydrocarbon molecules temporarily adsorbed on the glass. Again, under special conditions intense electron bombardment from a cathode will produce decomposition of the oxides in a glass surface.

The object of the present invention is to enable the undoubted efficacy of ionic bombardment to be utilised while reducing or eliminating the contamination referred to.

According to the present invention, in ionic bombardment cleaning apparatus, a cathode electrode providing bombardment for the purpose of producing an ion glow discharge is so disposed or arranged that the work surface is not directly exposed to electrons emitted by or in the vicinity of the cathode electrode, such electrons being accelerated within the cathode dark space and flowing directly towards the work surface.

In particular forms of apparatus embodying the invention, shielding means are provided between the cathode electrode and the work surface so as to intercept electrons accelerated within the cathode dark space and travelling directly towards the work surface, such shielding means permitting the desired ion glow discharge to be produced without hindrance. The invention is applicable to glow discharge cleaning apparatus operated from either A.C. or D.C. sources.

The provision of shielding means between a cathode and a work surface in accordance with the invention, is contrary to generally accepted practice in ionic cleaning technique and is in fact the reverse of the technique advocated in the past for the obtaining of successful cleaning. In carrying out the invention, the cathode shielding means are preferably, although not essentially, arranged within the cathode dark space to avoid wasteful production of positive ions in that region. If the shield is within the cathode dark space, the ionisation equilbrium is disturbed in that region with the result

that the discharge may cease. Accordingly, in carrying out the invention, the electrodes, whether A.C. or D.C. operated are arranged so that there is provided an alternative path of sufficient length for sustained ionisation elsewhere in the chamber when the electrodes are partially shielded within the dark space.

Alternative forms of apparatus constructed and arranged to operate in accordance with the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is an explanatory diagram.

Figure 2 shows in diagrammatic form one way of carrying out the invention,

Figure 3 shows also diagrammatically a slightly developed form of the apparatus for use with alternating current,

Figure 4 is a plan view of the arrangement shown in Figure 3,

Figure 5 shows diagrammatically an alternative form of apparatus; and

Figure 6 shows diagrammatically a further form of apparatus.

Referring to the drawings, in Figure 1 is shown a conventional rotary work holder **1** with a negative V-shaped electrode **2** of aluminium arranged for cleaning purposes and an anode **3**, these components being mounted within an enclosing chamber of conventional form, but not shown. Work pieces **16** are shown mounted beneath the work holder **1**. If the discharge is operated long enough a discoloured deposit may form on the work plane for the reasons already discussed. This deposit can be prevented by placing a shield electrode **4** as shown in Figure 2 between the cathode **5** and the work carried by the holder **1**, the geometry being arranged so as to permit a discharge to occur from the edges of the cathode which, as shown, is preferably of rod form. If desired, two such rods may be used arranged with shields as shown in Figures 3 and 4, the rods being connected to either side of an alternating high tension source of supply **6**. The cathodes and work holding assemblies are contained within an enclosing chamber **17** of conventional form, a pipe connection **18** being provided for the alternative connection of an evacuating pump or a source of gas supply.

In the book "Vacuum Deposition of Thin Films," by L. A. Holland, there is described a ring type electrode which may be used with a plane or a spherical holder generally of the form shown in Figure 5. Two ring electrodes **7** and **8** to which A.C. is supplied, are arranged within two earthed shields **9** and **10**. The outer shield **10** prevents the discharge from reaching the wall of the vessel, not shown, when it is made of glass and the inner shield **9** is arranged to prevent material from subsequent evaporation from depositing on the electrode surfaces. The space between the two ring electrodes is less than the operative cathode dark space so that the glow discharge is made to follow a long path within the centre of the vessel. This method of operation has been well established for some time but in applying the present invention the height of the inner electrode shield **9** is such that no part of the spherical work holder **11** is in a straight line between the top of the ring electrode **8** and the spherical holder. Instead of increasing the height of the inner electrode shield **9**, it may be fitted with an outwardly extending annular flange. The vapour source is shown at **12**.

