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[54] **ELECTRODE ARRANGEMENT SERVING TO ACCELERATE A CHARGE CARRIER BEAM IN A VACUUM**

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[51] **Int. Cl.** **H01j 31/02, H01j 29/46**

[58] **Field of Search** .... 313/82 R, 84, 83, 86, 63, 313/82; 328/233

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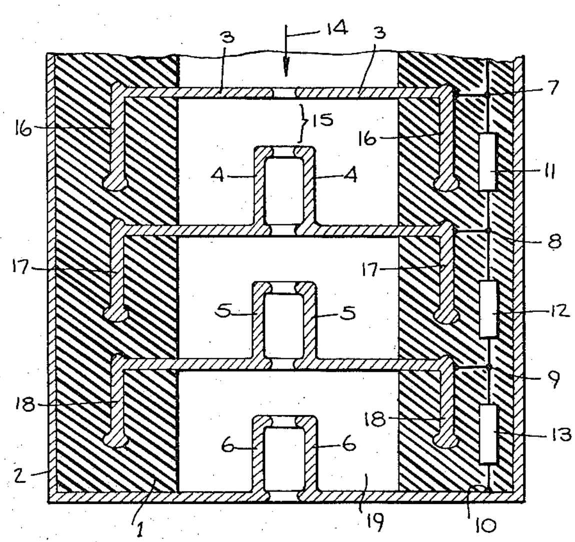
[57] **ABSTRACT**

An electrode assembly for accelerating charge carriers in a charge carrier beam includes acceleration electrodes fixedly mounted inside an evacuable chamber formed by an insulating body and a surrounding enclosure. A supplementary conductor element is embedded within the walls of the insulating body, in a fashion in which it substantially encircles, or circumscribes, both the acceleration path and also at least in part the acceleration electrodes. The supplementary conductor is conductively connected to one of the electrodes which it circumscribes, thus maintaining electrode and supplementary conductor at the same electric potential.

15 Claims, 4 Drawing Figures



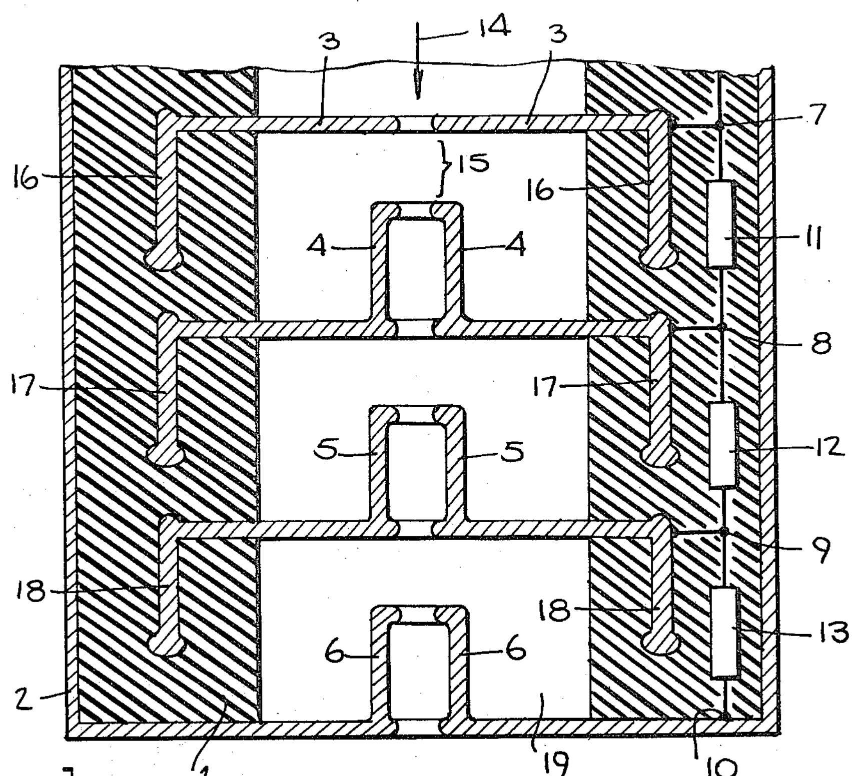


Fig. 1.

