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United States Patent

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[33] **Germany**
[31] **P 19 40 056.7**

[54] **ELECTRON-BEAM-PROCESSING MACHINE HAVING MEANS FOR DEFLECTING IMPURITIES FROM THE PATH OF THE ELECTRON BEAM**
29 Claims, 10 Drawing Figs.

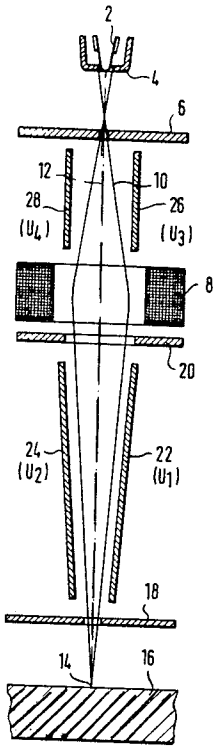
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[51] **Int. Cl.** **B23k 15/00,** H01j 37/26
[50] **Field of Search** ..... 13/31; 219/121 EB; 250/49.5 R, 49.5 TE, 49.5 A, 49.5 C, 49.5 D, 49.5 PE; 313/7; 417/48, 49

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Assistant Examiner—A. L. Birch
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ABSTRACT: Apparatus in electron-beam-processing machines for keeping the path of the working beam free of impurities, the apparatus having a screening device associated with the working beam for catching impurities, comprising an ionization device acting in the region of the working beam path, and a deflecting device effective in the region of the said beam path to produce a deflecting field for electrically charged particles, the ionization device being so formed that it acts with an ionization probability greater than that of the working beam on atom-sized or larger particles, the deflecting device exerting a sufficient deflecting action on such electrically charged particles, which move at substantially thermal speeds as to remove these particles from the path of the working beam.



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SHEET 1 OF 3

Fig.1

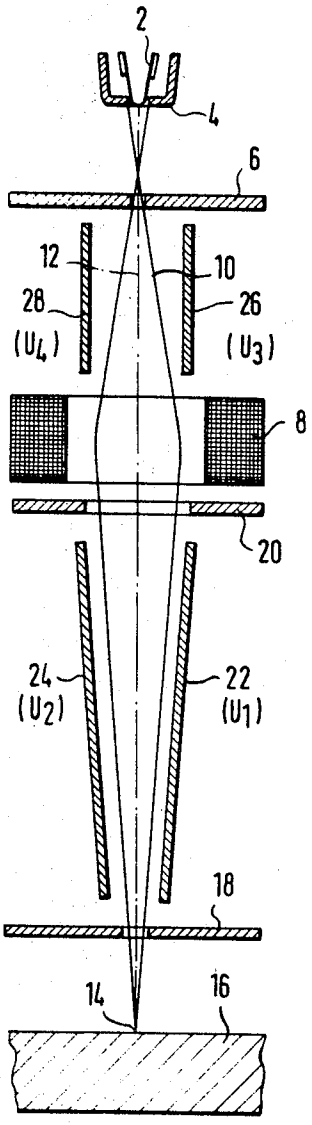
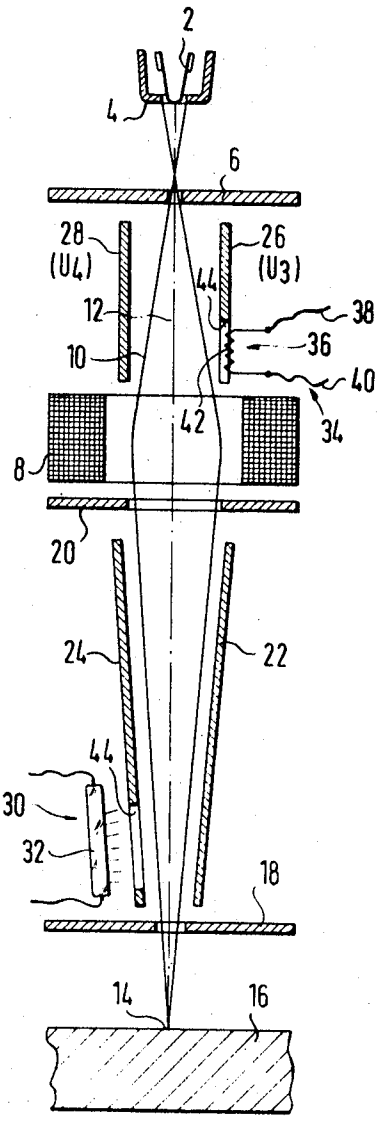


