219-121 SEARCH ROOM

Dec. 7, 1965 R. W. WINDEBANK 3,222,496

APPARATUS FOR WORKING MATERIALS BY MEANS OF AN ELECTRON BEAM

Filed April 4, 1963

FIG. 1

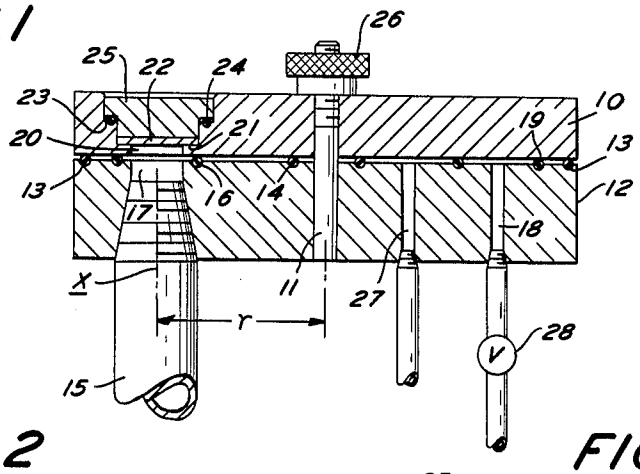


FIG. 2

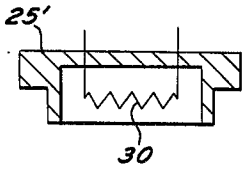


FIG. 3

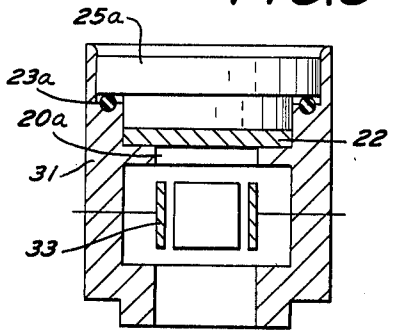


FIG. 4

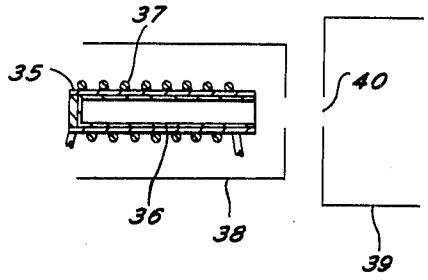


FIG. 6

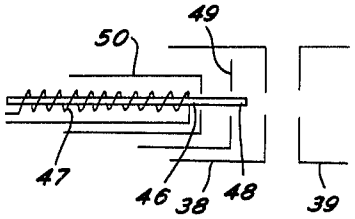
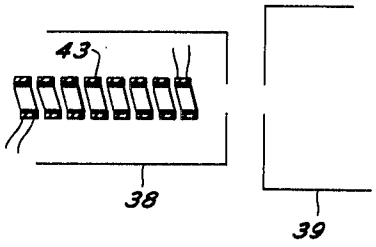


FIG. 5



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APPARATUS FOR WORKING MATERIALS BY MEANS OF AN ELECTRON BEAM

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4 Claims. (Cl. 219—121)

This invention relates to apparatus for working materials by means of an electron beam and is more particularly, although not necessarily exclusively, concerned with the cutting of a metal layer carried upon a suitable substrate by a sharply focussed electron beam under vacuo.

Among the objects of the invention are the provision of improved arrangements for inserting and removing workpieces into and from the evacuated working zone, for reducing the amount of beam energy required to effect a given cutting or other working operation, for reducing the localised heating effects upon the substrate caused by the beam cutting or other working operation, for annealing the workpiece during and after the working operation, and for providing a sharply focussed electron beam of minimum cross-section. Other objects will appear hereinafter.

FIGURE 1 is a sectional view of the apparatus of the present invention.

FIGURE 2 is a sectional view of a modification of the closure plug for the apparatus of the present invention.

FIGURE 3 is a sectional view of a modified head for the apparatus of the present invention.

FIGURE 4 is a sectional view of an electron beam gun for use in the apparatus of the present invention.

FIGURE 5 is a sectional view of a modification of the electron beam gun.

FIGURE 6 is a sectional view of another modification of the electron beam gun.

For the purpose of illustrating the invention there is shown in the drawings forms which are presently preferred, it being understood, however, that this inventoion is not limited to the precise arrangements and instrumentalities shown.

One feature of the invention relates to the provision of a carrier plate which is movable with respect to but has one surface in sealed connection with the evacuated system enclosing the operative electron beam, such plate being provided with a port therethrough adapted to receive the workpiece in sealed manner therein and which can be moved from a vacuum-free loading position to an operative position in register with the electron beam by movement of the carrier plate over one or more pumping ports by which the space between the workpiece and said sealed surface can be evacuated before the port registers with the beam position.

