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MULTIPLE CRUCIBLE FOR A PERMANENT MAGNET TRANSVERSE ELECTRON BEAM EVAPORATION SOURCE

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MULTIPLE CRUCIBLE FOR A PERMANENT MAGNET TRANSVERSE ELECTRON BEAM EVAPORATION SOURCE

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ABSTRACT OF THE DISCLOSURE

A block having a plurality of crucibles arranged in spaced relation and magnetizable pole pieces placed on opposite sides of each crucible. A permanent magnet has its two poles spaced the same distance apart as that which separates the pole pieces for each crucible. An electron beam source is positioned between the magnet poles and the block is movable to bring any desired crucible into registration with the electron beam and also to bring the associated poles for that crucible into registration with the magnet poles so that the electron beam will be focused on the material in the crucible.

An object of our invention is to provide an improvement over the form of our invention shown in our pending application on a permanent magnet transverse electron beam evaporation source, Serial No. 259,221, and issued Aug. 16, 1963, Patent No. 3,202,794. In the copending case we have a permanent magnet with a crucible disposed between the north and south poles of the magnet so that the flux lines lying between the poles will extend across the top of the crucible. A filament is placed so that the electron beam flowing from the filament will be transverse to the magnetic field. This will cause the beam to be bent and directed against the material in the crucible. A shield is placed between the filament and the crucible so that the vapor from the material in the crucible will not strike the filament.

In the present invention a crucible block is associated with the base or mounting block that carries a permanent magnet and the filament. This crucible block has a plurality of crucibles arranged in spaced relation along a row with a pole piece disposed between adjacent crucibles and an end pole piece disposed adjacent to each end crucible in the row. The spacing between the two pole pieces for any one of the crucibles is the same as the spacing between the legs or poles of the permanent magnet. The pole pieces are carried by the crucible block which is movable with respect to the permanent magnet and the filament which in turn are carried by the mounting block. The crucible block can be moved relative to the permanent magnet so as to bring any desired pair of pole pieces into registration with the legs of the magnet and the pair of pole pieces thus brought into registry, will be magnetized by the permanent magnet and will create a magnetic field that extends across the crucible lying between the pair of pole pieces.

The device can be placed in a vacuum chamber and be used for applying multi-layer coatings on an article. The means for shifting the crucible block with respect to the mounting block can be operable from a place outside of the vacuum chamber. Other objects and advantages will appear as the specification continues. The novel features of the invention will be set forth in the appended claims.

Detailed Description

In carrying out our invention, we place a mounting block indicated generally as A in FIGURES 1 and 5, on a support B for a bell jar or vacuum chamber C. The walls of the vacuum chamber may be transparent or a window, not shown, may be provided so that the operator can see within the chamber. The mounting block A is made of non-magnetic material and it has a body portion A1 with a recess 2 therein for receiving a U-shaped permanent magnet D.

The magnet D forms a part of the permanent magnet transverse electron beam gun shown in our copending application, Serial No. 259,221. FIGURE 5 shows a top plan view of the mounting block A, and the body 1 has a projection 3 that extends a short distance between the north and south poles 4 and 5 of the horseshoe magnet. Insulators 5' and 6 are supported by the projection 3, and they in turn carry filament holders E and F, respectively. The insulators 5' and 6 also carry a shield G that extends upwardly and lies between the front of the body and the filament holders E and F. The tops of the filament holders support the ends of a coiled filament H. FIGURE 4 shows the shield G as having a lip 6' that extends partially over the top of the filament H. The purpose of this will be described later.

FIGURES 1, 3, 4 and 5 show the body 1 of the mounting block A rotatably carrying two spaced apart front rollers J and K and a central rear roller L. A crucible block M, see FIGURE 2, is L-shaped in cross section, see FIGURE 4, and it has its undersurface 7, overlying the top of the body 1, of the mounting block A. This undersurface 7 has a longitudinal groove 8 for receiving the rollers J and K and these rollers slideably support the front portion of the crucible block. The crucible block M is made of non-magnetic material and has a depending back wall 9 provided with a longitudinal groove 10 on its inner surface 11, see FIGURES 1 and 4. The central rear roller L is received in the groove 10 and bears against the upper edge of the groove for aiding in slidably supporting the crucible block.

The upper surface of the crucible block M is provided with a row of spaced apart depressions or crucibles N, P and Q, see FIGURE 2. There can be two or more crucibles provided and we do not wish to be confined to any exact number. Magnetizable pole pieces 12, 13, 14 and 15, see FIGURE 2, are mounted in slots 16, 17, 18 and 19, respectively, see FIGURE 1 that are formed in the crucible block M. The pole pieces 12 and 13 are arranged in opposite sides of the crucible N, see FIGURE 2, and the pole pieces 13 and 14 are arranged on opposite sides of the crucible P. In like manner the pole pieces 14 and 15 are arranged on opposite sides of the crucible.
Q. All of the pole pieces are spaced the same distance apart as the distance between the poles 4 and 5 of the permanent magnet D, see FIGURE 1.