Fig.2



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Fig.3

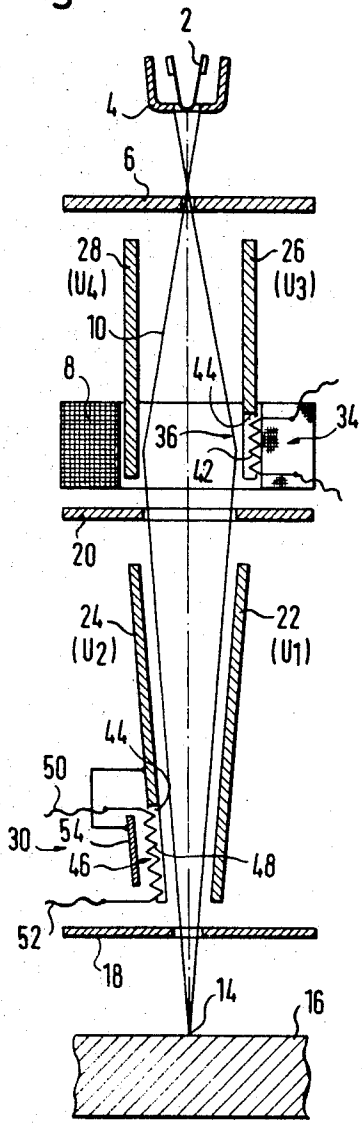


Fig.4

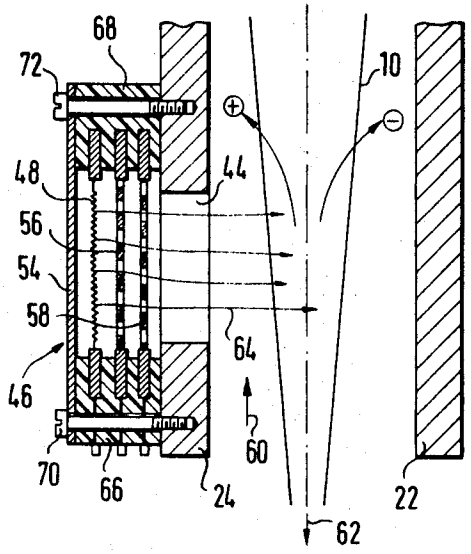


Fig.5

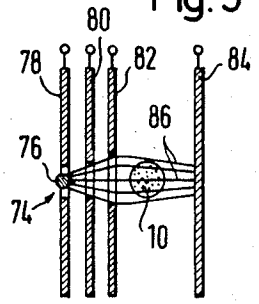
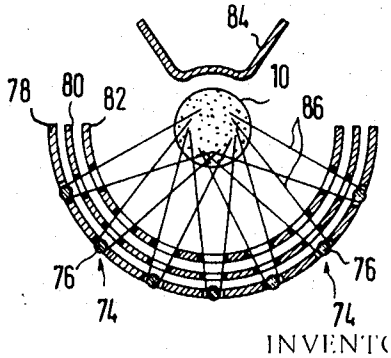