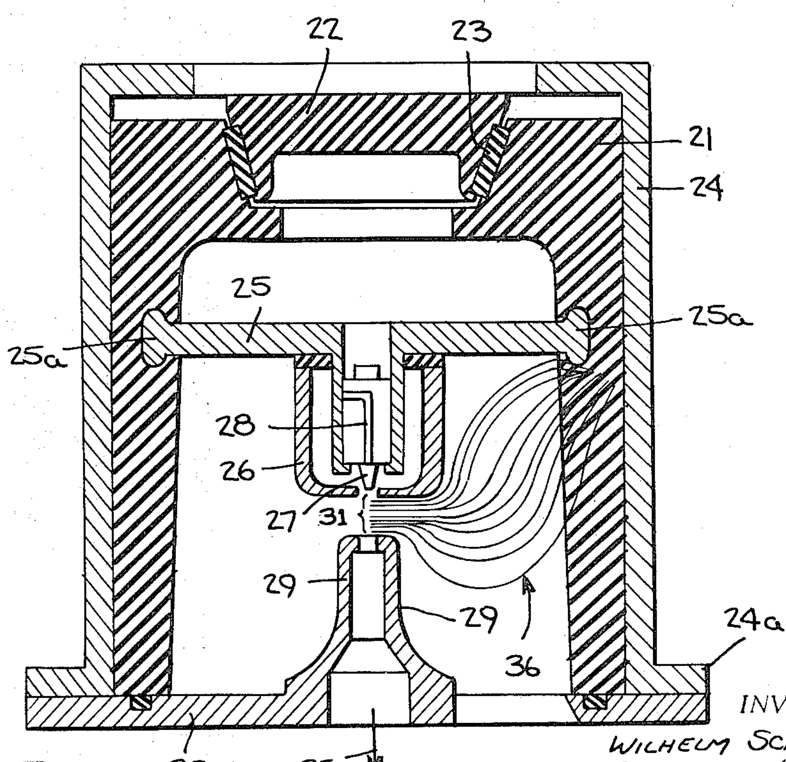


Fig. 2.

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Fig. 3.

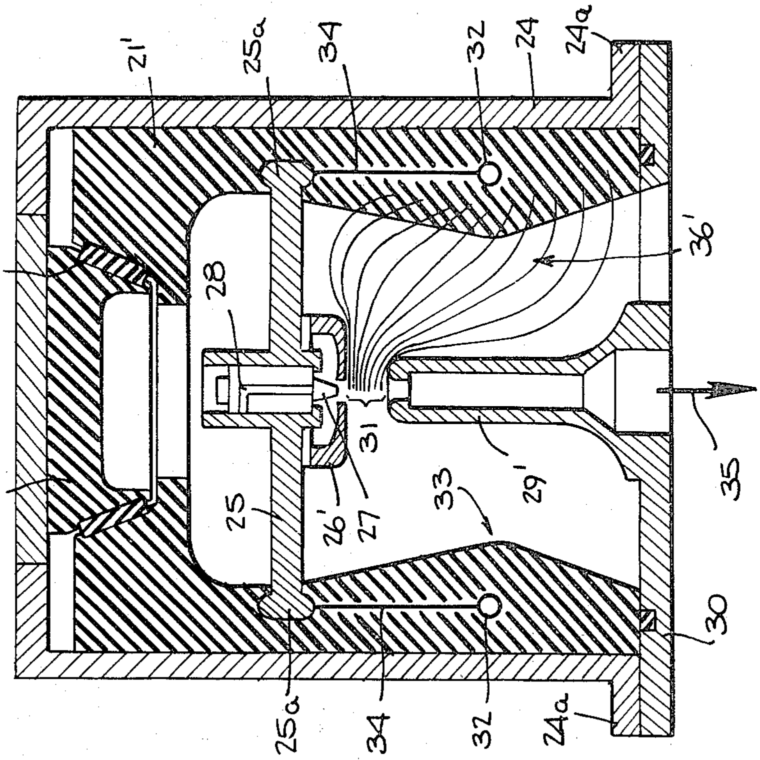
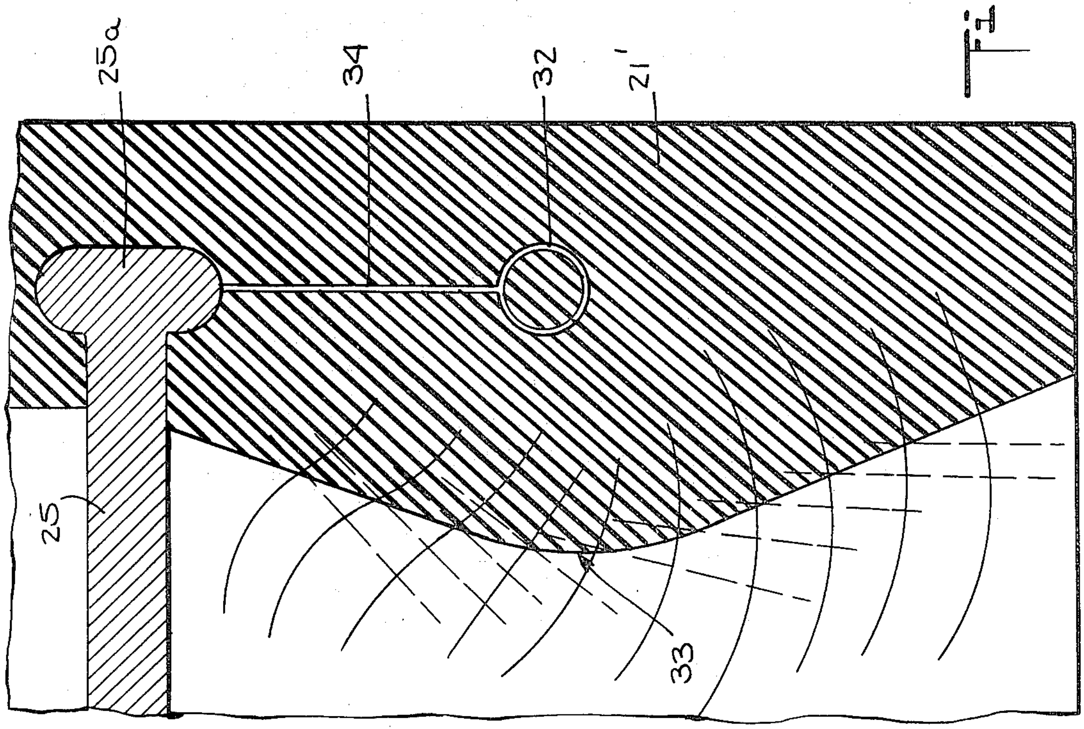


