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(54) **X-RAY SOURCE WITH TEMPERATURE CONTROLLER**

(57) An X-ray source (100) is disclosed, comprising a liquid target source (110) configured to provide a liquid target (J) passing through an interaction region (I). The X-ray source further comprises an electron source (120) configured to provide an electron beam (E) directed towards the interaction region such that the electron beam interacts with the liquid target to generate X-ray radiation, a housing (130) separating the interaction region from an ambient region, and a temperature controller (140) adapted to control a surface temperature of at least a portion of an inner wall (132) of the housing. The surface temperature is controlled such that it is sufficient to liquefy material that stems from the liquid target and has been deposited on the portion of the inner wall.

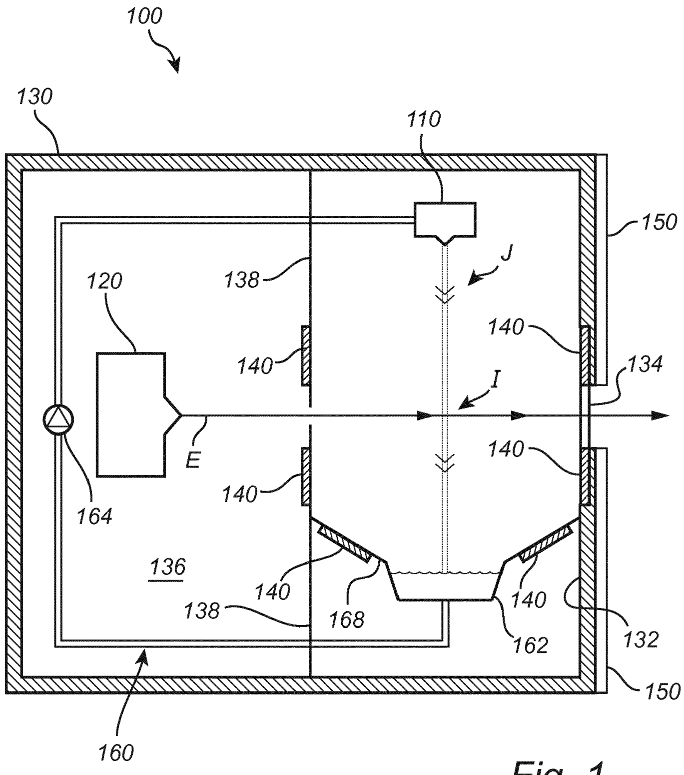

Fig. 1

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Description

Technical field

[0001] The invention disclosed herein generally relates to an electron impact X-ray source comprising a liquid anode. In particular, the invention relates to techniques for controlling the liquid anode material within a housing of the X-ray source, and to solutions allowing recirculation of the liquid anode material.

Background

[0002] X-rays may be generated by directing an electron beam onto a liquid target. In such systems, an electron source comprising a high-voltage cathode is utilized to produce an electron beam that impinges on a liquid target, which preferably may be formed by a jet of liquid metal provided inside a vacuum chamber. The position in space wherein a portion of the liquid jet is hit by the electron beam during operation is referred to as the interaction region or interaction point. The X-ray radiation generated by the interaction between the electron beam and the liquid target jet may leave the vacuum chamber through an X-ray window separating the vacuum chamber from the ambient atmosphere.

[0003] However, it has been a challenge to devise a liquid anode X-ray source that can operate for extended periods of time without interruptions for maintenance. For example, in previous X-ray sources using a liquid target, an operator has been required to halt the generation of X-rays in order to change or refill a target supply container.

Summary

[0004] It is an object of the present invention to provide an X-ray technology addressing at least some of the above shortcomings. A particular object is to provide an X-ray source and method that allows for improved control and recirculation of the material forming the liquid target.

[0005] By way of introduction, the context and some challenges relating to X-ray sources utilizing liquid targets will be briefly discussed.

[0006] An X-ray source of the mentioned type includes an electron source, such as e.g. an electron gun, and a liquid target source configured to provide a liquid target passing through an interaction region. Typically, the liquid target material is a metal which preferably has a relatively low melting point. Examples of such metals include indium, gallium, tin, lead, bismuth and alloys thereof. The system for providing the liquid target may include pressurizing means, a jet nozzle and a replenishment arrangement for collecting the liquid material at the end of the jet. To allow continuous operation of the X-ray source, it is desirable to recover the liquid target material used for generating the X-rays and to reuse the material in a closed-loop fashion.