The A.C. operated arrangement shown in Figure 5 may be adapted for D.C. operation by making one of the ring electrodes **7** or **8** a cathode and the other an anode. Preferably, the ring **8** constitutes the cathode.

Referring now to Figure 6, with the exception of the provision of a circular shield **13**, the form of discharge

cleaning apparatus shown is known. The cathode annular plate **14** is fixed opposite the surface **15** to be cleaned. After prolonged bombardment, apparatus of this form without the shield **13** may give rise to discoloured surface layers and the provision of the shield remedies the effect.

While the arrangement shown in Figure 6 is D.C. operated, it may be adapted for A.C. operation by splitting the annular cathode **14** into two elements each connected to an A.C. terminal.

It is here convenient to remark that some cleaning action may occur when a piece of glass is exposed to a cathode electrode at a gas pressure and with a separating gap such that the edge of the cathode dark space does not extend to the glass surface i.e. the glass is in the positive column or plasma of the glow discharge. Electrons in a plasma usually attain insufficient energy to dissociate hydrocarbon compounds whereas electrons traversing the cathode dark space can attain energies hundreds of times higher and give rise to decomposition. This method is unsatisfactory because, if the pressure should fall then the dark space extends and the glass surface immediately becomes exposed to bombardment by high velocity electrons, which may induce contamination. Again, a piece of glass of restricted area may be cleaned by resting it on a large cathode, but the surface of the glass is eroded by sputtering and may become electrically charged, thereby aiding diffusion of ions to the surface of the glass. Both effects are undesirable where optical glasses are concerned.

By using a shielded cathode system in accordance with the present invention electron induced contamination is avoided, and the glow discharge may be operated so that the glass is exposed to bombardment (*a*) in a plasma i.e. bombarded by positive ions, high energy neutral atoms, or molecules and low velocity electrons or (*b*) at the sides of the cathode space where the high velocity electrons traverse paths parallel to, or away from, the glass surface, whereas due to their smaller mean free path in the residual gas the high energy positive ions and neutral gas molecules are scattered and bombard the glass surface. Both methods (*a*) and (*b*) depend on such factors as voltage and current density of the glow discharge, the nature and pressure of the gas and the dimensions and geometry of the electrode system. A specific system may be operated in either state, usually by changing the working pressure. Thus, raising the applied voltage and lowering the gas pressure will make the dark space expand causing method (*a*) to change to method (*b*). The latter method is preferable because it produces a greater temperature rise in the glass and thereby prevents easy re-condensation of matter after cleaning.

Apparatus embodying the invention has been successfully used with a variety of gases, such as nitrogen, hydrogen, oxygen, air and oxygen and effective cleaning has been achieved.

It will be appreciated that the electrode systems described are arranged to prevent electrons travelling directly from the electrodes to the surface undergoing cleaning. Further, the intention is to immerse the surface to be cleaned in a discharge which is rich in positive ions and high energy neutral molecules and atoms. When chemically active gases are used then the cleaning atmosphere is rich in active constituents as well as positive ions and high energy neutral particles. In neither case is the glass exposed to bombardment by high energy electrons. Accordingly other electrode systems may be designed in which the cathode is so shielded that a glow discharge may be produced in the vessel without high velocity electrons travelling directly from the vicinity of or from the cathode surface.

I claim:

1. Ionic bombardment cleaning apparatus comprising a chamber containing an ionisable gas and enclosing an electron emitting cathode providing bombardment for the purpose of producing an ion glow discharge, a holder for work to be cleaned by ionic bombardment and shielding means disposed between the cathode electrode and the work surface of said holder so as to intercept electrons travelling directly towards said work surface, such shielding means permitting a desired ion glow discharge to be produced without hindrance.

2. Ionic bombardment apparatus according to claim 1 in which said shielding means are disposed within the cathode dark space to avoid wasteful production of positive ions in that region.

3. Ionic bombardment apparatus according to claim 1 in which said shielding means for electrodes between which said ion discharge is produced intercept any straight line between the electrodes and said work surface.

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