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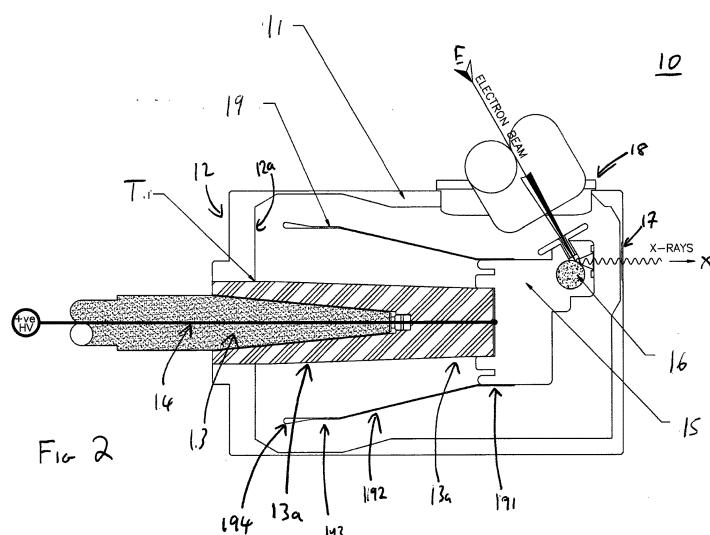
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(54) Title of the Invention: **Target assembly for an x-ray emission apparatus and x-ray emission apparatus**  
Abstract Title: **Target assembly for an x-ray emission apparatus with suppression electrode**

(57) A target assembly for an x-ray emission apparatus comprising a vacuum chamber 11 with at least one conductive wall 12, the apparatus further comprises insulating element 13 projecting through the conductive wall and a high voltage element 14 extending along the insulating element from outside the chamber; the high voltage element extends to an end portion of the insulating element furthest from the conductive wall where an x-ray generating target 16 is located; The x-ray generating target is electrically connected to the high voltage element; the apparatus also comprises a suppressive electrode 19 arranged at the end portion of the insulating element; the suppressive electrode suppresses acceleration towards the insulating element of electrons which are emitted from a junction between the insulating element and the conductive wall. High voltage breakdown is prevented. The apparatus may comprise an electron beam apparatus arranged to accelerate a beam of electrons towards an x-ray generating target. The suppressive (flowerpot) electrode may be connected to the high voltage element and extends towards the conductive wall. The suppressive electrode may have a thickened or rounded region.