Fig.6



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Fig.7

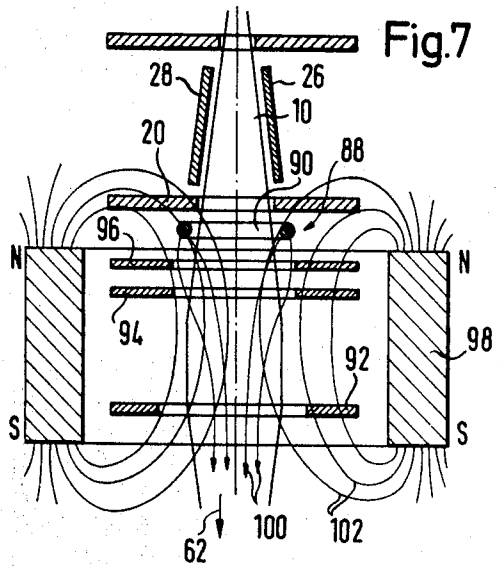


Fig.8

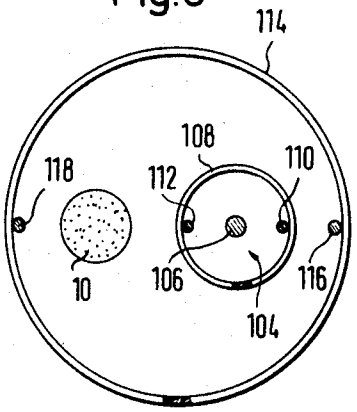


Fig.9

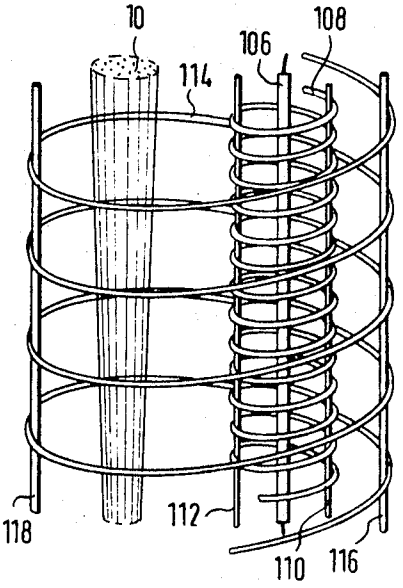
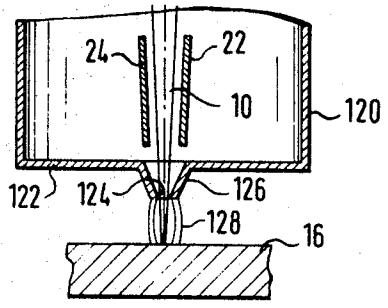


Fig.10



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ELECTRON-BEAM-PROCESSING MACHINE HAVING MEANS FOR DEFLECTING IMPURITIES FROM THE PATH OF THE ELECTRON BEAM

PRIOR APPLICATION

In Federal Republic of Germany on 6th Aug. 1969 and numbered. P 19 40 056.7

The invention concerns an apparatus in electron-beam-processing machines for keeping the beam path of the working beam free of impurities. The apparatus includes a screening device associated with the working beam, to collect impurities.

When processing workpieces with electron-beam-processing machines, the material at the beam impact point is caused to evaporate or scatter; but this material appears as an impurity in the machine and can cause high-tension flashovers at the beam source. Screening devices usually associated with the working beam are unable to present such impurities from flying directly into the beam path.

To avoid such interference, it has been proposed to direct the energy beam through screens axially offset relative to one another by a deflecting device. The beam has deflected errors impressed thereon which have to be compensated to prevent them from the causing the properties of the working spot to deteriorate. Other means for avoiding the said interference use prismatic accelarator sections, e.g. electrostatic fields with a curved or tilted axis of rotation, or rotationally symmetrical electrostatic lenses which are intended to filter out the disturbing stream of impurities from the beam. Even these means have disadvantages. With prismatic accelerator fields the cathode is indeed protected, but it does not prevent particles from entering the accelerating sections. Electrostatic lens arrangements only act on charged particles, and since the degree of ionization owing to the very high electron speed in electron beam processing machines is very low, the majority of neutral particles are not filtered out.

The object of the present invention is to protect the beam source from the action of impurities by simple means, and in a highly effective manner.

According to the present invention there is provided an apparatus in electron-beam-processing machine for keeping the path of the working beam free of impurities, the apparatus having a screening device associated with the working beam for catching impurities, comprising an ionization device acting in the region of the working beam path, and a deflecting device effective in the region of the said beam path to produce a deflecting field for electrically charged particles, the ionization device bring so formed that it acts with an ionization device greater than that of the working beam on atom-sized or larger particles, the deflecting device exerting a sufficient deflecting action on such electrically charged particles, which move at substantially thermal speeds as to remove these particles from the path of the working beam.

In the apparatus of the invention, the use of an ionizing device producing a high degree of ionization ensures that a large proportion of the uncharged particles of impurity is ionized. These ionized particles, owing to their relatively low (substantially thermal) speeds, can be effectively deflected from the beam path of the working beam, and held back by the screening devices by relatively week deflecting means, which have no noticeable deflecting effect on the relatively fast electrons.