Fig. 4.



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ELECTRODE ARRANGEMENT SERVING TO ACCELERATE A CHARGE CARRIER BEAM IN A VACUUM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention concerns an electrode arrangement serving to accelerate a charge-carrier beam in a vacuum, within an insulating body and a surrounding enclosure element, and consisting of at least two conductor elements at different electric potentials, disposed at an axial spacing from one another, and forming an acceleration path, with middle passageway openings for the charge carrier beam.

2. Prior Art

Ordinarily the conductor elements of such electrode arrangements are provided with conductive holding parts or the like conductively connected to the electrodes, which holding parts are therefore at the same potential as their respective electrodes. The holding parts are fastened in the wall of the insulating body surrounding the evacuable chamber defined by the interior walls of the insulating body.

Furthermore, such an insulating body ordinarily has, along with a very high dielectric strength and breakdown voltage, a large surface creep distance between the holding elements fastened in the insulating walls for the conductor elements and those parts external to the insulating body, which are at ground potential.

For example there is known an arrangement serving for the acceleration of electrons where the conductor elements forming an acceleration path are connected in their respective cases with electrically conductive holding elements which are fastened in the wall of an evacuable cylinderical hollow element consisting of insulating material while at least one electrode is connected to a grounded outer conductor surrounding the insulator. The insulator in such case thus surrounds the conductors elements so closely that, except for the conductive contact between electrode and outer conductor, the electric insulation capability between the accelerating electrodes at the high negative potential and the outer conductor is determined primarily by the dielectric strength of the insulating material, which is substantially greater than that of a vacuum. In this known arrangement, because of the use of the fixed insulator between the acceleration electrodes and the outer conductor, a substantial reduction of the insulation path therebetween is made possible, so that the arrangement may be designed with relatively small diameter.

On the other hand with the known arrangement it has turned out that the frequency of the occurrence of voltage flash-overs at the inner wall of the insulator is still relatively great, in particular when for example acceleration voltages in the region of 100 kv are provided. This phenomenon is to be ascribed to the fact that very high electric field strengths are produced at the surface of the insulator inner wall, so that any charge carriers, such as free secondary electrons and the like available in the inner space of the insulator, because of the pattern of the lines of force of the electric field, become accelerated in a direction toward the insulator inner wall, whereby on occasion a further number of charge-carriers become liberated there. As a result of this, there then occur undesirable high-voltage flash-overs, through which naturally the functioning ability and the

reliability of the arrangement become greatly impaired. The said phenomena are moreover undesirably promoted in that in the region of the attaching connection for the electrically-conductive holding elements for the acceleration electrodes in the insulating element a great density increase of the field is produced, and also at the insulating surface, so that it can be particularly easy for the critical field strength determining the flash-over to become exceeded, particularly since in this surface region (as also at the remaining surfaces of the insulator inner wall) the lines of force of the electric field enter the insulator surface under an acute angle promoting a flash-over, and directed so that the negative charge-carriers in the vacuum become accelerated toward the insulator surface.