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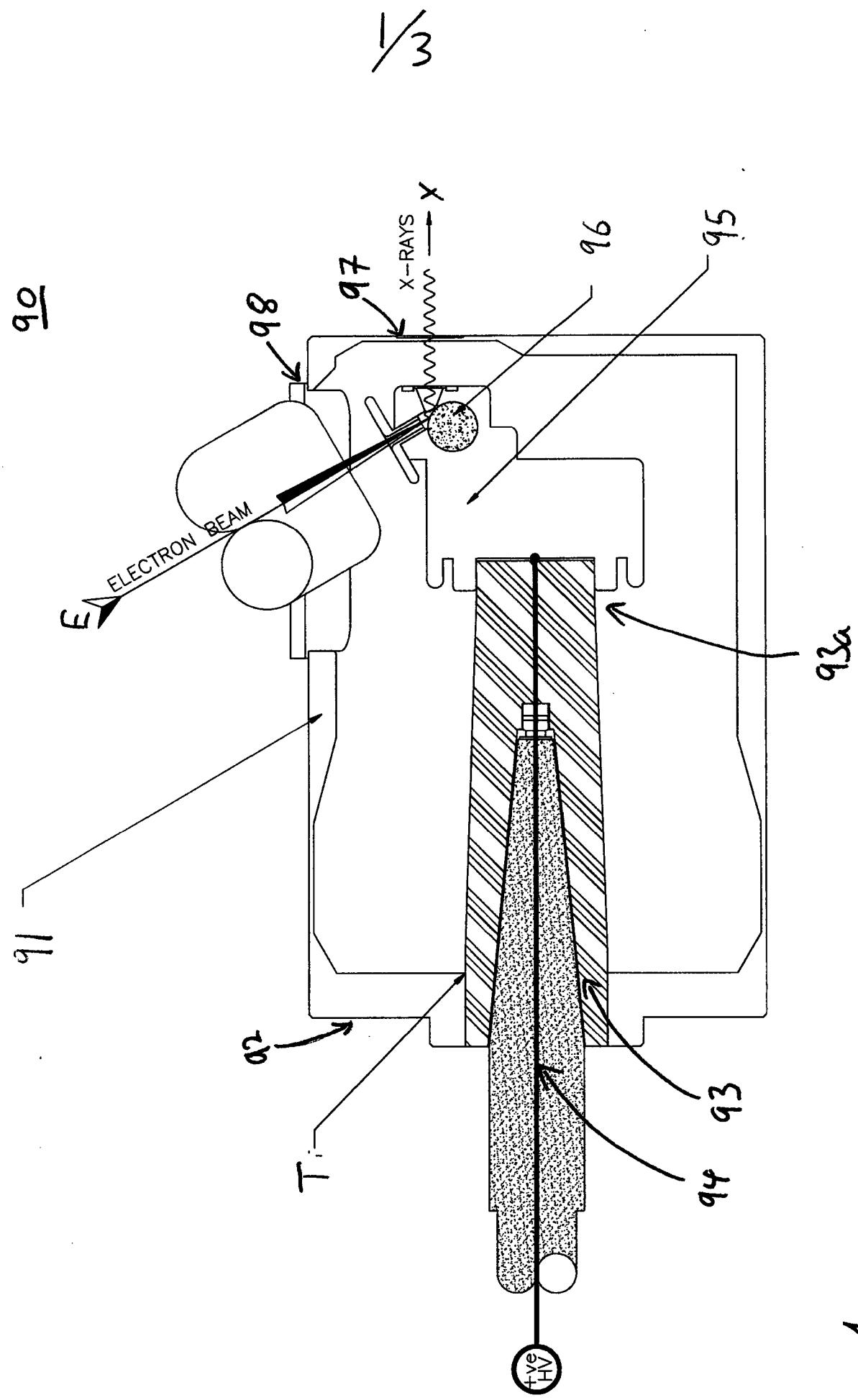
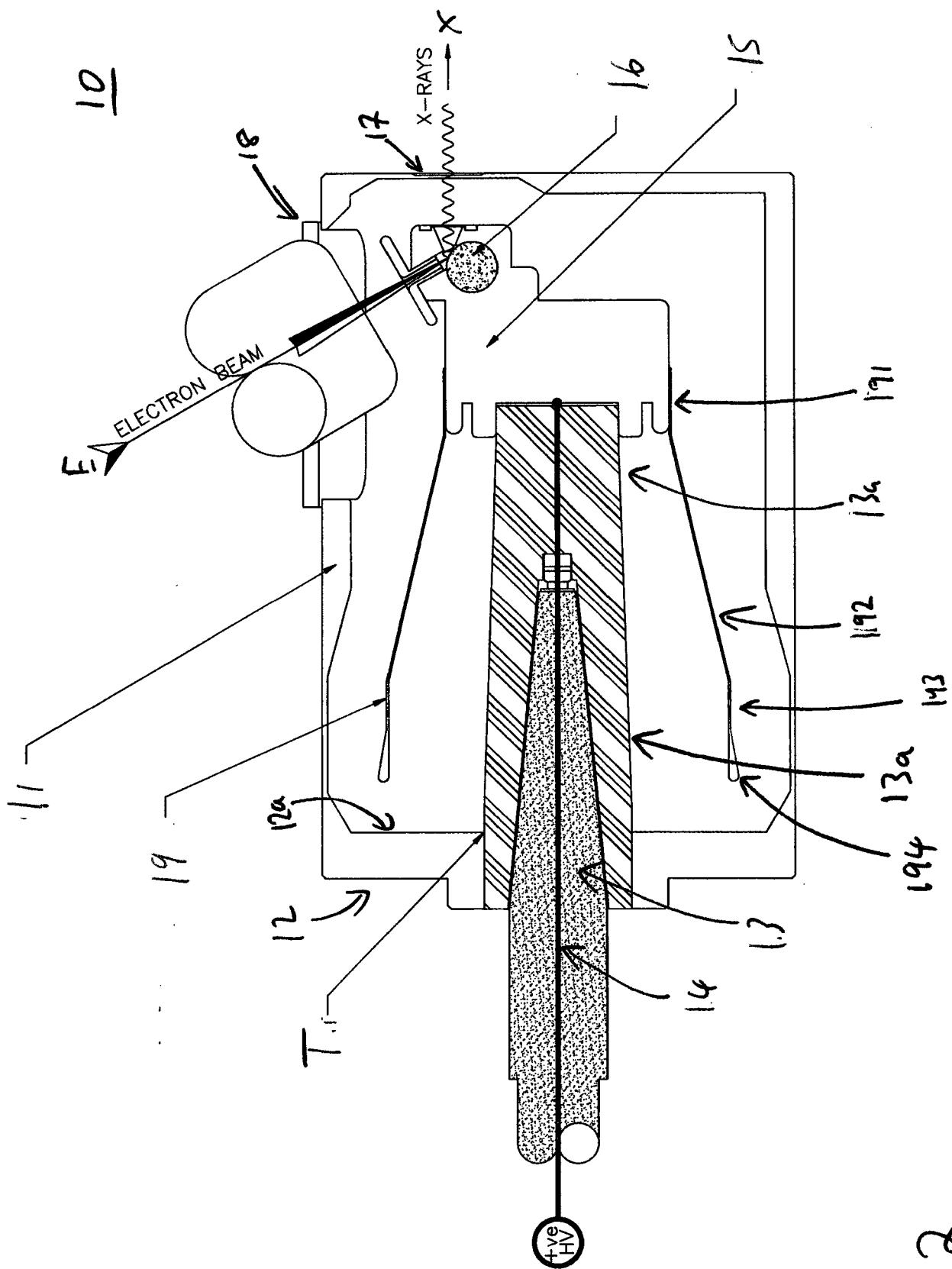