The lower edges of the pole pieces 12 to 15 inclusive lie flush with the under surface 7 of the slidable crucible block M, and this surface is spaced just a slight distance above the tops of the poles 4 and 5 of the permanent magnet D. In FIGURE 1, we show the pole piece 13 aligned with and positioned directly above the pole 4 of the magnet D. The pole piece 14 is aligned directly above the other pole 5 of the permanent horse-shoe magnet. Therefore the pole pieces 13 and 14 will in effect become a part of the magnet D and be an extension of the magnet poles 4 and 5. A magnetic field will now extend between the pole pieces 13 and 14 and will overlie the central crucible P. The magnetic attraction between the poles 4 and 5 and the adjacent pole pieces 13 and 14, will cause the permanent magnet D to tend to yieldingly hold the pole pieces in alignment with the magnet poles 4 and 5 and prevent the crucible block M from moving with respect to the mounting block A.

Before describing one mechanism for moving the crucible block M into three different positions with respect to the mounting block A, it is best to set forth that the mounting block is placed within the vacuum chamber C and is secured to the support B. A substrate-supporting frame F is mounted on the support B, and within the vacuum chamber C, see FIGURE 1. The frame has a portion overlying the crucible block M and this portion carries the substrate S on which one or more layers of vaporized material are to be applied to the undersurface 21 of the substrate. The substrate S is positioned on the frame R so as to overlie the central crucible P and the filament H. When the filament is connected to a source of current, not shown, the electron beam indicated by the curved dash lines 22 in FIGURE 4, will flow transversely to the magnetic flux lines that extend between the pole pieces 13 and 14 and the magnetic field will bend the electron beam 22 so that it will be focused upon and strike a metal pellet T in the crucible for vaporizing the metal. FIGURE 1 illustrates how the atomic vapor will be directed upwardly in the vacuum chamber C, as shown by the dot-dash diverging lines 23, so as to strike the undersurface 21 of the substrate S and apply a coating or layer 20 of the metal on the substrate.

The other crucibles N and Q, shown in FIGURE 2 can carry other metals or materials which are to be vaporized. We will now describe one means for moving the crucible block M into three different positions with respect to the mounting block A, so as to bring either the crucible N or the crucible Q into the position now occupied by the center crucible P. We do not wish to be confined to this particular crucible block moving means because various other types could be used. We show a water inlet pipe 24, and a water outlet pipe 25 both connected to the back wall 9 of the crucible block M. The block has water passages therein, not shown, communicating with the inlet and outlet water pipes and extending adjacent to the three crucibles N, P and Q for cooling them while the pellet material is being bombarded by the electron beam. This will prevent the crucibles from melting while still permitting the electron beam 22 to change the pellet T into a vapor.

The two water pipes 24 and 25 extend through an opening 26 in the wall of the vacuum chamber C, see FIGURE 1. A disc 27 is welded to the pipes 24 and 25 and a hexagonal nut 28 is secured to the rim of the opening 26 in the vacuum chamber C, and its threads are secured to the disc 27. The bellows U encloses the portions of the pipes 24 and 25 that extend from the opening 26 to the disc 27 and permit the pipes to be moved in order to move the crucible block M from the position shown in FIGURE 1, into either one of the other two positions indicated by the dot-dash line M1 or M2. An arm 28 extends from the disc 27 and has a threaded bore 29 for receiving the threads of a screw V. The screw has one end rotatably connected to the vacuum chamber C by a bearing 30, and has its other end provided with a crank handle 31.

If the operator wishes to move the crucible N into a position where the pole pieces 12 and 13, associated with this crucible will align with the magnet poles 4 and 5, he actuates the crank 31 for rotating the screw V for moving the arm 28 into the dot-dash line position shown at A in FIGURE 1. The other hand if the operator wishes to move the crucible Q into a position where the pole pieces 14 and 15, associated with this crucible will align with the magnet poles 4 and 5, he actuates the crank 31 for rotating the screw V for moving the arm 28 into the other dot dash line position shown at B in the same figure. The water inlet pipe 24 is connected to a source of water, not shown, and the water outlet pipe 25 is connected to a water drain, not shown.

In FIGURES 2, 3 and 4, we show the crucible block M as being provided with overhanging lips 32, 33 and 34, that are positioned in front of the crucibles N, P and Q in the crucible block M. FIGURE 4 shows the lip 33 overhanging the lip 6' on the shield G. Both the lips 6' and 33 prevent the atomic vapor from the pellet T in the crucible P, from striking and contaminating the filament H.