Finally, there is one further substantial drawback to the known arrangement, in that the resultant electric field along the surface of the insulator wall, between each two attaching connections of the holder elements for the accelerating electrodes parallel to the z-axis, do not run linearly, and thus the static field distribution, produced in each case by the particular situation of the conductor elements forming an acceleration path, and the creep-current distribution on the insulator surface, deviate considerably from one another.

SUMMARY OF THE INVENTION

The present invention starts out from the problem of constructing an electrode arrangement of the kind mentioned at the outset in such a way that even with very high acceleration voltages the danger of voltage flash-overs in the interior space of the hollow insulating element can be excluded practically completely during operation.

This problem is solved through the creation of an electrode arrangement with at least two conductor elements forming an acceleration path, which arrangement is in accordance with the invention characterized in that for the purpose of forming, or influencing the distribution of the electric field outside the acceleration path, there is provided in a supplementary way at least one electric conductor element which is embedded in the wall of the insulating element, and which substantially surrounds or circumscribes both the acceleration path and also at least in part the acceleration electrodes. This supplementary conductor or electrode is maintained at the same potential as the acceleration electrode with the more negative potential relative to the electrode following in the direction of acceleration. The supplementary conductor or electrode also be disposed to extend around the accelerating electrode which is downstream, relative to the charge-carrier beam path, of the electrode to which it is conductively connected.

The invention in a surprising way offers the possibility of predetermining the distribution of the electric field in the interior of the insulating element in such a way that there occur directly at the inner insulator surface substantially smaller field strengths than previously, so that the probability of reaching critical field strengths, responsible for highvoltage flashovers, can be greatly diminished.

In a general way the invention leads to desirable linear distribution of the strength of the electric field along the inner surface of the insulating element, while only in the interior of the walls of the insulating element, is it still possible for high electric field strengths to occur, but these, because of the great dielectric strength of the insulating material, are entirely harmless.

Furthermore, the lines of force of the electric field now pass into the insulator walls at an angle that, contrary to the previous arrangements, accelerates away from this surface any free negative charge-carriers.

In an advantageous way the supplementary conductor element or electrode serving for forming the field outside the acceleration path is connected directly and conductively with the associated acceleration electrode which is at the more negative potential. Such a connection can be produced in a simple way through the holding element for the acceleration electrode which holding element is fastened in the wall of the insulator body.

In many applications of the electrode arrangement of the invention, along the lines of perfecting the linearizing effect for the electric field strength at the inner insulator surface, it may be of advantage if in accordance with a further development of the invention the wall of the insulating body, in the embedding region of one of the supplementary conductor or electrodes serving for forming the field, in each case has a buckling or constriction directed toward the interior of the hollow space.

Tests already carried out of the electrode arrangement of the present invention for accelerating electrons, using acceleration voltages in the region of **150** kv, have shown that a design of the arrangement which is very favorable is obtained when the degree of buckling or constriction of the inner wall of the insulating body is in each case made greatest in a region where the free end, the end which is not directly connected to the accelerating electrode or with its holding element, of a supplementary conductor element or electrode according to the invention serving to form the field is embedded in the wall of the insulating body.

This free end of the supplementary conductor element or electrode, the end which is not directly connected to the aacceleration electrode or with its holding element, is for the purpose of reducing the field strength at its surface preferably provided with a thickening that is substantially circular in cross section. In some cases however, it may be advantageous if the conductor element or electrode embedded in the insulator body wall is provided at its end, instead of with a massive thickening, with an annular spiral of wire, which is to be recommended particularly with a view to installing the conductor element or electrode for example in a moldable resin as an insulating material.

In just this respect it may also be advantageous if the supplementary conductor element or electrode is in each case made in the form of a wire mesh bent into a cylindrical peripheral surface that is molded into the wall of the insulating wall of molded resin.

It is moreover possible in accordance with the invention, to provide a supplementary conductor element or electrode for forming the electric field outside the associated acceleration path through metallizing a surface provided for this purpose within the wall of the insulating body. This metallized surface must naturally in its turn be in conductive connection with the associated accelerating electrodes or with their holders.

The foregoing characteristics and forms of construction of the invention, and also other advantageous details of electrode arrangements made in accordance with the invention, will be evident from the following description, taken in combination with the drawings showing examples of construction.