Fig 1

2/3



2  
E 5

3/3

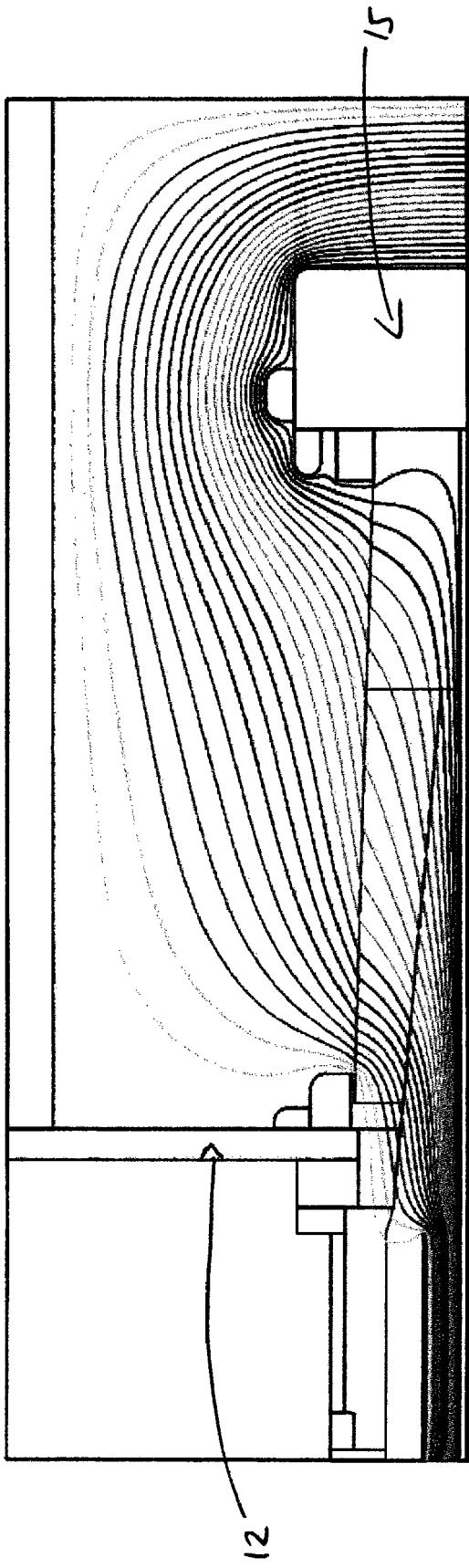


Fig 3a

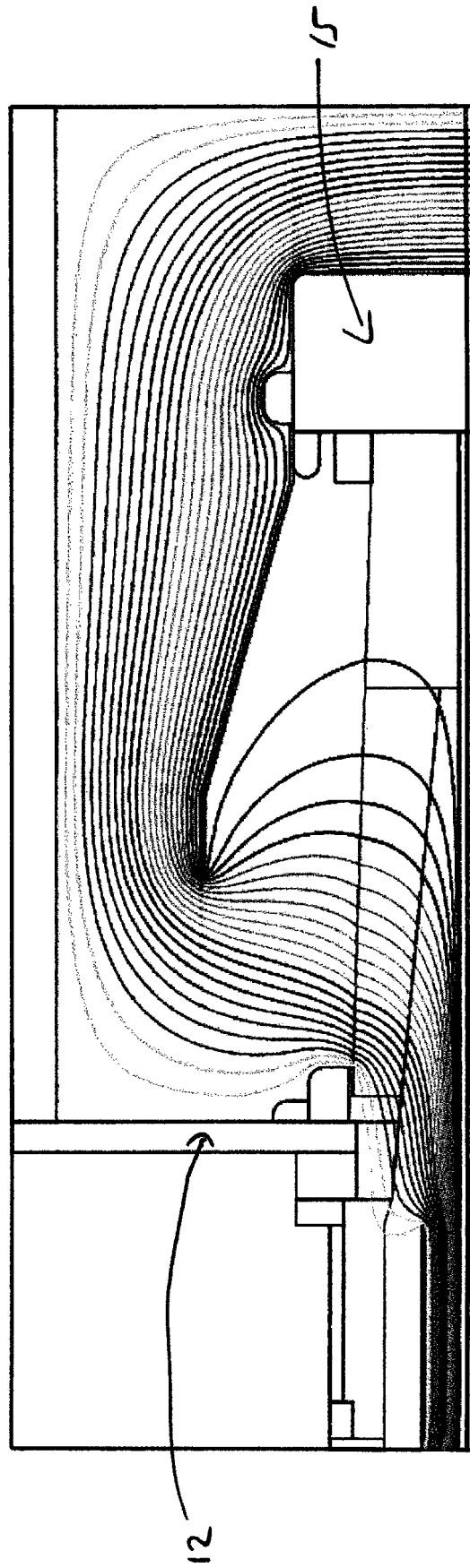


Fig 3b

TARGET ASSEMBLY FOR AN X-RAY EMISSION APPARATUS AND  
X-RAY EMISSION APPARATUS

5

Technical Field

The present disclosure relates to x-ray emission apparatuses and particularly to target assemblies for such apparatuses.

10 The present disclosure provides target assemblies which are able to achieve higher x-ray emission energies by elevating the electrical potential of the x-ray emission target relative to ground.

15 Background

In x-ray imaging, metrology and spectroscopy systems, there is often a need to achieve emission of x-ray beams with relatively higher x-ray energy, that is, with shorter x-ray wavelength. Such beams can provide improved resolution-ray penetration, and hence improved contrast and resolution, especially when used in imaging apparatuses, and particularly in microfocus imaging apparatuses.

25 In x-ray emission apparatuses, x-ray emission is achieved by bringing a beam of accelerated electrons into interaction with a target of an x-ray generating material, usually a metal with a relatively high atomic number (Z) such as tungsten. The electrons are accelerated by emission from a 30 source of relatively more negative electrical potential than the target, such that the electrons emitted from the source accelerate away from the source toward the target. Thermionic emission, for example, may be used to generate appropriate electrons for acceleration.

35

Electron beam generation and x-ray emission is usually performed under high vacuum conditions, because the presence of air in an electron beam apparatus can cause absorption of the electron beam and can prevent the maintenance of the high 5 potential differences required to produce high-energy electrons, and thereby x-rays. However, even in an ultra-high vacuum system, there is a difficulty in achieving increasingly greater accelerating potentials, because increasing the potential of the source relative to the walls 10 of the vacuum chamber in which it is enclosed increases the risk of vacuum breakdown and dissipation of the high potential difference, leading to failure. This can be mitigated to some degree by increasing the size of the vacuum chamber, but this renders the apparatus bulky, expensive and 15 difficult to manufacture.