[0007] On a technological level, supply of the liquid target material in a closed-loop manner has been found to entail potential weaknesses. Debris and vapour stemming from e.g. the interaction between the electron beam and the liquid target result in material leaving the target and travelling through the chamber. If this material deposits on an inner wall of the vacuum chamber it may be more or less permanently lost from the circulation. Moreover, if liquid target material deposits or adsorbs to various surfaces such as e.g. the X-ray window, the electron source and other parts that are critical to the operation and performance of the X-ray source, the X-ray source may eventually need to be taken out of operation for maintenance and repair. These challenges are addressed and mitigated by the present invention.

[0008] Proposed herein, in accordance with a first aspect of the invention, is therefore an X-ray source comprising a liquid target source configured to provide a liquid target passing through an interaction region, and an electron source configured to provide an electron beam directed towards the interaction region such that the electron beam interacts with the liquid target to generate X-ray radiation. Further, the X-ray source comprises a housing for separating the interaction region from an ambient region, and a temperature controller adapted to control a surface temperature within the housing such that the surface temperature is sufficient to liquefy material that stems from the liquid target and has been deposited on the surface.

[0009] The surface, whose temperature may be controlled by the temperature controller, may be any surface or surface portion arranged in the chamber and onto which material of the liquid target may deposit or adsorb. The surface may e.g. be arranged on an aperture, electrode or collector arranged within the chamber, and/or form part of at least a portion of an inner wall of the housing. In some examples, the portion of the inner wall of the housing may refer to the housing structure in which the X-ray window is arranged, or to the X-ray window itself. It should however be noted that a distinction is made between the X-ray window and the housing. The X-ray window may be fitted or framed in the housing, such that the X-ray window together with the housing forms an enclosure that delimits the chamber, or interaction region, from the surroundings.

[0010] According to a second aspect, a method for generating X-ray radiation from an X-ray source according to the first aspect is proposed. The method comprises the following steps:

- providing the liquid target passing through the interaction region;
- directing the electron beam towards the interaction region such that the electron beam interacts with the liquid target to generate X-ray radiation; and
- recirculating material of the liquid target after the interaction with the electron beam, wherein the material of the liquid target is maintained at a temperature

sufficient to keep the material liquid during the recirculation.

[0011] It will be appreciated that the step of recirculating material of the liquid target may comprise liquefying material that stems from the liquid target and has been deposited or adsorbed on a surface arranged in the chamber, such that at least some of the material flows away from the surface. As discussed above, the surface may e.g. be arranged on an aperture, electrode or collector arranged within the chamber, and/or form part of at least a portion of an inner wall of the housing or the X-ray window. The liquefying may e.g. be achieved by controlling a temperature of the surface such that the temperature is sufficient to liquefy the material that has been deposited on the surface.

[0012] According to a third aspect, a method for preventing de-alloying in an X-ray source according to the first aspect is provided. The method comprises the steps of:

- providing the liquid metal target comprising an alloy of at least two metal elements, each having a respective melting point;
- directing an electron beam towards the liquid target such that the electron beam interacts with the liquid target to generate X-ray radiation; and
- preventing decomposition of debris, generated from the liquid target, on a surface arranged within the housing by keeping the temperature of said surface above the highest one of the respective melting points.

[0013] As stated above, the surface may be arranged as a separate part or element within the housing, and/or form part of at least a portion of the housing and/or X-ray window.

[0014] By liquefying liquid target material that has been deposited or adsorbed on surfaces in the chamber of the X-ray source, the material may be transported away from these surfaces and collected for reuse or removal from the system. Thus, the present inventive concept allows for an X-ray source having an increased uptime during which X-ray radiation may be generated without the need of maintenance or repair. By liquefying material that has been deposited within the chamber, the material may flow away from the surface, such that accumulation of material on the surface may be avoided or at least reduced. Further, in case the material comprises an alloy of two or more metal elements having different melting points, the temperature may be kept above the highest one of the respective melting points so as to prevent the deposited material, or debris, from decomposing into its constituents as it is recycled. Thus, the quality and composition of the material of the liquid target may be maintained during the recycling.