**Operation**

From the foregoing description of the various parts of the device, the operation thereof may be readily understood. If three different layers of material are to be applied to the undersurface 21 of the substrate S, then three pellets T of the different materials chosen are placed in the three crucibles N, P and Q. A vacuum is created in the vacuum chamber C and the pipe 24 is connected to a source of water, not shown, while the pipe 25 communicates with a water drain, not shown.

If the metal pellet T in the crucible N, is the first one from which a vapor is desired so as to apply a coating 20 of this material on the undersurface 21 of the substrate S, then the crank handle 31 is actuated for moving the crucible block M into the dot-dash line position M1, shown in FIGURE 1. This will cause the crucible N over the filament H. The permanent magnet D will cause a magnetic field to be established between the pole pieces 12 and 13 which register with the magnet poles 4 and 5, respectively.

The filament H is now connected to a source of current, and it will throw off an electron beam 22 that is transverse to the flux lines of the magnetic field between the pole pieces 12 and 13. This magnetic field will bend the electron beam and focus it onto the pellet T in the crucible N, for vaporizing the metal. The vapor 23 will strike the undersurface 21 of the substrate S and form the layer 20. The operator can make the layer or coating 20 as thick as he wishes.

The operator now actuates the crank handle 31 to move the crucible block M into the full line position shown in FIGURE 1. This will bring the center crucible P into a position above the filament and its pellet T will be bombarded by the electron beam 22. The same operation takes place as explained for the pellet T in the crucible N. A second layer, not shown, of atomic material from the pellet T in the crucible P, will be applied to the layer 20. The same operation is repeated if a third layer is to be applied to the substrate S. The crank handle 31 is actuated for moving the crucible block M into the dot-dash line position M1, shown in FIGURE 1. The crucible Q is to be placed over the filament Q and its pellet T will be vaporized by the electron beam 22. A third layer, not shown, of the material forming the pellet T in the crucible Q, will be applied to the second layer. This completes the operation and the substrate S can be removed from the vacuum chamber C and it will have three layers of material applied to its surface 21.
We claim:
1. In combination:
   (a) a mounting block;
   (b) a permanent magnet supported by said block and having spaced apart poles;
   (c) an electron beam producing filament carried by said block and being insulated therefrom and being disposed between the poles of said permanent magnet;
   (d) a crucible block slidably carried by said mounting block and having a plurality of crucibles arranged in a row and spaced from each other;
   (e) pole pieces carried by said crucible block and disposed between adjacent crucibles with end pole pieces associated with the end crucibles in the row so that each crucible has a pair of pole pieces associated therewith, the distance between the two pole pieces in each pair being the same as that between the permanent magnet poles; and
   (f) means for moving said crucible block with respect to said mounting block for bringing any desired crucible into association with said filament, this movement aligning the pair of pole pieces associated with the crucible with the poles of the permanent magnet;
   (g) whereby a magnetic field will be established between the pole pieces thus aligned with the magnet poles and this magnetic field will receive and bend the electron beam issuing from said filament for focusing it on the material in the crucible for vaporizing the material.
2. The combination as set forth in claim 1 and in which
   (a) a vacuum chamber encloses said mounting block and said crucible block and the means for moving said crucible block is disposed exteriorly of said chamber; and
   (b) means is mounted in said chamber for supporting a substrate that is to be coated with the vapor from the material in the crucible that is being bombarded by the electron beam.
3. In a device of the type described:
   (a) a mounting block;
   (b) a U-shaped permanent magnet carried by said block and having its two spaced-apart poles extending upwardly;
   (c) an electron beam producing filament carried by and disposed in front of said block and between the poles of said magnet, said filament being insulated from said block;
   (d) a crucible block having a row of spaced-apart crucibles and being slidably carried by said mounting block and made of non-magnetic material;
   (e) magnetic pole pieces carried by said crucible block and disposed between adjacent crucibles with end pole pieces associated with the end crucibles in the row so that each crucible has a pair of pole pieces associated therewith, the distance between the two pole pieces in each pair being the same as that between the permanent magnet poles; and
   (f) means for moving said crucible block with respect to said mounting block for bringing any desired crucible into association with said filament, this movement aligning the pair of pole pieces associated with the crucible with the poles of the permanent magnet;
   (g) whereby a magnetic field will be established between the pole pieces thus aligned with the magnet poles and this magnetic field will receive and bend the electron beam issuing from said filament for focusing it on the material in the crucible for vaporizing the material.
4. The combination as set forth in claim 3 and in which
   (a) a vacuum chamber encloses said mounting block and said crucible block and the means for moving said crucible block is disposed exteriorly of said chamber; and
   (b) means is mounted in said chamber for supporting a substrate that is to be coated with the vapor from the material in the crucible that is being bombarded by the electron beam.

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