Accordingly, it has been proposed in a modified form of x-ray system to have a high negative potential difference between the electron source and the walls of the vacuum chamber and a 20 high positive potential difference between the walls of the vacuum chamber and the x-ray target. In such a design, sometimes called a bipolar system, the electron beam is not only accelerated away from the electron source, but is accelerated toward the target. The total accelerating 25 potential is the difference in potential between the source and the target, but the apparatus can be smaller as compared with a conventional apparatus because the potential difference between each of i) the source and the chamber and ii) the chamber and the target is much less than the total 30 accelerating potential. Accordingly, the risk of vacuum breakdown is mitigated. Further, a magnetic focussing lens that is conventionally held at ground potential may be interposed in the beam tunnel between the negative cathode electrode and the positive target.

35

However, in realising such configurations, there has been a problem in stability of the positive part of the apparatus,

namely that portion of the apparatus which contains the high-voltage target.

A candidate configuration for such a target assembly is shown  
5 in cross-section in Fig. 1. In Fig. 1, target assembly 90 has  
a vacuum chamber 91 which defines an enclosure for the target  
apparatus. Vacuum chamber 91 is adapted to maintain a  
sufficiently high vacuum, typically  $10^{-5}$  mbar or better. Such  
vacuums may be achieved by ensuring that the enclosure is  
10 suitably vacuum-sealed, and then by applying a suitable  
vacuum pump, such as a turbo pump, to a pump port (not  
shown). High vacuum is necessary to support the electron  
beam.

15 The vacuum chamber 91 is held at ground potential, by a  
connection to ground (not shown).

At least one wall 92 is conductive, and advantageously the  
entire enclosure is conductive to avoid static accumulation.  
20 A suitable conductive material for forming the at least one  
conductive wall 92, and also the whole vacuum chamber 91, is  
aluminium.

A slightly tapered, rod-like insulating element 93 projects  
25 through conductive wall 92 of vacuum chamber 91. Insulating  
element 93 may be formed, for example of an insulating resin  
such as epoxy resin or polyetherimide (PEI) resin. Insulating  
element 93 contains a high voltage conductor 94 arranged  
coaxially with the insulating elements, which may be  
30 connected to a high voltage supply positioned outside chamber  
91.

In the configuration shown in Fig. 1, insulating element 93  
and conductor 94 each have a two-part construction, to enable  
35 easy coupling and decoupling of the chamber from the high  
voltage source. Insulating element 93 may, for example, be  
formed by a combination of a first tapered rod, having an

internal tapered cavity formed within the first tapered rod, and a second tapered rod having external taper to match the internal taper of the first tapered rod so as to be accommodated within the first tapered rod. The conductor 94 5 may, for example, then be provided with a first part in the second tapered rod, and a second part within the first tapered rod. The first and second parts of the conductor may mate via a conductive coupler when the second tapered rod is accommodated in the cavity of the first tapered rod. However, 10 such a configuration is not essential, and insulating element 93 and conductor 94 can each be of unitary construction.

Insulating element 93 supports, at an end portion 93a which is furthest from conductive wall 92, target housing 95. 15 Target housing 95 is electrically connected to high voltage conductor 94. The high voltage carried on conductor 94 is exposed to the vacuum contained within chamber 91 at this point. Housing 95 supports x-ray generating target 96 and elevates x-ray generating target 96 to the high potential of 20 conductor 94 by providing an electrical connection between conductor 94 and target 96.

In this configuration, housing 95 is made of a radiodense material, for example an 80% tungsten / 20% copper alloy. 25 Housing 95 has a cone-shaped opening to allow the generated x-rays, which have been generated by x-ray generating target 96, to emerge. This approach is able to limit the x-rays to a cone-shaped beam that is just large enough to illuminate a detector with which the apparatus is intended to operate at 30 its intended position and orientation. Such an approach may reduce unwanted x-ray scatter, which may improve contrast. Such an approach may also reduce the thickness of any shielding need for parts of the apparatus that are not arranged along the direction of x-ray beam X.

35

The cone-shaped aperture may be closed by a thin transparent window, formed of, for example, a thin sheet of radiolucent

material such as aluminium or beryllium to avoid gas, which has been generated by x-ray generating target 96 under irradiation by electron beam E, being ejected into the space between target housing 95 and an opposing wall of chamber 91,  
5 in which space a high electric field may be present. Such an approach may also therefore improve stability against gas-induced vacuum breakdown.

In this configuration, the target housing 95 is also provided  
10 with an entrance tunnel through which the electron beam E is able to reach the x-ray generating target 96. The entrance tunnel may have a deliberately reduced diameter. Such a configuration may provide a throttle to impede the gas which may be ejected from x-ray generating target 96 as described  
15 above.

Chamber 91 has an x-ray emission window 97 arranged adjacent to x-ray generating target 96 so that x-rays X generated from the target can exit the chamber while preserving the high  
20 vacuum in the chamber. Such a window may be made, for example of a thin sheet of a material which is radiolucent (or transparent to x-rays) such as aluminium or beryllium. Target 96 is made of a high-atomic number (high-Z) material such as tungsten, which is able to generate x-rays when irradiated  
25 with a suitably high-energy electron beam.

Chamber 91 also has an electron beam acceptance aperture 98 through which an electron beam E may be introduced so as to impinge on x-ray generation target 96. Electron beam  
30 acceptance aperture 98 may have a mounting arrangement, not shown, adapted to couple target assembly 90 to an electron-beam gun so as to form a unitary vacuum chamber in a so-called two-arm arrangement. Such a mounting arrangement may include, for example, high vacuum seals arranged between an  
35 exit port of the electron-beam generator and beam introduction aperture 98 of target assembly 90.