[0015] The material that stems from the liquid target may be present in the chamber as particles or vapour, of which at least some may eventually deposit or adsorb onto surfaces within the chamber. The terms 'particles' and 'vapour' may thus refer to free particles, including debris, droplets, ions, and atoms, that may be generated during operation of the X-ray source. Further, particles such as e.g. debris may be generated by e.g. splashing, heavy impacts or turbulence of the liquid target.

[0016] The term 'liquid target' or 'liquid anode' may, in the context of the present application, refer to a liquid jet, a stream or flow of liquid being forced through e.g. a nozzle and propagating through the interior of the chamber or housing. Even though the jet in general may be formed of an essentially continuous flow or stream of liquid, it will be appreciated that the jet additionally, or alternatively, may comprise or even be formed of a plurality of droplets. In particular, droplets may be generated upon interaction with the electron beam. Such examples of groups or clusters of droplets may also be encompassed by the term 'liquid jet' or 'target'. Alternative embodiments of liquid target may include multiple jets, a pool of liquid either stationary or rotating, liquid flowing over a solid surface, or liquid confined by solid surfaces.

[0017] As already mentioned, the housing may refer to a structure defining the chamber (such as e.g. a vacuum chamber) in which the interaction region is located. The housing may, together with a window for exiting the X-ray radiation, form an enclosure for separating the interior of the X-ray source from the surrounding environment or ambient region. Preferably, the housing may be hermetically sealed to allow operation at a reduced pressure, also referred to as vacuum.

[0018] The temperature controller may comprise a thermal management system for adding and/or removing heat to/from at least a portion of the housing. The controller may e.g. comprise a heater and/or cooler coupled to a regulator for maintaining the temperature at a desired level during operation of the X-ray source. Further, the controller may comprise a temperature sensor. Preferably, the controller is automatically operated to reduce the need for manual intervention by the operator.

[0019] In an embodiment, the temperature controller may be further adapted to maintain the surface temperature below a boiling point of the material. Hence, the temperature may be high enough to make the liquid target material liquid but sufficiently low to avoid boiling and generation of vapour.

[0020] In case the material of the liquid target comprises at least a first substance having a first melting point and at least a second substance having a second melting point, the surface temperature may be maintained above the highest one of the melting point so as to ensure that both substances are turned into (or maintained) liquid. By turning both constituents of the target material liquid, de-alloying may be avoided.

[0021] In case the material of the liquid target comprises a first and a second substance having different boiling points, the temperature may be held below a lowest one of the boiling points to avoid boiling of any constituent of the target material.

[0022] The first and second substance may be formed of a respective element, such as a metal, and/or a compound, that may be mixed into the liquid target material.

[0023] In an embodiment, the X-ray source may comprise a heat management means for maintaining an outer wall of the housing at a temperature that is lower than the surface temperature of the inner wall. This may be of a particular advantage when the inner wall is heated to a temperature that risks to cause damage to the surroundings and to constitute a poor working environment. The temperature of the outer wall of the housing may e.g. be controlled or reduced by means of a thermal isolation arranged between the outer wall and the surface of the inner wall, or by means of an active cooling system utilising e.g. water cooling, air cooling or a Peltier element.

[0024] In an embodiment, the X-ray source comprises a liquid target replenishment arrangement adapted to collect material of the liquid target that has been deposited on the portion of the inner wall, to use the collected material to at least partly replenish the liquid target, and to maintain the material at a temperature above the melting point of the liquid target material in order to facilitate transportation and pumping of the liquid target material. In particular, the replenishment system may comprise a tubing surrounded by heating elements. This aspect may be particularly important when the melting point of the target material is above room temperature.