The ionization may be carried out in a variety of ways, as for example, by ionizing beams such as ultraviolet radiation, slow electrons or the like. The deflecting device may include electrostatic, electromagnetic or magnetostatic units. Tests with conventional electron beams processing machines with beam outputs of between 1 and 10 kw. have shown that ionization devices which operate with slow electrons can be used in path of the working beam over a distance of 10 cm. with a current density of 1amp per cm.^{2} whereby this giving a decisive improvement in the separating effect relative to arrangements without additional ionization. Furthermore it has been found

that when using electrostatic deflecting devices, very low deflecting voltages of a few hundred volts can be used; with such low deflecting voltages electrons of the working beam, which have energies in the order of magnitude of 0.1 mev. are only insignificantly deflected, and the properties of the working beam remain substantially unchanged.

The invention will be described with reference to the accompanying drawings, In which:

FIG. 1 is a schematic longitudinal section through an electron beam machine with deflecting devices,

FIG. 2 is a schematic longitudinal section similar to FIG. 1 through an electron-beam-processing machine with a deflecting device in accordance with the invention,

FIG. 3 is an alternative embodiment of an electron beam machine with a device in accordance with the invention,

FIG. 4 is a part view of an embodiment of an device in accordance with the invention, enlarged relative to FIGS. 1 to 3,

FIG. 5 is a section taken at right angles to the working beam of an alternative embodiment of a deflecting device in accordance with the invention,

FIG. 6 is a sectional view of a further embodiment of a device in accordance with the invention, also taken at right angles to the working beam,

FIG. 7 is a fragmentary view of a further embodiment of a device in accordance with the invention, shown as in axial section with respect to the beam,

FIG. 8 is a transverse sectional view of a further embodiment,

FIG. 9 is a perspective view of the embodiment shown in FIG. 8,

FIG. 10 is an axial section of a further embodiment of a device in accordance with the invention. The electron beam machine shown in FIG. 1 contains essentially a cathode 2, a control electrode 4, an anode 6 and a focusing device 8. The energy beam 10 has a beam axis and is focused on the processing point 14 of a workpiece to be processed. Processing may involve milling, boring, cutting, welding, heating, annealing and the like. During processing, the workpiece 16 produces substances such as occluded gases evaporated workpiece material, and spattered workpiece particles at the processing point 14 which constitute undesired impurities. These intrude on the path of the electron-beam-processing machine, and especially the acceleration section thereof. To keep the beam path substantially free of such impurities a screen device is provided, which in the simplest case is a single screen e.g., the anode screen 6. Preferably a further screen 18 is mounted over the workpiece. The machine shown also contains a further screen 20 below the focusing device 8. The openings of the screens are slightly greater than the beam diameter at the location of the screens.

The machine shown in FIG. 1 also contains a deflecting device for ionized impurity components; this is in an electrostatic deflecting device and consists of two plate-shaped deflecting electrodes 22, 24 which are arranged on each side of the beam path and are preferably replaceable. The deflecting electrodes may also be of arcuate section and curved around the beam. The potentials of the deflecting electrodes 22 and 24 are designated by U1and U2. These potentials are small compared with the accelerating voltage used to form the working beam 10, this voltage exists between the cathode system 2, 4 and the anode 6 and may be in the region of 100kv. The potentials of the deflecting electrodes may be such that U1=0volts and U2+100volts. With defection potentials of this order, the working beam 10 consisting of relatively fast electrons is not noticeably deflected; since, however, the speeds of the particles of impurities released at the processing point 14 are relatively low and mainly determined by the temperature prevailing at the processing point, such deflecting voltages suffice to remove ionized particles of impurities from the beam path. The particles are deposited either on the deflecting electrodes themselves, or on the adjacent screens, e.g. screen 20 or the anode screen 6. It is obvious, that with stated potentials of the deflecting electrodes 22, 24, positive

particles of impurities are deflected to the left in FIG. 1, and negative particles of impurities are deflected to the right. In any case, the deflecting device is so formed that over a part of the path of the working beam 10 it produces a deflecting field acting transversely to the beam path.