In operation, target assembly 90 of Fig. 1 accepts an electron beam through aperture 98, which impinges on target 96, thereby generating x-rays X which are emitted through window 97. Target 96 is maintained at an elevated voltage via  
5 the electrical connection, through target housing 95, with conductor 94, which is supported within vacuum chamber 91 by insulating element 93 which extends through conductive wall 92 of the vacuum chamber 91. By such an arrangement, the incident electron beam through aperture 98 can be further  
10 accelerated by the high positive potential of target 96 derived from conductor 94. Higher-energy X-rays may thereby be produced.

However, the configuration shown in Fig. 1 may exhibit a  
15 disadvantage in that, when the conductor 94 carries a high positive potential, a high potential gradient exists between conductor 94 and the surrounding chamber 91, especially conductive wall 92. Although insulating element 93 prevents the vacuum enclosed within vacuum chamber 91 from contacting  
20 conductor 94, and hence isolates conductor 94 from the vacuum, electrons are emitted from the most negative surface in the chamber, which electrons can multiply or avalanche as they interact with the surface of the insulating element that separates the most positive electrode, namely conductor 94,  
25 from the rest of the chamber. These processes can lead to an ionised path being created that allows a high voltage breakdown, with a convergent rapid discharge of the energy stored within the high-voltage-generating elements of the target assembly. In the configuration of Fig. 1, the  
30 conductive wall 92 of the housing, at least, acts as a strongly negative electrode creating a very large area that can provide a copious source of electrons.

Especially, at the interface T between i) the insulating  
35 element 93, ii) the metal wall 92 of the vacuum chamber, and iii) the vacuum, the potential barrier is lower and electrons easily escape from the metal into the vacuum. These electrons

are accelerated towards the insulating element surface where they accumulate, causing the insulating element surface to become locally negatively charged, but also causing the release of multiple secondary electrons, especially if the 5 incident electrons have energy significantly above 100eV. These secondary electrons are also accelerated and cause further charging of the insulating element, as they "hop" progressively along the length of insulating element 93 towards target housing 95. This process leads to surface 10 degassing of insulating element 93. The local gas cloud so produced may eventually become ionised by the avalanche electrons, creating a gas plasma channel through which the stored electrical energy and the high voltage system may suddenly and violently be discharged.

15

Such a discharge inhibits the maintenance of a stable high voltage source, and may be highly damaging to the apparatus.

Accordingly, there is a requirement for an improved target 20 assembly which is able to inhibit such processes and which is able to maintain a high, stable, positive potential between the target and the enclosing vacuum chamber.

#### Summary

25

According to a first aspect of the invention, there is provided a target assembly for an x-ray emission apparatus. The apparatus may comprise a vacuum chamber. The vacuum chamber may have at least one conductive wall. The apparatus 30 may comprise an insulating element. The insulating element may project through the conductive wall. The apparatus may comprise a high voltage element. The high voltage element may extend along the insulating element. The high voltage element may extend from outside the chamber. The high voltage element 35 may extend to an end portion of the insulating element furthest from the conductive wall. The apparatus may comprise an x-ray-generating target. The x-ray-generating target may

be arranged at the end portion of the insulating element. The x-ray generating target may be electrically connected to the high voltage element. The apparatus may comprise a suppressive electrode. The suppressive electrode may be  
5 arranged at the end portion of the insulating element. This suppressive electrode may be configured to suppress acceleration towards the outer surface of the insulating element of electrons which are emitted from a junction between the outer surface of the insulating element and an  
10 inner surface of the conductive wall.

In one configuration, the suppressive electrode may be electrically connected to the high voltage element.

15 In one configuration, the suppressive electrode may extend from the end portion of the insulating element toward the conductive wall.

20 In one configuration, the suppressive electrode may surround at least part of the length of the insulating element.

In one configuration, the suppressive electrode may have a tapered portion which is tapered outwardly from the end portion of the insulating element.

25 In one configuration, the suppressive electrode may have a parallel portion nearest the conductive wall which is parallel to the outer surface of the electrode.

30 In one configuration, the suppressive electrode may be formed of a sheet.

In one configuration, the suppressive electrode may be formed of metal.

35 In one configuration, the high voltage element may be a conductor.

In one configuration, the suppressive electrode may have a thickened region at an end portion nearest the conductive wall.

5

In one configuration, an edge of the suppressive electrode which faces the conductive wall may be rounded.

10 In one configuration, the x-ray-generating target may be supported in a target housing.

In one configuration, the suppressive electrode may extend from the target housing.

15 In one configuration, the vacuum chamber may have an aperture for accepting an electron beam.

20 In one configuration, the vacuum chamber may have an aperture for passing x-rays generated from the x-ray-generating target.

In one configuration, the conductive wall may have a flat inner surface.

25 In one configuration, the high voltage element may be arranged to provide a potential of at least +100kV relative to the conductive wall.

30 In one configuration, the high voltage element may be arranged to provide a potential of at least +150kV relative to the conductive wall.

35 In one configuration, the high voltage element may be arranged to provide a potential of at least +200kV relative to the conductive wall.

In one configuration, the conductive wall may be arranged to be earthed.

According to a second aspect of the present invention, there  
5 is provided an x-ray emission apparatus. The x-ray emission apparatus may comprise the target assembly of the first aspect. The apparatus may comprise an electron beam apparatus. The electron beam apparatus may be arranged to accelerate a beam of electrons towards an x-ray generating  
10 target. The x-ray emission apparatus may thereby generate x-ray radiation.

Brief description of the drawings

15 For a better understanding of the present invention, and to show how the same may be carried into effect, reference will be made, by way of example only, to the accompanying drawings, in which:

20 Figure 1 shows an example of an x-ray-emission target assembly in cross-section which is relatively more susceptible to HV (high voltage) breakdown;

25 Figure 2 shows an embodiment of an x-ray-emission target assembly in cross-section which is relatively less susceptible to HV breakdown.