[0025] In an embodiment, a number of particles produced from the interaction between the electron beam and the liquid target may be estimated. This estimation may be used for controlling the electron beam, such that the estimated number of particles is below a predetermined limit. Further, the estimated number of particles may be used for controlling the surface temperature so as to avoid accumulation of material on the surface. As the degree of vaporisation of the liquid depend, *interalia,* on the vapour pressure of the material of the liquid target, the temperature of the liquid target, and in particular the size of the heated surface area of the liquid target, the vaporisation from the target may be controlled by varying the heat induced in the liquid by the electron beam. The induced heat may e.g. be varied by changing the spot size at the interaction region, the electron current of the beam, or a focus of the beam. Alternatively, or additionally, the temperature of the liquid target at the interaction region may be controlled by e.g. cooling the material of the liquid target, or supplying new material, of a different temperature, to the interaction region. Thus, by obtaining a measure or indication of the number of particles produced from the interaction between the electron beam and the liquid target and adjusting the electron beam or liquid target accordingly, the vaporisation rate may be kept at a desired level.

[0026] According to an embodiment, the estimated number or particles produced from the interaction between the electron beam and the liquid target may be a measure of the vaporisation rate of the liquid target. By knowing the vaporisation rate, the operation of the X-ray source may be adjusted accordingly to keep the vaporisation within a preferred range. The allowed vapourisation rate may e.g. be determined by the X-ray source's capability of keeping the material deposited on the surface liquid.

[0027] The estimated number of particles may e.g. be provided by means of a particle sensor, which e.g. may comprise a particle trap, a particle repeller and/or one or several measuring devices for measuring a trap current and a repeller current. The particle sensor may further comprise a processing device, or processing circuitry, configured to estimate the number of particles based on the trap current and the repeller current.

[0028] The particle trap may be realised as an electrically conductive element, such as e.g. a conductive plate or shield, having a surface towards which positively charged particles may be accelerated by means of an electric field. The electric field may e.g. be generated by an electric potential difference applied to the particle trap. The electric potential difference should thus be selected such that positively charged particles are attracted to the trap and, preferably, deposited or adsorbed at the trap. The electric potential difference may thus have a negative sign relative to ground or to the positively charged particles, and may also, in the context of the present application, be referred to as a negative electric potential. It will however be appreciated that the particle trap may as well be connected to ground, i.e., be provided with a zero potential. In such case, it may be advantageous to provide the trap with a physical shape and location that increases the interactions with the particles, or, in other words, such that it is hit by as many particles as possible, to compensate for the lack of electrostatic attraction.

[0029] The particle repeller may be realised as an electrically conductive element, such as e.g. a conductive plate or shield that may be similarly configured as the particle trap. The particle repeller should however be configured such that positively charged particles may be accelerated or deflected away from the repeller. This may be achieved by an electric potential difference causing an electric field that diverts the positively charged particles from the repeller. The electric potential difference may thus be selected to have a positive sign relative to ground or the positively charged particles, and may also, in the context of the present application, be referred to a positive electric potential. The particle repeller may be used for deflecting particles from trajectories that otherwise would allow them to pass towards the electron source.

[0030] The technology disclosed may be embodied as computer readable instructions for controlling a programmable computer in such manner that it causes an X-ray source to perform the method outlined above. Such instructions may be distributed in the form of a computer-program product comprising a non-volatile computer-readable medium storing the instructions.

[0031] It will be appreciated that any of the features in the embodiments described above for the X-ray source according to the first aspect above may be combined with the methods according to the second and third aspect of the present invention, and vice versa.

[0032] Further objectives of, features of, and advantages with the present invention will become apparent when studying the following detailed disclosure, the drawings and the appended claims. Those skilled in the art will realize that different features of the present invention can be combined to create embodiments other that those described in the following.

Brief description of the drawings

[0033] The invention will now be described for the purpose of exemplification with reference to the accompanying drawings, on which:

figure 1 is a schematic, cross sectional side view of an X-ray source according an embodiment of the present invention;

figure 2 schematically illustrates a method for generating X-ray radiation according to an embodiment of the present invention; and

figure 3 schematically illustrates a system for generating X-rays according to an embodiment of the present invemtion.

[0034] All figures are schematic, not necessarily to scale, and generally only show parts that are necessary in order to elucidate the invention, wherein other parts may be omitted or merely suggested.