To improve the effect, several deflecting devices may be provided in the machine of FIG. 1. Thus the deflecting device 22, 24 already described may be supplemented by a second deflecting device with electrodes 26 and 28 located above the focusing device 8. To reduce the effect of the deflecting devices on the working beam 10, this second deflecting device 26, 28 can be operated with a reversed polarity as compared with the first deflecting device 22, 24, for example, the deflecting electrode 26 may be connected to a potential U_3=300 volts and the deflecting electrode 28 to a potential U_4=0 volts. It should be understood that the potential values given are merely examples and that in practice lower potentials, of the order of 100 v. give quite satisfactory deflecting actions especially with working beams of relatively small diameter, where the deflecting electrodes can be located closely together. The deflecting electrodes 26, 28 are preferably replaceable; the screen 20 and the anode screen 6 may also be replaceable. Since the relatively fast electrons of the working beam 10 exert only a small ionizing effect, an ionizing device acting in the region of the path of the working beam 1 is provided in the electron beam processing machine shown in FIG. 2 this is so designed that it acts more strongly on the particles of impurities located in the beam path then the working beam 10. In the embodiment shown in FIG. 2 the first deflecting device comprising the deflecting electrodes 22 and 24 is provided with a first ionization device 30, which is shown as an ultraviolet radiator 32. The second deflecting device which consists of the deflecting electrodes 26 and 28, is provided with a second ionizing device 34 which is shown as an auxiliary electron source 36 with an auxiliary cathode 42 operated via supply leads 38, 40. The ionizing devices 30 and 34 are each located at the ends of the associated deflecting devices 24 or 26, remote from the beam source 2, 4, 6. This is because the flight direction of the particles of impurities is generally opposite to the direction of movement of the electrons of the main beam 10, i.e. upwards in FIGS. 1 and 2. In the embodiment of FIG. 2 the ionization devices 32, 34 act through cutouts 44, 44 in the deflecting electrodes on the space traversed by the working beam 10. With reference to the second ionization device 34 operating with an auxiliary cathode 42, the auxiliary electrons emitted by the electrode 42 can be accelerated into the deflecting field between the deflecting electrodes 26 and 28. For this purpose the deflecting electrode 26, through the cutout 44 of which the auxiliary electrons enter the beam path, is operated at a relatively negative potential. The potential u_3 of the deflecting electrode may be −26 volts, whilst the potential u_4 of the deflecting electrode 28 can be +100 volts. Instead of the electrons emitted by the auxiliary source of electrons being accelerated in the deflecting field, the auxiliary electron source may also have its own accelerating system associated therewith; such embodiments are described below.

The embodiment shown in FIG. 2 also contains screens 18 and 20; it is of particular importance that above and between the individual deflecting devices screens 20 and 6 are provided. If it is desired to avoid changing the anode screen 6, this screen 6 may have an interchangeable screen (not shown) located near it.

In the embodiment shown in FIG. 3 the first ionization device 30 has an auxiliary electron source 46 with an auxiliary cathode 48. The auxiliary cathode is heated via supply leads 50 and 52. A screen 54 is connected with the deflecting electrode 24 so as to interfere as little as possible with the deflecting field of the lower or first deflecting device 22, 24. A further feature of the embodiment shown in FIG. 3 is that the auxiliary cathode 42 of the second ionization device 34 is located within the focusing device 8 which as usual is a magnetic coil. As a result, the magnetic focusing device 8 acts with respect to the slower auxiliary electrons emitted by the magnetic focusing device 8 as a magnetic deflector which in known manner extends the tracks of these auxiliary electrons by curving or spiraling them and accordingly increases their ionization probability in the ionization region between the deflecting electrodes 26 and 28. It is, of course, readily possible to provide a separate magnetic auxiliary device, in order to extend the tracks of the auxiliary electrons by curvature or spiraling. The embodiment shown in FIG. 4 corresponds substantially to the lower part (first deflecting and ionization device) of FIG. 3, but with the difference that the auxiliary electron source 46 (with the auxiliary electrode 48) of the first ionization device 30 has its own accelerating system associated therewith, this consisting of the auxiliary control electrode 56 and auxiliary anode 58. These two electrodes may be sieve or lattice like devices and the auxiliary control electrode 56 may be made as a slotted screen. The auxiliary control electrode 56, like the screen 54, is supplied with a potential which is slightly negative relative to the auxiliary cathode 48, and is preferably regulatable, whilst the auxiliary anode 58 is fed with a potential which is positive relative to the auxiliary cathode 48, so that the auxiliary electrons emitted from the cathode 48 are accelerated by the anode 58 in quantity and focusing which are controllable by the potential of the auxiliary control electrode 56. These electrons enter the ionization region through meshes the meshes of electrode 56 and through the cutouts 42 of the deflecting electrode 24, in the ionization region between the deflecting electrodes 22 and 24. The figure shows schematically the deflection of positive and negative particles of impurity to the relatively negative deflecting electrode 24 or the relatively positive deflecting electrode 22. The direction of flight of the particles of impurities is indicated by the arrow 60, and the direction of the working beam by the arrow 62. The arrows 64 indicate tracks of auxiliary electrons. FIG. 4 also shows that the parts of the ionization device are supported in two insulating material blocks 66, 68, which turn in are fastened to the deflecting electrode 24 by means of screws 70, 72.