Figure 3a is a equipotential diagram relating to the assembly of Figure 1; and

30 Figure 3b is an equipotential diagram relating to the assembly of Figure 2.

Detailed description

35 One embodiment of the present disclosure is shown in Fig. 2 in cross-section. Fig. 2 shows a target assembly for an x-ray

emission apparatus of similar construction to the configuration shown in Fig. 1. Elements having reference numerals of the form 9x in Fig. 1 are given reference numerals of the form 1x in Fig. 2 and may be assumed to be of 5 substantially identical construction. For an understanding of the construction and operation of these aspects of the embodiment of Fig. 2, reference is made to the disclosure with regard to Fig. 1 above.

10 Unlike the configuration shown in Fig. 1, the embodiment shown in Fig. 2 is further provided with a suppressive electrode 19. The suppressive electrode 19 is arranged at the end portion 13a of insulating element 13 and extends toward conductive wall 12. The suppressive electrode may be referred 15 to as a "flowerpot" by those skilled in the art, due to its resemblance in shape to the common garden container as shown in Fig. 2. However, such a designation is considered to be non-limiting as, as explained below, variation in the shape and geometry of suppressive electrode 19 is possible which 20 retaining at least some of the advantages of the same.

In the present embodiment, therefore, suppressive electrode 19 is formed of four principal sections. A first section is approximately cylindrical, and surrounds target assembly 15, 25 thereby to provide a good structural and electrical connection thereto. This portion is indicated as cylindrical support portion 191 in Fig. 2.

Extending away from cylindrical support portion 191 toward 30 conductive wall 12 is conical tapered portion 192. Tapered portion 192 is tapered or flared outwardly as it extends away from housing 15 toward conductive wall 12. Therefore, the suppressive electrode 19 is progressively spaced further from the outer surface of insulating element 13 as suppressive 35 electrode 19 approaches conductive wall 12.

Extending from tapered portion 192 is cylindrical parallel portion 193.

Extending from parallel portion 193 towards wall 12 is  
5 thickened region 194, which is thickened and rounded at the  
edge at which suppressive electrode 19 approaches conductive  
wall 12. Thickened region 194 can be formed, for example, as  
a thickened solid region by thickening and/or rounding the  
material from which suppressive electrode 19 is made, or  
10 alternatively, for example, by folding the material, from  
which suppressive electrode 19 is made, back on itself to  
form a rounded end.

The configuration of suppressive electrode 19 shown in Fig. 2  
15 has been found to be especially effective in suppressing the  
acceleration, toward the outer surface of insulating element  
13, of electrons which are emitted from the triple junction T  
between the outer surface of the insulating element 13, the  
inner surface 12a of conductive wall 12, and the vacuum  
20 enclosed by vacuum chamber 11.

However, variation in the geometry, shape and construction of  
suppressive electrode 19 is possible, as those skilled in the  
art will appreciate.

25 In the configuration of Fig. 2, the suppressive electrode 19  
is electrically connected to the high voltage conductor 14.  
This provides particularly effective suppression of the  
acceleration of electrons from the triple junction T.  
30 However, it is possible for the electrode to be at a  
different potential, as required, for example due to the  
presence of a resistive element between high voltage  
conductor 14 and suppressive electrode 19, which may act as a  
voltage divider.

35 In Fig. 2, the suppressive electrode 19 extends from the end  
portion of the insulating element 13 toward the conductive

wall. A gap exists between the thickened edge region 194 of suppressive electrode 19 and conductive wall 12. In other configurations, this gap may be increased or decreased as required.

5

In the configuration of Fig. 2, the suppressive electrode 19 surrounds part, but not all, of the length of insulating element 13, such that a gap exists between thickened region 194 and conductive wall 12. However, the proportion of the 10 length of the insulating element, as well as the absolute size of the gap between the conductive wall 12 and the thickened region 194, may be varied in accordance with the overall design of the apparatus.

15 In the configuration of Fig. 2, tapered portion 192 is provided which tapers outwardly from the end portion 13a of insulating element 13. A taper angle of tapered portion 192 is around 12 degrees in the present embodiment, although variation of the taper angle may be adopted by for example 20  $\pm 10$  degrees, without limitation. In some situations, a tapered portion may not be provided, and the suppressive electrode may, for example, be of cylindrical form. In other configurations, the tapered portion may be tapered inwardly.

25 In the configuration of Fig. 2, the suppressive electrode has a parallel portion 193 extending from tapered portion 192 towards conductive wall 12. In variant embodiments, this portion may be extended, or may be absent. Where present, it need not be strictly parallel, but may for example also be 30 tapered inwardly or tapered outwardly.

In the configuration shown in Fig. 2, the suppressive electrode 19 is formed from a sheet of metal, specifically aluminium. For example, suppressive electrode 19 may be 35 formed from machined or spun aluminium. Other conductive materials, such as copper foil, could also be contemplated. Such a configuration provides good structural properties as

well as good electrical conductivity. However, in other configurations, the electrode may be formed of a sheet of metal mesh, for example, which may reduce material usage and weight, and may be easier to form.

5

In the configuration shown in Fig. 2, suppressive electrode 19 has a thickened region 194 nearest to conductive wall 12. Such a thickened region may avoid concentrating the electric field and thus may reduce the possibility of vacuum breakdown 10 between the electrode 19 and wall 12. However, in other configurations, this thickened portion may be absent. In the configuration of Fig. 2, the thickened portion has a rounded end, although again this rounded end may be absent as it may not be required in certain configurations of vacuum chamber.