Detailed description of embodiments

[0035] An X-ray source 100 according to an embodiment of the invention will now be described with reference to figure 1. As indicated in figure 1, a vacuum chamber 136 may be defined by an enclosure comprising a housing 130 and an X-ray transparent window 134 that separates the vacuum chamber 136 from the ambient atmosphere. The X-rays may be generated from an interaction region I, in which electrons from an electron beam E may interact with a liquid target J.

[0036] The electron beam E may be generated by an electron source 120, such as e.g. an electron gun 120 comprising a high-voltage cathode, directed towards the interaction region I. The electron beam E may follow a trajectory or path between the electron source 120 and the interaction region I, wherein the trajectory may be adjusted by electron-optical means and/or the configuration of the electron source 120. The electron source 120 may further be controllable so as to allow for parameters of the electron beam to be adjusted, such as e.g. beam current, intensity, width, heigh and electron energy. Furthermore, the electron source 120 may be arranged to provide a plurality of electron beams.

[0037] As illustrated in the present figure, the chamber 136 may be divided into a cathode part and an anode part by a separating wall 138. The wall may e.g. be arranged to protect the electron source 120 from being contaminated by debris generated from the liquid target J. Further, an aperture may be provided in the separating wall 138, through which the electron beam E may pass towards the interaction region I.

[0038] The anode, or liquid target J may be formed of a liquid jet J intersecting the interaction region I. The liquid jet J may be generated by a target generator 110 comprising a nozzle through which a fluid, such as e.g. liquid metal or a liquid alloy, may be ejected to form the jet J propagating towards and through the interaction region I. Alternatively, the liquid target J may be formed of multiple jets, a liquid reservoir or a pool, which may be stationary or rotating, or a liquid curtain or sheet that may float on a surface or propagate freely within the chamber 136.

[0039] The X-ray source 100 may further comprise a closed loop circulation system, or a liquid target replenishment arrangement 160, which may be located between a collection reservoir 162 for collecting the material of the liquid target J, and the target generator 110. The replenishment system may be adapted to recirculate the collected material of the liquid target to the target generator 110 by means of a pump, such as a high-pressure pump 164 adapted to raise the pressure to at least 10 bar, preferably at least 50 bar or more, for generating the target jet J.

[0040] The X-ray source 100 may also comprise a temperature controller 140 for controlling a temperature of a surface arranged within the chamber 136. As illustrated in the present figure, temperature controller 140 may, in one non-limiting example, be realised by a plurality of heating elements 140 arranged to heat one or several portions of surfaces within the chamber 164, onto which material from the liquid target J tend to deposit. Possible locations are e.g. close to the aperture in the separating wall 138 and around (or on) the X-ray window 134. The X-ray window 134 may be thermally connected to the housing 130 so as to allow the temperature of the X-ray window 134 to be controlled by controlling the temperature of the portions of the housing 130 close to the X-ray window 134. It will however be appreciated that the temperature controller 140 may be arranged to control the temperature of any surface within the chamber 136, and in particular any part of the inner wall 132 of the housing 130.

[0041] By maintaining the above-mentioned locations at a temperature sufficient to liquefy material of the liquid target J, accumulation of liquid target material on those surfaces may be avoided or at least limited. Thus, the controller 140 should be capable of keeping a least the surface temperature above the melting point of the liquid target material, and preferably, in case the material is an alloy or composition of substances having different melting points, above a highest one of the melting points. It is however realised that the controller 140 also may be adapted to remove heat from those surfaces in order to keep the surface temperature below a boiling point of the material and thereby reduce the risk of excessive generation of vapour. Thus, the controller 140 may operate as a heater, a cooler or both, depending on operational parameters of the X-ray source 100.

[0042] The liquefied material may, preferably, be transported away from the temperature controlled surface(s) and removed from the chamber 136 or reused by the target generator 110. In one example, this may be achieved by means of gravitational influence causing the liquefied material to flow towards a bottom of the chamber 136. As illustrated in figure 1, a collection reservoir 162 may be arranged to collect the liquid material flowing from the temperature controlled surfaces. The transport may e.g. be facilitated by a slanting surface 168 acting as a guiding means or funnel towards the reservoir 162. In some examples, the slanting surface 168 may comprise a temperature controller 140 for maintaining the material liquid during the transport or recirculation.