One embodiment of this feature of the invention is shown in FIGURE 1 of the attached drawing where the carrier plate is in the form of a metal disc **10** rotatable about a central stud **11** secured in a metal block **12**. This block **12** carries an O-ring seal or similar gasket member **13** adjacent its peripheral edge and a further O-ring of like seal **14** around the stud **11**. The continuously pumped electron beam system, indicated schematically

only at **15**, is sealed to the block **12** with its mean beam axis x at a chosen distance r from the axis of the stud **11**. A further O-ring or like seal **16** surrounds an aperture **17** in the block **12**, said aperture forming a continuation of the evacuated space of the system **15** while at a position diametrically opposite the aperture **17** and at the same radial distance r the block **12** is provided with a relief port **18** leading through valve **28** to atmosphere. This port is also surrounded by an O-ring or like seal **19**. A pumping port **27** through the block **12** is connected to a source of vacuum, e.g., that associated with the system **15**.

The disc **10** is provided, again at the same radial distance r from the axis of the stud **11** with a port-like aperture **20** shaped to provide a thin and narrow shelf **21** for reeciving the workpiece **22** in the form of a metal film carried upon the underside of a glass disc substrate. Above such workpiece receiving zone a shoulder surface **23** carries an O-ring or like seal **24** for sealing a closure disc or plug **25**. The upper end of the stud **11** is conveniently screw-threaded and provided with a clamping nut **26**.

In the operation of this embodiment, the narrow space between the opposing surfaces of the disc **10** and block **12** confined within the peripheral seal **13** and limited also by the further seals **14**, **16** and **19**, is continuously pumped through port **27**. With the disc **10** rotated through 180° to bring the aperture **20** in register with the relief port **18**, the workpiece **22** is inserted in position and the plug **25** secured and sealed in position. The disc **10** is then rotated through 180° to bring such aperture **20** into register with the beam system **15**. The valve **28** is meanwhile closed so that immediately the small space beneath the workpiece **22** becomes in fluid communication with the small volume and continuously pumped space between the disc **10** and block **12**, such workpiece space is also evacuated and when it reaches the position of the system **15** causes substantially no change in the vacuum level of the latter. Working of the metal film of the workpiece, e.g., cutting of such film, may take place without any appreciable delay, for instance, within 5 to 10 seconds. To enhance the security of the vacuum, the clamping nut **26** may be tightened during the working phase. Removal of the workpiece is effected by return of the aperture **20** to its initial position in register with the relief port **18** and then opening valve **28** followed by removal of the plug **25** and replacement of the finished workpiece by a fresh workpiece. If desired, the disc **10** may be provided with a, preferably even, number of equi-spaced apertures **20** so that a continuous flow of workpieces to and from the working zone may be achieved.

Another feature of the invention relates to the provision of means for heating the metal component of the workpiece and/or the substrate upon which it may be carried to an elevated temperature close to that of the operating temperature arising during the working phase, either just before or more preferably during the actual working phase.

One arrangement by which this may be achieved is illustrated in FIGURE 2 of the drawing where an electric heater **30** of any suitable form is incorporated within the closure plug **25'** so as to lie closely adjacent the back of the workpiece **22** during the working operation.

By raising the temperature of the substrate and/or the metal film of the workpiece to within, say 200° C. of

the melting point of the metal film, the energy required from the beam to effect cutting is substantially reduced thereby permitting the use of a lower current density in the beam with accompanying easing of the problem of obtaining a fine focussing of the beam to a spot of very small size. In addition, the workpiece is fully annealed after the cutting operation and the risk of fracture or crazing of the substrate is reduced or even avoided. The rate of cooling of the workpiece may obviously be controlled by regulation of the energy supplied to the heater 30.

Deflection of the electron beam to perform, for example, cutting of the metal film of the workpiece, may be effected by beam deflection plates or other means forming part of the system 15. Alternatively, the beam deflection system may be incorporated within a separate and interchangeable head as shown at 31 in FIGURE 3 which is adapted to fit into and be sealed in the aperture 20 of the disc 10 instead of the closure plug 25 of FIGURE 1. The workpiece 22 is now mounted in an equivalent aperture 20*a* at the upper end of the head 31 and sealed by similar means including a closure plug 25*a* and a seal ring 23*a*. The beam deflection means are indicated schematically at 33. Heating means for raising the temperature of the workpiece may also be incorporated in such interchangeable head 31. Different heads may be used to accommodate different forms and sizes of workpiece.

Yet another feature of the invention relates to the provision of a sharply focussed electron beam by the use of an emitting cathode of very small cross sectional area in a plane normal to the beam direction.

One example of improved cathode construction is shown in FIGURE 4 and has the form of a small tungsten tube 35 of, say, 0.001" internal diameter closed at one end and provided upon its inner surface with suitable oxide or other emissive coating 36. Such tube is arranged to be heated by means of an external heater winding 37 whereby the emitted electrons are directed axially out of the open end of the bore of the tube in a very small cross-section beam. To assist in confining the beam the heater may be surrounded by a negatively polarised shield or grid 38, while a positively charged anode 39 with a small diameter central aperture 40 may likewise be used to accelerate and control the focussing of the electron beam.