15

In the configuration of Fig. 2, the x-ray-generating target 16 is arranged in a target housing 15, and is offset relative to the central axis 14 defined by conductor 14. However, this configuration is exemplary, and the location of target 16 may 20 differ. The position of target 16 shown in Fig. 2 is in some cases advantageous for easy accessibility of target 16 to the incident electron beam entering through aperture 18.

In the configuration shown in Fig. 2, the suppressive electrode 19 extends from target housing 15. However, suppressive electrode 19 may in certain circumstances extend directly from insulating element 13, or may be provided on a separate support structure around insulating element 13 other than target housing 15.

30

In the configuration of Fig. 2, the suppressive electrode 19 is symmetric about the axis of conductor 14. However, such symmetry may not be required, and suppressive electrode may, for example, exhibit an oval, rather than rounded, cross-35 section looking along the axis of conductor 14, or may exhibit another cross section looking in this direction, for

example to take account of possible variations in the geometry of chamber 11.

In the configuration shown in Fig. 2, the vacuum chamber 11 has an aperture 18 for accepting an electron beam into the vacuum chamber to impinge upon target 16 in a so-called two-arm arrangement. However, in other configurations, the vacuum chamber may also enclose an electron beam emission source, together with one or more appropriate electron-optical lenses (including, for example, magnetic lenses and electrostatic lenses), beam shapers and the like so as to form a complete system within one chamber 11. Accordingly, the configuration of Fig. 2 is modular and can be retrofitted to an existing electron beam generation apparatus, but the principles can equivalently be applied to a non-modular system wherein all elements are contained within the one unitary vacuum enclosure.

In the configuration shown in Fig. 2, the vacuum chamber has an x-ray emission window 17 for passing x-rays to a sample or other object under investigation. The presence of a solid window across aperture 17 allows the sample to be external to the chamber 11, such that the sample may be held in an atmosphere, rather than in a vacuum. However, in other configurations, it is acceptable to arrange the entire x-ray system, including a sample mount and a detector for the x-ray radiation having passed through the sample, within a unitary vacuum chamber 11.

In the configuration shown in Fig. 2, the inner surface 12a of conductive wall 12 is flat, and extends perpendicular to outer surface 13a of insulating element 13. Such configuration is advantageous in avoiding high potential gradients within the vacuum chamber 11. However, other configurations are possible in which wall 12a is, for example, curved inwardly or outwardly.

In the configuration shown in Fig. 2, the high voltage conductor 14 is arranged to provide a positive potential of, for example, at least +100kV relative to the conductive wall. However, with increasing voltage, the advantage of target 5 potential elevation in terms of achieving higher electron beam energies is increased, but so too is the risk of vacuum breakdown and instability. Accordingly, the presence of suppressive electrode 19 becomes even more advantageous at more elevated potentials, such as +150kV, +200kV, or even 10 higher, of the high voltage conductor 14 relative to conductive wall 12.

In the configuration shown in Fig. 2, the conductive wall 12 is arranged to be earthed, although in some circumstances it 15 may be desirable to adjust the potential of the conductive wall 12 relative to earth to obtain a favourable balance between the potential on high voltage conductor 14 and the potential on conductive wall 12, as well as the potential of any components of the electron beam generation side of the 20 electron beam apparatus, such as an electron-emitting cathode. In other embodiments, a favourable balance may be obtained by adjusting the share of the total accelerating voltage borne by target 16 relative to earth and that borne by an emitting cathode, for example.

25 In the configuration shown in Fig. 2, a high voltage conductor 14 provides the high positive potential to target 16. Accordingly, a high voltage must be provided to high voltage conductor 14 outside chamber 11, which is sustained 30 long its full length. However, in an alternative configuration, an alternative high voltage element, such as a voltage multiplier, for example a Cockcroft-Walton voltage multiplier, may be used to at least partially develop the high voltage progressively along the length of insulating 35 element 13 on the basis of a lower drive voltage applied from outside the chamber. Even though such a situation may result in a reduced field at the triple junction T as compared with

the situation of a high voltage conductor, the provision of a suppressive electrode as herein disclosed may be beneficial in suppressing any electron emission from the triple junction which may result.

5

The embodiment of Fig. 2 is shown accepting an electron beam through aperture 18. However, an embodiment of the apparatus includes an embodiment wherein an electron beam apparatus is coupled to electron acceptance aperture 18 to provide a 10 complete x-ray emission apparatus.

Many variations are possible within the scope of the embodiment disclosed in connection with Fig. 2, without deviating from the essential principles of the invention 15 herein disclosed. Such variants may be made using only routine workshop trial and error for the optimum configuration for any given geometry of vacuum chamber 11, insulating element 13 and conductor 14.

20 Now, an explanation will be made of at least one advantage which may be achieved with a suppressive electrode as herein disclosed and exemplified by the embodiment of Fig. 2, or variants thereof, with reference to the equipotential lines achieved in the absence of and presence of, respectively, 25 suppressive electrode 192.

In Fig. 3a, the configuration of Fig. 2 is shown in cross-section, suppressive electrode 19 having been removed. The configuration is thus similar to Fig. 1. Equipotential lines 30 arising from a +220kV potential on high voltage conductor 14 are also shown, at 10kV intervals.

As can be seen in Fig. 3a, along almost the entire length of 35 insulating element 13, there is a very significant component of the electric field (which crosses the equipotential lines at right angles) into the outer surface of the insulating element 13. Accordingly, any electrons emitted from triple

junction T, regardless of their angle of emission, will be captured by the positive potential and will be accelerated toward the surface of the insulating element, potentially giving rise to instability and discharge.