[0043] The X-ray source 100 may further comprise a heat management means 150 for controlling the temperature of an outer wall of the housing 130. The heat managemenet means 150 may e.g. comprise a heat barrier in terms of e.g. a thermal insulation film attached to the outer wall, or a wall material having a sufficiently low thermal conduction between the inner surface and the outer surface, e.g. a multi-layered or honeycomb structured material. Other examples may include active air cooling or water cooling utilising an air flow or a coolant that may be pumped through channels in thermal contact with the housing 130. Other examples may include Peltier elements for preventing the outer surface from reaching too high temperatures.

[0044] The temperature controller 140 may e.g. comprise a heater, such as e.g. a resistive heating element, coupled to a regulator and a sensor (not shown) for monitoring and regulating the temperature. The heater may in some examples be integrated in the wall of the housing 130, or added as a separate element to the surface of the inner wall or on a surface opposing the surface onto which the material tend to deposit.

[0045] A method for generating X-ray radiation from an X-ray source, and for preventing de-alloying in the X-ray source, in accordance with some embodiments of the invention, will now be described with reference to figure 2. For clarity and simplicity of this disclosure, the method will be described in terms of 'steps'. It is emphasized that 'steps' are not necessarily processes that are delimited in time or separate from each other, and more than one 'step' may be perfomed at the same time in a parallel fashion. The intended outlook of this disclosure is that the 'steps' represent the different treatments that a liquid target material undergoes during its loop through an X-ray source adapted to perform the method. The X-ray source may be similarly configured as the X-ray source 100 discussed in connection with figure 1.

[0046] In step 10, the pressure of the liquid target material may be raised to a high pressure. The high pressure should be sufficient in order for the liquid metal jet to obtain a high propagation speed in the chamber 136 once ejected from the nozzle of the liquid target source 110. Typically, the high pressure may be at least 10 bar, preferably 50 bar and up to more than 100 bar. With reference to figure 1, the liquid target material that is being pressurized may be accommodated in a closed loop liquid target replenishment arrangement 160 comprising a high-pressure pump 164, preferably a diaphragm pump or other high-pressure pump.

[0047] In step 20, the pressurised liquid target material may be conducted towards a nozzle of the target source 110, at which the material is ejected into the chamber 136. A steady (spatially continuous) liquid-metal jet J may then be formed and used as a target for an electron beam E, which may be directed 30 towards the interaction region I of the chamber 136. The electron beam E may impact the liquid target material in the interaction region I, and part of the electron beam energy may be converted into X-rays.

[0048] The nozzle orifice to be used may have such shape and dimensions that the ejected liquid material assumes the form of a physically continuous jet J. The jet may tend to relax into a state of lower surface energy and thereby typical change its shape. This may lead to jet breakup into a spray, droplets or other kinds of discontinuous portions forming debris that may contaminate the chamber 136 and accumulate on surfaces within the chamber 136.

[0049] In order to recirculate material (such as debris) from a surface onto which is has deposited, the material may be maintained 40 at a temperature sufficient to keep the material liquid. Thereby, the material may be recirculated from the surface. The recirculation may hence comprise a step of controlling 40 the surface temperature such that it is above a melting point of the material, and preferably above a highest melting points in case the material comprises two or more compounds or metals. Additionally, the temperature may be controlled such that boiling is avoided.

[0050] The liquid material may then be allowed to flow towards a collection reservoir 162, at which it may be collected 50 and transported 60 back to the target source 110.

[0051] Figure 3 schematically illustrates a system for generating X-rays, comprising an X-ray source 100 according to the embodiments described above in connection with figures 1 and 2, a processing device (or processing circuitry) 200 and a temperature controller (or controlling circuitry) 300. The processing device 200 may be configured to receive information from a sensor or measuring device (not shown) e.g. indicating a surface temperature to be controlled, an estimated amount of generated debris, and/or an estimated amount of material accumulated on the surface. In some examples, the sensor or measuring device may be incorporated in the temperature controller 300.

[0052] The processing device 200 may further be configured to output information to the controller 300, which may be configured to control the heat added to the surface so as to maintain the surface temperature at a level that is sufficient to liquefy the liquid target material deposited on the surface, and/or to control the heat removed from the surface so as to avoid boiling of the deposited material. The system may operated according to a feedback loop, in which the temperature information received by the processing device 200 may be used for adjust the operation of the temperature controller 300. The adjusted operation may result in a temperature change, which may be determined by the processing device 200, etcetera.