DESCRIPTION OF THE DRAWINGS

FIG. **1** shows schematically an axial section through a part of a multistage linear accelerator, which is provided with an electrode arrangement according to the invention;

FIG. **2** shows schematically an axial section through an electron-beam producing system having an electrodes arrangement made in a known manner;

FIG. **3** shows schematically an axial section through an electron-beam producing system having an electrode arrangement according to the invention;

FIG. **4** gives a detail view of the arrangement of FIG. **3.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

The linear accelerator of FIG. **1** for charge-carrier beams has a cylindrical insulating body **1,** in the interior of which is provided a likewise cylindrical hollow space **19,** which can be evacuated in a known manner by means of a pumping contrivance that is not shown. The insulating body **1** contains in its inner space **19** a number of accelerating electrodes **3** to **6** arranged relative to one another, in each case with centered middle passage openings for a charge-carrier beam coming from a source that is not shown and indicated schematically by **14.** In this case it is, for example, a matter of a beam of electrons that is to be accelerated, and therefore the conductor elements **3** to **6** will form the following approximate potential stages:

Conductor element **3**: 300 kv
Conductor element **4**: 200 kv
Conductor element **5**: 100 kv
Conductor element **6**: ground potential (0kv),

For this purpose the individual conductor elements **3** to **6** are connected to corresponding taps **7** to **10** of a resistance chain having the resistances **111** to **13,** and acting as a voltage divider.

Normally the conductor elements, between which there is in each case formed an acceleration path for the electrons beam (the acceleration path between the conductor elements **3** and **4** is designed **15**), are fastened by holding elements in the wall of the insulating body **1.**

In accordance with the present invention, however, there are now also provided, for the special forming of the electric field, in a region situated outside an acceleration path, supplementary conductor elements **16, 17** and **18,** that are embedded in the wall of the insulating body **1,** and are conductively connected with their respective associated conductor elements **3, 4, 5** of the acceleration region. The conductor elements **16, 17** and **18** are hereby disposed cylindrical peripheral surface coaxial with the arrangement of the accelerating electrodes **3, 4** and **5,** and in each case surround the associated acceleration path and also at least in part the electrodes forming this path in each case, and at a radial spacing from the axis of the arrangement.

For example, in this way the conductor element **16** surrounds the acceleration path **15** and in part also the corresponding acceleration electrodes **3** and **4.**

During further consideration of FIG. **1** it is also seen that the conductor elements **3** and **16, 4** and **17,** as well as 5 and **18**, are in each case assembled practically into a substantially pot-shaped electrode. Thus, each electrode between the first and last electrode in the acceleration direction of the multistage linear accelerator preferably consists in each case of a hollow-cylinder conductor element, **17** and **18** respectively, outside an acceleration path, and having a comparatively large diameter, and of the accelerating electrodes proper, **4** and **5** respectively, conductively connected with these conductor elements **17** and **18** respectively, and in their turn likewise made in the form of hollow cylinders and being of relatively small diameter, the conductor element **17** or **18**, however, being directed by its free end in the opposite axial direction, that is, in each case toward the following electrode, and whereby each two successive electrodes of this arrangement following one another in the axial direction extend at least in part into one another.

By means of this kind of partial overlapping of the parts of two successive electrodes following one another in the axial direction there is thus obtained the form of construction described in the foregoing, with which the conductive elements **16, 17** and **18**, serving in the required way for the contemplated forming of the electric field in a region outside an accelerating path, surround this acceleration path, and the corresponding parts of the accelerating electrodes at a radial spacing from the axis of the electrodes arrangement. At the output side multistage linear accelerator has its end electrode **6** connected to an external conductor **2**, for example, at ground potential, and surrounding the insulating body **1**.

In FIG. **2** is shown an electron-beam producing system of known type of construction. It comprises chiefly a vacuum housing which consists of a hollow-cylinder insulating body **21**, on whose outer peripheral surface is provided a grounded electric conductor **24** in the form of a sheet-metal case.

In the interior of the insulating body **21** is disposed a cathode system having parts conducting high voltage, whereby the electric insulation between this cathode system and the metallic envelope **24** is determined substantially by the dielectric strength of the insulating body **21**. The cathode system is fastened to the insulating body **21** by the aid of the support ring **25**. This support ring **25** is by its rim part **25***a*, rounded off for electric reasons, molded into the wall of the insulating body. The contact area between the rim part **25***a* and the insulating body **21** is hereby made so large that the heat from the hot cathode when it is in operation flowing off over the support ring **25** can not heat excessively the places of contact with the insulating body **21**. The cathode system at the high-voltage potential consists of a Wehnelt electrode **26**, in whose control opening is situated V-shaped hot-cathode **27**, which is in its turn fastened in a holder **28**. The top of the insulating body **21** is provided with an easily removable cover **22**, which is likewise made of insulating material, and is made as a cone having an insulating and a vacuum-tight rubber cuff **23**.