5

In contrast, when a suppressive electrode is used as shown in Fig. 3b, corresponding to the configuration of Fig. 2, the component of the electric field directed toward the insulating element 13, at least for the first part of the 10 insulating element extending from wall 12, is much reduced. Therefore, the tendency is for electrons to be accelerated along, rather than into, insulating element 13.

Further, within the opening defined by thickened portion 194 15 of suppressive electrode 19, the electric field direction gradually changes from a slight inclination toward insulating element 13 to a significant inclination away from insulating element 13, toward suppressive electrode 19.

20 Thus, suppressive electrode 19 is not only able to divert the emitted electrons away from the surface of insulating element 13, but is also able to capture the diverted electrons.

25 Yet further, within the opening defined by thickened portion 194 of suppressive electrode 19, the equipotential lines become relatively greater in spacing one from another, indicating a reduction in electric field strength along the length of the surface of insulating element 13, at least, in this region.

30

Thus, suppressive electrode 19 is also able to reduce the accelerating field experienced by the emitted electrons in this region.

35 Again, it can be appreciated from Fig. 3b that variations in the shape and geometry of suppressive electrode 19 will allow the same effect to be maintained, and may in some circumstances be advantageous for accommodating different

geometries of enclosure, target housing and other elements of the system. However, such variations can easily be adopted by the skilled person using basic electron optical principles, once the importance of suppressive electrode 19 as a concept 5 is recognised.

Accordingly, the configuration in Fig. 2 and its variants hereby described and claimed provides at least a solution to the technical problem of avoiding high voltage breakdown in 10 bipolar x-ray systems having a negative-potential emission source and a positive-potential target. Such configuration can thus achieve higher working electron voltages, and thus x-ray beam energies, leading to improved x-ray penetration, and hence improved contrast and resolution especially in 15 microfocus x-ray imaging systems.

Claims

1. A target assembly for an x-ray emission apparatus, the apparatus comprising:

5 a vacuum chamber having at least one conductive wall; an insulating element projecting through the conductive wall;

10 a high voltage element extending along the insulating element from outside the chamber to an end portion of the insulating element furthest from the conductive wall;

15 an x-ray-generating target arranged at the end portion of the insulating element and electrically connected to the high voltage element; and

20 a suppressive electrode arranged at the end portion of the insulating element and configured to suppress acceleration toward the outer surface of the insulating element of electrons which are emitted from a junction between the outer surface of the insulating element and an inner surface of the conductive wall.

20

2. The target assembly of claim 1, wherein the suppressive electrode is electrically connected to the high voltage element.

25 3. The target assembly of claim 1 or 2, wherein the suppressive electrode extends from the end portion of the insulating element towards the conductive wall.

30 4. The target assembly of claim 1, 2 or 3, wherein the suppressive electrode surrounds at least a part of the length of the insulating element.

35 5. The target assembly of any preceding claim, wherein the suppressive electrode has a tapered portion which is tapered outwardly from the end portion of the insulating element.

6. The target assembly of any preceding claim, wherein the suppressive electrode has a parallel portion nearest the conductive wall which is substantially parallel to the outer surface of the electrode.

5

7. The target assembly of any preceding claim, wherein the suppressive electrode is formed of a sheet.

8. The target assembly of any preceding claim, wherein the  
10 suppressive electrode is formed of metal.

9. The target assembly of any preceding claim, wherein the high voltage element is a conductor.

15 10. The target assembly of any preceding claim, wherein the suppressive electrode has a thickened region at an end nearest the conductive wall.

20 11. The target assembly of any preceding claim, wherein an edge of the suppressive electrode which faces the conductive wall is rounded.

12. The target assembly of any preceding claim, wherein the x-ray-generating target is supported in a target housing.

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13. The target assembly of claim 12, wherein the suppressive electrode extends from the target housing.

30 14. The target assembly of any preceding claim, wherein the vacuum chamber has an aperture for accepting an electron beam.

35 15. The target assembly of claim 12 or 13, wherein the vacuum chamber has an aperture for passing x-rays generated from the x-ray-generating target.

16. The target assembly of any preceding claim, wherein the conductive wall has a flat inner surface.

17. The target assembly of any preceding claim, wherein the 5 high voltage element is arranged to provide a potential of at least +100kV relative to the conductive wall.

18. The target assembly of any preceding claim, wherein the 10 high voltage element is arranged to provide a potential of at least +150kV relative to the conductive wall.

18. The target assembly of any preceding claim, wherein the high voltage element is arranged to provide a potential of at least +200kV relative to the conductive wall.

15 19. The target assembly of any preceding claim, wherein the conductive wall is arranged to be earthed.

20 20. An x-ray emission apparatus comprising:  
the target assembly of any preceding claim, and  
an electron beam apparatus arranged to accelerate a beam  
of electrons toward the x-ray-generating target, thereby to  
generate x-ray radiation.

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**Examiner:** Mr Jorge Quintero

**Claims searched:** 1-20

**Date of search:** 20 June 2016

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	WO 2008/062519 A1 TAMURA TOMOMI et al - See whole document.
A	-	EP 0634885 A1 NAKAMURA TSUTOMU et al - See Figures 2-5 and related description.
A	-	WO 2009/006592 A2 KLINKOWSTEIN et al - See whole document.
A	-	US 6125169 A WANDKE et al - See whole document.
A	-	US 6775354 B1 ROFFERS et al - See whole document.

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup> :

Worldwide search of patent documents classified in the following areas of the IPC

H01J

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, TXTA, INSPEC, NPL, XPAIP, XPESP, XPETSI, XPI3E, XPIEE, XPIETF, XPIOP, XPIPCOM, XPSPRNG



**International Classification:**

Subclass	Subgroup	Valid From
H01J	0035/16	01/01/2006
H01J	0005/06	01/01/2006