FIG. 5 is a section normal to the working beam 10, and shows an auxiliary electron source 74 having an auxiliary cathode 76 provided with its own focusing device. This focusing device is formed as an electrostatic cylinder lens and consists of an auxiliary control electrode 78, which is held at a preferably regulatable potential, slightly negative relative to the auxiliary electrode 76, with a positive auxiliary anode relative to the auxiliary cathode 74 and a deflecting electrode 82 negative with respect to the cathode 76. In these electrodes slots are formed extending parallel to the auxiliary cathode 76, and on the other side of the working beam 10 there is a positive deflecting electrode 84 substantially parallel to the deflecting electrode 82 and positive relative to the auxiliary cathode 76, so that the auxiliary electrons emitted by the auxiliary cathode 76 follow tracks indicated by the lines 86. The electrostatic focusing device for the auxiliary electrons shown in FIG. 5 with the auxiliary cathode 78 parallel to the working beam, results in a substantially line-shaped focusing in the plane of the working beam 10, so that ionization probability is correspondingly increased.

FIG. 6 shows a multiple use of the principle shown in FIG 5. Thus, around a part of the circumference of the working beam 10 there are several deflecting electrodes 82 of substantially equal potentials, and auxiliary electron sources 74 each including an auxiliary cathode 76 and auxiliary control electrode 78. Over part of the remaining portion of the circumference of the beam a relatively positive deflecting electrode 84 is provided. It is readily seen that as shown in FIG. 6 the electrodes 78, 80 and 82 belonging to the individual auxiliary cathodes 76 are formed as circumferential sections of cylindrical surfaces, between which there are corresponding slotlike cutouts for the passage of the linear by focused auxiliary electron tracks 86. It has been that with the focusing means of FIG. 6, overlapping of the auxiliary electron tracks 86 and an accordingly high auxiliary electron current density is obtained in the associated axial region of the working beam 10.

The embodiment shown in FIG. 7 contains an electron source 88 with an annular auxiliary cathode 90 surrounding the working beam 10. There is also an annular auxiliary anode 92 offset in the direction of the beam, which accelerates the auxiliary electrons emitted by the auxiliary cathode 90 substantially parallel to the working beam 10. In the arrangement shown in FIG. 7 there is also an electrostatic focusing device with ring electrodes 94 and 96. In operation the electrode 94 may have a potential of +100 v. the electrode 96 a potential of −100 v. and the anode 92 a potential of +300 v. Furthermore a control electrode (not shown) may also be provided near the auxiliary cathode 90, to allow the emission current to be adjusted in a manner known in connection with Wehnelt electrodes. From the form of the auxiliary electron source the auxiliary electrons are focused along the axis of the working beam 10 and accordingly there is an increased rate of ionization. The particles of impurities ionized in the ionizing region, if they are not caught by the screen 20, are deflected from the path of the working beam by deflecting device. This deflecting device is offset against the direction of the beam with respect to the auxiliary electron source 88, i.e. it is located on the side of the auxiliary electron source 88 remote from the workpiece to be processed. The direction of the working beam 10 is again indicated by arrow 62 in FIG. 7.

FIG. 7 also shows the use of an additional magnetic device in the form of a ring magnet 98, to obtain an additional focusing of the auxiliary electrons or even, with a correspondingly powerful magnet, an elongation of the auxiliary electron tracks by curving or spiralling. Some auxiliary electron tracks 100, which are obtainable with the arrangement of FIG. 7, are indicated therein; some magnetic lines of force 102 are also shown.