At the opposite side of the insulating body **21** is disposed an anode **29**, having a partly-cylindrical partly-funnelshaped inner bore, and extending into the hollow space of the insulating body **21** in such a way that, between the opening of the Wehnelt electrode **26** and the anode opening, there is formed an acceleration path **31** for the electrons emerging from the control opening of the Wehnelt electrode **26**. The under side of the insulating body **21** is set vacuum-tight on a plate **30** integral with the anode **29**, which plate in its turn is connected with a flange **24**a of the grounded metallic case **24**. The anode **29** is thus also at ground potential

The arrow **35** indicates the direction of the accelerated electron beam emerging from the anode bore.

To the electron-beam producing system of FIG. **2** there also belong chiefly a contrivance for evacuating the inner space of the insulating body **21**, as well as electric supply devices or conductors for the cathode system. For the sake of clarity however, such constructional parts are omitted from FIG. **2**, particularly since they are without importance for understanding the invention. For such an understanding, the following is rather of importance:

As can be seen by the aid of the pattern of the equipotential lines, designated in common by **36** and drawn in the right-hand part of the system shown in FIG. **2**, there exists a great crowding together of the corresponding electric field in a region in which is situated the rim part **25***a* of the support ring **25** for the cathode system in the wall of the insulating body **21**. This electrically conductive support ring **25**, with its rim part **25***a*, is namely at the same high potential as the cathode system, which has a potential difference of for example 150 kv in comparison with the anode **29** that is at ground potential. The comparatively small difference of potential between the Wehnelt electrode **26** on the one side and the hot-cathode **27** and also the support ring **25** on the other side can be neglected in these considerations

The potential gradient produced by the given arrangement of the electrically conductive parts, in the present case that is chiefly the cathode system with the Wehnelt electrode, the support ring **25**/**25***a* and the anode **29**, results in a very nonlinear distribution of the electric field strength, in particular also at the inner surface of the insulating body **21**, so that there exist here electric surface regions or places at which the electric field strength can readily assume a critical value or exceed it and an electric flash-over occurs.

In addition, the lines of force of the resultant electric field which enter into the inner surface of the insulating body **21**, have entry angles through which any free negative charge-carriers, such as secondary electrons, under the influence of the electric field become accelerated toward the insulating body, and thus further increase the probability of flash-overs. Finally, it should be mentioned that in the region of the anchoring of the support ring **25** in the insulating body **21** a substantial thermal load on the molded resin occurs, because the support ring is connected with the cathode system so as to conduct heat very well, so that in our opinion certain waste-gas effects may occur from thermal overload.

The aforesaid detrimental phenomen and difficulties can however be avoided to a great extent by the aid of an electrode arrangement according to the invention, as will be shown in detail by the aid of FIGS. **3** and **4**.

FIGS. **3** shows schematically in an axial section an electron-beam producing system that has certain similarities with the system shown in FIG. **2**, so that the same reference numerals have been used for similar parts. In accordance with FIG. **3** there is provided an evacuable insulating body **21'**, inside which are housed a cathode system having the parts **25, 26'**, **27** and **28,** and also an anode **29'**. **25** again designates an electrically conductive support ring, which is on the one hand conductively connected with the cathode **27** or its holder, and is on the other hand fastened by its rounded-off rim part **25***a* in the wall of the insulating body **21'**. The insulating body **21'** is moreover provided with a cap **22, 23.** The anode **29'**, substantially in the form of a hollow cylinder, is conductively connected with a plate **30** disposed at the underside of the insulating body **21'**, which is in its turn connected to a flange **24***a* of an enclosure formed by a grounded metal external conductor **24** directly surrounding the insulating body **21'**.

In accordance with the invention there is now embedded in the wall of the insulating body **21'** within the molded resin a further electric conductor element **34,** having substantially the shape of a cylindrical shell running parallel to the enclosure **24,** and being at its upper annular side conductively connected with the rim-part **25***a* of the support ring **25,** so that it is at the same electric potentials as the cathode system.