An alternative example of cathode construction is shown in FIGURE 5 where, instead of providing a separate heater winding, the internally coated cathode tube is constructed as a helix 43 of flat metal strip, heating being effected by passing a suitable direct current therethrough, the positive terminal of the heating source being connected to the end of the cathode helix lying nearest the anode 39.

Yet a further example of cathode construction is shown in FIGURE 6 and takes the form of a straight length of tungsten wire 46 arranged to lie coincident with the beam axis. This wire is provided with a heating coil 47 there around at a position slightly spaced from the end lying nearest the anode 39. The wire cathode is arranged to be heated by means of the heating coil 47 to a temperature whereby its tip 48 is within the emitting temperature range; thereafter a boost in temperature is obtained at the tip by means of ion bombardment either from a separate anode 49 or by means of the main beam current. The heater winding is preferably surrounded by a negatively charged shield. 50 and 39 indicate respectively the normal grid and anode electrodes. To enhance the degree of ion bombardment a slow leak of suitable gas, say, hydrogen, may be arranged to occur in the vicinity of the cathode tip 48.

In yet another arrangement according to the invention, the electron gun of the system 15 is designed in the form of a linear accelerator with such accelerator constructed as a tube resistive material having a high resistivity. For example, the tube may have a diameter of less than 1 millimetre, a length of about 4 centimetres and a wall thickness of the order of 0.5 millimetre. Such tube then acts to collimate the electron beam and produces a uniform voltage gradient. The accelerating voltage is applied across the ends of the tube and by suitable graduation of the resistive value of the tube material along the tube length, the voltage gradient can be made to follow a prescribed law to enable a controlled beam velocity to be obtained.

Such an accelerator tube may be made with magnetic properties for instance, of a suitable ferrite, such that, with a suitably positioned coil, a magnetic lens effect can be obtained at one or both ends of the tube in order to shape the cross-section of the electron beam. The applied magnetic field may be of a value below that producing saturation in the accelerator tube whereby the field inside the tube is at a minimum or alternatively the applied field may be above the saturation level of the tube material so that a field is produced inside the tube to shape the beam while it is being accelerated thereby to confine the beam to a minimum cross-section.

In experimental constructions ferrite tubes of the order of size quoted above and with overall resistance values of between 400 and 1000 megohms have been successfully used in conjunction with normal magnetic and/or electrostatic focussing systems.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. Apparatus for working materials by means of an electron gun comprising a base disc; a carrier plate extending across and slightly spaced from a surface of said base disc; means rotably supporting said carrier plate on said base disc; first sealing means between the adjacent surface of said base disc and carrier plate, said first sealing means extending completely around the base disc adjacent to but spaced from the edge of the base disc; said base disc having an electron gun receiving aperture and a relief port extending therethrough, said electron gun receiving aperture and said relief port being equally spaced from the axis of rotation of said carrier plate and opening, into the space between the base disc and carrier plate within said first sealing means; a second sealing means between the adjacent surfaces of said base disc and carrier plate, said second sealing means surrounding the electron gun receiving aperture; a third sealing means between the adjacent surfaces of the base disc and carrier plate, said third sealing means surrounding the relief port; said base disc having a pumping port extending therethrough and opening into the space between the base disc and carrier plate within said first sealing means and outside of said second and third sealing means, said pumping port adapted to be connected to means for reducing the pressure in the space between the base disc and carrier plate which is inside said first sealing means and outside of said second and third sealing means; said carrier plate having an aperture therethrough spaced from the axis of rotation of said carrier plate a distance equal to the spacing of each of the electron gun receiving aperture and the relief port from said axis of rotation, means in said carrier plate aperture for supporting the material to be worked; and a closure plug removably mounted across said carrier plate aperture; said carrier plate being rotatable with respect to said base disc between a first position in which the carrier plate aperture is over the electron gun receiving aperture and a second position in which the carrier plate aperture is over the relief port.

2. Apparatus in accordance with claim 1 in which the means rotatably supporting the carrier plate on the base disc comprises a stud secured to said base disc and extending through said carrier plate, said carrier plate be-

ing rotatable on said stud, a nut threaded on the end of said stud which projects from said carrier plate and engaging the carrier plate to secure the carrier plate over the base disc, and sealing means between the adjacent surface of the base disc and carrier plate around said stud.

3. Apparatus in accordance with claim 1 in which the means for supporting the material to be worked includes a cylindrical head removably mounted at one end in the carrier plate aperture, means in said head for deflecting the beam of an electron gun, means in said head for supporting the material to be worked, and the closure plug is removably mounted across the other end of said head.

4. Apparatus in accordance with claim 1 including an electric heater within the closure plug.

References Cited by the Examiner

UNITED STATES PATENTS

2,264,210	11/1941	Krause	250—49.5
2,852,683	9/1958	Peters et al.	250—41.9
2,939,955	6/1960	Rommerts	250—49.5
2,992,347	7/1961	Dehn	313—82
3,004,183	10/1961	Levin	313—82
3,073,951	1/1963	Burdg	250—41.9
3,135,855	6/1964	Barber	219—121
3,136,883	7/1964	Radtke	219—121

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