In the embodiment shown in FIGS. 8 and 9 an auxiliary electron source 104 is used having an auxiliary cathode 106 extending substantially parallel to the working beam 10. The auxiliary cathode 106 is enclosed by a grid 108, which in the manner usual in electron tubes may consist either of a wire mesh, or as shown in FIG. 8, a wire spiral supported on rods 110, 112. The grid 108 and the working beam are enclosed by an envelope electrode which in FIG. 9 is shown as a wire spiral supported on two rods 116, 118 but may also consist of a wire mesh, or a perforated or imperforate sheet. In operation, the grid 108 is held at a positive potential relative to the auxiliary cathode 108 and the envelope electrode 114 at a potential negative relative to the auxiliary cathode 106. By suitable selection of the potential of the lattice 108 and the envelope electrode 114 with reference to the potential of the auxiliary electrode 106, and with suitable spacing of the grid 108 with electrons emitted by the auxiliary cathode 106 are concentrated in the space between the grid 108 and the auxiliary electrode 114, so that the repulsion of the auxiliary electrons at the envelope electrode 114 and the acceleration of these electrons through the grid 108 result in oscillating auxiliary electron track, thus highly increasing the rate of ionization in the region of the working beam 10. The relatively heavy negative and positive particles produced by ionization of impurities are deflected to the grid 108 or towards the envelope electrode 114 where they are at least partly deposited. It is also possible to provide additional collecting electrodes (not shown). It is of course also expedient in the embodiment of FIGS. 8 and 9, to cover the cross section outside the working beam 10 by screens in the axial regions outside the ionization and deflecting device on which screens the impurities are deposited.

Suitable data for the operation of the embodiment shown in FIGS. 8 and 9 are readily ascertained by tests; this applies both to the potentials used and to the spacing of the turns of the grid 108 and of the envelope electrode 114. It should be particularly noted that in the embodiment of FIGS. 8 and 9, the grid 108 and the envelope electrode 114 operates as deflecting devices; is it also possible to provide additional deflecting electrodes.

When the working beam passes through an intermediate partially evacuated chamber, deflecting and ionization devices may also be provided in the intermediate chamber or even outside it. Owing to the relatively high gas pressure therein, ionization devices may also be used in which auxiliary electrons producing the ionization are obtained from a cold cathode, e.g. by peak discharge or from a high current are; again, magnetic auxiliary devices such as the ring magnet 98 shown in FIG. 7 may be used, to extend the auxiliary electron tracks by curving or spiralling. An arrangement with a high-current arc is shown schematically in FIG. 10. In a chamber 120 of an intermediate pressure stage system located over the workpiece 16, not shown in detail, deflecting electrodes 22, 24 are arranged on both sides of the path of the working beam 10. The ionization device is here formed by the workpiece 16 and an auxiliary electrode 122 located thereover, which has a screen opening 124 for the passage of the working beam 10 and an annular projection 126 surrounding this opening. Between this projection 126 and the workpiece 16 a high-current arc 128 is struck and maintained: the very powerful electric ionization produced acts to prevent the impurities formed from flying through the screen opening 124 against the beam direction. The auxiliary electrode 122 forms the outermost closure wall of the intermediate pressure stage system; in this case a minute opening 124 is used.

All embodiments are similar in that the acceleration distance of the working beam, e.g. in FIGS. 1 to 3 the distance between the cathode 2 and the anode 6, lies outside the operative region of the deflecting device. This device and the associated ionization means are thus located in a space free of high-tension fields.

Other embodiments are possible, including the provision of more than two deflecting and ionization devices one after the other, in the direction of the beam.

I claim:

1. In electron-beam-processing machines apparatus for keeping the path of the working beam free of impurities, comprising a screening device associated with said working beam for catching impurities, an ionization device acting in the region of the said beam path to produce an ionization probability greater than that of said working beam on particles of impurity therein, and a deflecting device producing a deflecting field for said ionized particles, effective in the region of said working beam to remove said particles from said beam path.

2. Apparatus as recited in claim 1, wherein said deflecting device produces a deflecting field transverse of said beam path along at least a proportion of said path.

3. Apparatus as recited in claim 1 wherein said ionization device is arranged in an end region of said deflecting device remote from the source of said beam.

4. Apparatus as recited in claim 2 comprising a plurality of deflecting devices acting over a part of said beam path on said ionized particles.

5. Apparatus as recited in claim 4, comprising at least two deflecting devices acting on said ionized particles with opposite deflecting actions.