This conductor element **34** has the function of influencing and forming in the desired way the electric field in a region outside the acceleration path **31** having a great potential gradient, that is chiefly in the rotation-symmetrical region between the accelerating electrodes **26'**, **29'** of the electron-beam producing system and the inner wall of the insulating body **21'**. The substantially hollow-cylinder anode **29'** is hereby pulled with its relatively narrow neck in an axial direction quite high in the inner space of the insulating body **21'**, and it lies with its upper bore-opening at a relatively small spacing from the control opening of the Wehnelt electrode **26'**.

The conductor element **34,** which extends from the support ring **25** within the insulating body wall in a direction practically opposite to that of the anode **29'**, is as respects its extension parallel to the axis shaped so that it surrounds coaxially both the acceleration path **31** and also the cathode system with the Wehnelt electrode **26'** and a certain part of the anode **29'**, as can be seen from FIG. **3.** At its lower rim the conductor element **34** is terminated by means of an annular wire spiral **32.** In the region where the conductor element **34** is embedded in the molded resin the wall of the insulating body **21'** has a buckling **33** directed toward the interior of the hollow space, the greatest degree of the buckling **33** being adjacent the end **32** of electrode **34.** By means of this illustrated measure it is ensured that the electric field strength along the inner curved surface of the insulating body **21'** is substantially uniform, is linearly distributed that is, so that places of particular compression of the electric field are avoided. As has been shown by measurements, with the arrangement of the invention as shown by way of example in FIG. **3,** a decrease of the maximum field strength at the insulator surface by a factor of at least **3** is obtainable, whereby now the lines of force of the electric field run in directions toward the insulator surface and enter there at angles so that accidentally produced secondary negative charge-carriers, such for example as secondary electrons, become accelerated away from the insulator surface.

FIG. **3** also shows, analogously to the illustration of FIG. **2,** the new pattern of the equipotential lines, designated in common by **36'** and lying in the vertical section plane, and this namely from the axis of the acceleration path **31** toward the inner wall of the insulating body **21'** situated at the right. It can be seen in particular that the surface region in the immediate vicinity of the rim part **25***a* of the support ring **25** anchored in the insulating body wall and at high tension, is practically field-free; whereas in the z-direction the density of equipotential lines, and thus also the density of the lines of force of the corresponding electric field along the insulator surface does indeed at first increase, but then remains practically constant, without centers of high electric field strength becoming formed on the insulator surface.

This phenomenon of linearization of the electric field can be made still clearer by the aid of FIG. **4.** FIG. **4** shows a large section out of the electron-beam producing system of FIG. **3,** whereby it is a matter of a region of the insulating body **21'** having a curved surface, into the wall of which there is molded the conductor element **34** serving for forming the field, this element on the one shand being connected with the rim part **25***a* of the suppor-ring **25** which is at cathode potential, and being on the other hand at its free end, for the purpose of avoiding an electric flash-over in the insulating material, provided with an annular wire spiral **32.** In addition to showing the pattern of the equipotential lines, FIG. **4** in the region of the transition from the vacuum to the insulating body **21'** also shows by dotted lines the group of lines emerging in the region of the insulator surface.

From the foregoing there can be seen particularly well and clearly the fact that there is attainable by the invention a linear distribution of the electric field strength along the inner surface of the insulator.

It is finally worth mentioning that as a result of the arrangement of the supplementary electric conductor or electrode in the molded resin, and of the automatically produced increased heat-contact area, a further advantage is obtained, namely an improved withdrawal of heat from the hot support ring **25** through the insulating body **21** and to the enclosure **24,** in particular when the conductor element **34** consists of a material having great heatconductivity, of copper for example.

What is claimed is:

1. An electrode assembly for accelerating a charge-carrier beam, comprising:

a. an enclosure having therein an insulating body and an evacuable chamber defined by the inside walls of said insulating body, said chamber being adapted to allow passage of the charge-carrier beam along a path therethrough;

b. at least two separately spaced accelerating electrodes, each having a passageway therethrough, the beam path passing through said passageways, said accelerating electrodes being stationarily mounted within said insulating body and being maintainable at predetermined differing electric potentials to propel the charge-carriers of the charge-carrier beam along said path;

c. and body protecting means for accelerating electrons away from said inside walls of said insulating body, said body protecting means including electrode conductor means extending substantially about said beam path and at least in part also extending about said accelerating electrodes and spaced in a radial direction with respect to said accelerating electrodes, said electrode conductor means being embedded within said walls of said insulating body;

d. means for maintaining said electrode conductor means at an electric potential which is a function of the potential of at least one of said accelerating electrodes,

said means for maintaining the potential of said electrode conductor means comprising an electrically conductive connection between said electrode conductor means and one of said accelerating electrodes which is adjacent upstream of the accelerating electrode about which said electrode conductor means extends with respect to said beam path.