6. Apparatus as recited claim 4, comprising a plurality of ionization devices spread out along said beam path.

7. Apparatus as recited in claim 6, with at least one ionization device associated with each deflecting device.

8. Apparatus as recited in claim 4, comprising a screen between individual adjacent deflecting devices.

9. Apparatus as recited in claim 1, wherein said deflecting device comprises electrostatically acting deflecting electrodes arranged along said beam path, said electrodes having means ensuring easy replacement thereof.

10. Apparatus as recited in claim 1, wherein said ionization device comprises an auxiliary electron source, which produces electrons of lower energy than the electrons in said working beam.

11. Apparatus as recited in claim 10, comprising an acceleration system for each said auxiliary electron source.

12. Apparatus as recited in claim 10, comprising a focusing device for each auxiliary electron source, said focusing device producing linear focusing of electrons from said auxiliary source.

13. Apparatus as recited in claim 1, comprising a glow discharge space in said ionization device for ionization of said particles of impurities.

14. Apparatus as recited in claim 1, comprising a high-current arc discharge space in said ionization device for ionization of said particles of impurities.

15. Apparatus as recited in claim 14, comprising an auxiliary electrode provided with a small aperture, said high-current discharge space extending between the impact region of the working beam on the workpiece and said auxiliary electrode.

16. Apparatus as recited in claim 10, wherein said auxiliary electron source is provided with an auxiliary cathode extending parallel to said working beam.

17. Apparatus as recited in claim 16, comprising a grid surrounding said auxiliary cathode and an envelope electrode surrounding said working beam and said grid.

18. Apparatus as recited in claim 17 comprising a grid surrounding said electron source which is at a positive potential relative thereto and an envelope electrode surrounding said grid and at a negative potential relative to said electron source, said potentials and the spacings of said grid causing electrons emitted by said electron source to be concentrated in the space between said grid and said envelope electrode and to execute oscillatory movement therein to produce relatively heavy negative and positive particles by ionization of impurities, said negative particles concentrating at said grid and said positive particles concentrating at said envelope electrode, said particles being at least in part, deposited on said grid and said electrode.

19. Apparatus as recited in claim 9, wherein said ionization device comprises an auxiliary electron source which produces electrons of lower energy than the electrons in said working beam, the apparatus further comprising at least two deflecting electrodes provided on opposite sides of said working beam said electrodes being charged to different electric potentials, said auxiliary electron source being so positioned that auxiliary electrons generated thereby to produce ionization are accelerated in the electric field between said deflecting electrodes.

20. Apparatus as recited in claim 9, wherein said ionization device comprises an auxiliary electron source and a negative deflecting electrode associated therewith, said electrode defining an aperture near which said source is located.

21. Apparatus as recited in claim 19, comprising a plurality of auxiliary electron sources and deflecting electrodes arranged around part of the circumference of said working beam, said electrodes connected to substantially the same potential, and at least one relatively positive deflecting electrode occupying at least part of the remaining circumference.

22. Apparatus as recited in claim 10, wherein said auxiliary electron source is so formed that the low-energy electrons therefrom move in the region of said working beam and substantially parallel thereto.

23. Apparatus as recited in claim 22, wherein said auxiliary electron source is provided with an auxiliary cathode at least partly surrounding the path of said working beam and an annular auxiliary anode offset with respect thereto along the direction of said working beam, said auxiliary anode accelerating the electrons emitted by said auxiliary cathode substantially parallel to said working beam.

24. Apparatus as recited in claim 23, comprising at least one deflecting device in an axial region of said working beam on the side of said auxiliary electron source remote from said workpiece to be processed.

25. Apparatus as recited in claim 23, comprising a focusing device for said auxiliary electron source, wherein said focusing device is so formed that it concentrates said electrons into a substantially cylindrical space extending substantially coaxial to said working beam.

26. Apparatus as recited in claim 10, comprising a magnetic device which in the ionization region of said apparatus extends the tracks of said electrons supplied by said auxiliary electron device by curvature thereof.

27. Apparatus as recited in claim 26, comprising a working beam magnetic focusing device, wherein said auxiliary electron source is so arranged that said magnetic focusing device also acts to curve the tracks of electrons emitted by said ionization device.

28. Apparatus as recited in claim 1, wherein the acceleration path of the electrons in said working beam lies outside of the working region of said deflecting device.

29. Apparatus as recited in claim 1, wherein said screening device is provided with at least one replaceable screen.

* * * * *