2. The electrode assembly of claim **1**, in which said electrode conductor means is of a generally cylindrical configuration.

3. The electrode assembly of claim **2**, in which said electrode conductor means is conductively connected to the one of said accelerating electrodes about which said electrode conductor means extends, and said electrode conductor means and said one of said electrodes in combination have a configuration which is generally cylindrical, having one open end and one closed end, said closed end having said passageway located therein.

4. The electrode assembly of claim **1**, in which:

a. each of said accelerating electrodes comprises, in the region of said passageway therethrough, through which said beam path extends, an openended cylinder portion of conductive material,

b. said electrode conductor means being conductively connected to and extending about the said cylindrical portion of a first one of the accelerating electrodes, and

c. said electrode conductor means additionally extends about the said cylindrical portion of an acceleration electrode which is adjacent to and upstream of said first one of the accelerating electrodes with respect to the beam path of said charge carriers.

5. The electrode assembly of claim **1**, in which said means for maintaining the potential of said electrode conductor means comprises an electrically conductive connection between said electrode conductor means and the one of said accelerating electrodes which is adjacently upstream of the accelerating electrode about which said electrode conductor means extends with respect to said beam path, further comprising means for maintaining said accelerating electrodes at different electric potentials, including:

a. a voltage dividing circuit adapted to be connected across a source of voltage, and

b. electrically conductive taps connecting each of said accelerating electrodes to a different point of electrical potential on said voltage divider circuit.

6. The electrode assembly of claim **1**, in which one of the said accelerating electrodes about which said electrode conductor means extends is fastened to the inside walls of said chamber by a conductive holding element, and said electrically conductive connection is between said holding element and said electrode conductor means.

7. The electrode assembly of claim **1**, in which the said inside walls of said insulating body includes an inward projecting portion in the region of said electrode conductor means.

8. The electrode assembly of claim **3**, in which the said inside walls of said insulating body includes an inward projecting portion in the region of said electrode conductor means, the greatest degree of inward constriction being adjacent said open end of said cylindrical configuration formed by said electrode conductor means and said one of said accelerating electrodes about which said electrode conductor means extends.

9. The electrode assembly of claim **3**, in which the thickness of said electrode conductor means is greatest in the region near said open end of said cylindrical configuration.

10. The electrode assembly of claim **3**, further comprising an annular conductive body attached to said electrode conductor means and extending generally along and around said open end of said cylindrical configuration.

11. The electrode assembly of claim **10**, in which said annular conductive body comprises a wire spiral.

12. The electrode assembly of claim **1**, in which said electrode conductor means comprises a woven wire mesh embedded within the material of said insulating body.

13. The electrode assembly of claim **1**, in which said electrode conductor means comprises a metallized surface within the walls of said insulating enclosure.

14. The electrode assembly of claim **1**, in which said electrode conductor means is made of a material having high thermal conductivity.

15. An electrode assembly for accelerating a charge-carrier beam, comprising:

a. a hollow insulating body and a hollow evacuable chamber defined by the inside walls of said insulating body, said chamber being adapted to allow passage of the charge-carrier beam along an acceleration path therethrough, a grounded electric conductor disposed on the outer surface of said insulating body;

b. at least two separately spaced accelerating electrodes, each having a central passageway therethrough, the beam passing through said passageways, said accelerating electrodes being stationarily mounted within said insulating body and being maintainable at predetermined differing electric potentials to propel the chargecarriers of the charge-carrier beam along said acceleration path, one of said accelerating electrodes and said earthed electric conductor covering on the outer surface of the insulating body;

c. at least a supplementary electrode being of a generally cylindrical configuration extending coaxially about said acceleration path and at least in part also extending about said accelerating electrodes and spaced in a radial direction with respect to said accelerating electrodes, said supplementary electrode being totally embedded within said walls of said insulating body and modifying the electric field external of said path;

d. means for maintaining said supplementary field modifying electrode at an electric potential which is a function of the potential of at least one of said accelerating electrodes,

said means for maintaining the potential of said supplementary field modifying electrode comprising an electrically conductive and direct connection between said supplementary field modifying electrode and one of said accelerating electrodes which is adjacently upstream of the accelerating electrode about which said supplementary field modifying electrode extends with respect to said acceleration path, whereby the distribution of the electric field in the region of said inside walls of said insulating body is made relatively constant and the lines of force of the electric field pass into the insulator walls at an angle such that free negative charge carriers are accelerated away from the surface of said inside walls of said insulating body.

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