[0053] The person skilled in the art realises that the present invention by no means is limited to the examples and configurations described above. On the contrary, many modifications and variations are possible within the scope of the appended claims.

Claims

1. An X-ray source (100) comprising:

a liquid target source (110) configured to provide a liquid target (J) passing through an interaction region (I);
an electron source (120) configured to provide an electron beam (E) directed towards the interaction region such that the electron beam interacts with the liquid target to generate X-ray radiation;
a housing (130) separating the interaction region from an ambient region;
a temperature controller (140) adapted to control a surface temperature of at least a portion of an inner wall (132) of the housing such that the surface temperature is sufficient to liquefy material that stems from the liquid target and has been deposited on the portion of the inner wall.

2. The X-ray source according to claim 1, wherein the temperature controller is further adapted to maintain the surface temperature below a boiling point of the material.

3. The X-ray source according to claim 1 or 2, wherein the liquid target comprises a first substance having a first melting point and a second substance having a second melting point, and wherein the temperature controller is adapted to maintain the surface temperature above the highest one of the first melting point and the second melting point.

4. The X-ray source according to claim 3, wherein the first substance has a first boiling point and the second substance has a second boiling point, and wherein the temperature controller is further adapted to maintain the surface temperature below a lowest one of the first boiling point and the second boiling point.

5. The X-ray source according to claim 3 or 4, wherein the liquid target is an alloy formed of the first substance and the second substance.

6. The X-ray source according to any one of the preceding claims, further comprising a heat management means (150) adapted to maintain an outer wall of the housing at a temperature being lower than the surface temperature of the inner wall.

7. The X-ray source according to claim 6, wherein the heat management means is selected from the group comprising:

thermal insulation;
active air cooling;
water cooling; and
a Peltier element.

8. The X-ray source according to any one of the preceding claims, further comprising a liquid target replenishment arrangement (160) adapted to collect material of the liquid target that has been deposited on the portion of the inner wall, use the collected material to at least partly replenish the liquid target, and to maintain said material at a temperature above the melting point of the liquid target material.

9. The X-ray source according to any one of the preceding claims, wherein said temperature controller comprises at least one of:

a temperature sensor;
a heater;
a cooling arrangement.

10. A method for generating X-ray radiation from an X-ray source (100) comprising an interaction region (I) and a housing (130) separating the interaction region from an ambient region, the method comprising:

providing (20) a liquid target (J) passing through the interaction region;
directing (30) an electron beam (E) towards the interaction region such that the electron beam interacts with the liquid target to generate X-ray radiation; and
recirculating (40, 50, 60) material of the liquid target after the interaction with the electron beam;
wherein the material of the liquid target is maintained at a temperature sufficient to keep the material liquid during the recirculation.

11. The method according to claim 10, wherein the step of recirculating material of the liquid target comprises:

liquefying material that stems from the liquid target and has been deposited on the portion of the inner wall, such that at least some of the material flows away from said portion.

12. The method according to claim 10 or 11, wherein the step of recirculating material of the liquid target comprises:

controlling (40) a surface temperature of at least a portion of an inner wall of the housing such the surface temperature is sufficient to liquefy the material that has been deposited on the portion of the inner wall.

13. The method according to claim 12, wherein the surface temperature is maintained below a boiling point of the material.

14. The method according to claim 12 or 13, wherein the liquid target comprises a first substance having a first melting point and a second substance having a second melting point, and wherein the surface temperature is maintained above the highest one of the first melting point and the second melting point.

15. A method for preventing de-alloying in an X-ray source comprising a housing separating the interaction region from an ambient region, the method comprising:

providing (20) a liquid target comprising an alloy of at least two metal elements each having a respective melting point;
directing (30) an electron beam towards the liquid metal target such that the electron beam interacts with the liquid target to generate X-ray radiation;
preventing (40) decomposition of debris, generated from the liquid target, on at least a part of an inner wall of said housing by keeping the temperature of said part above the highest one of said melting points.

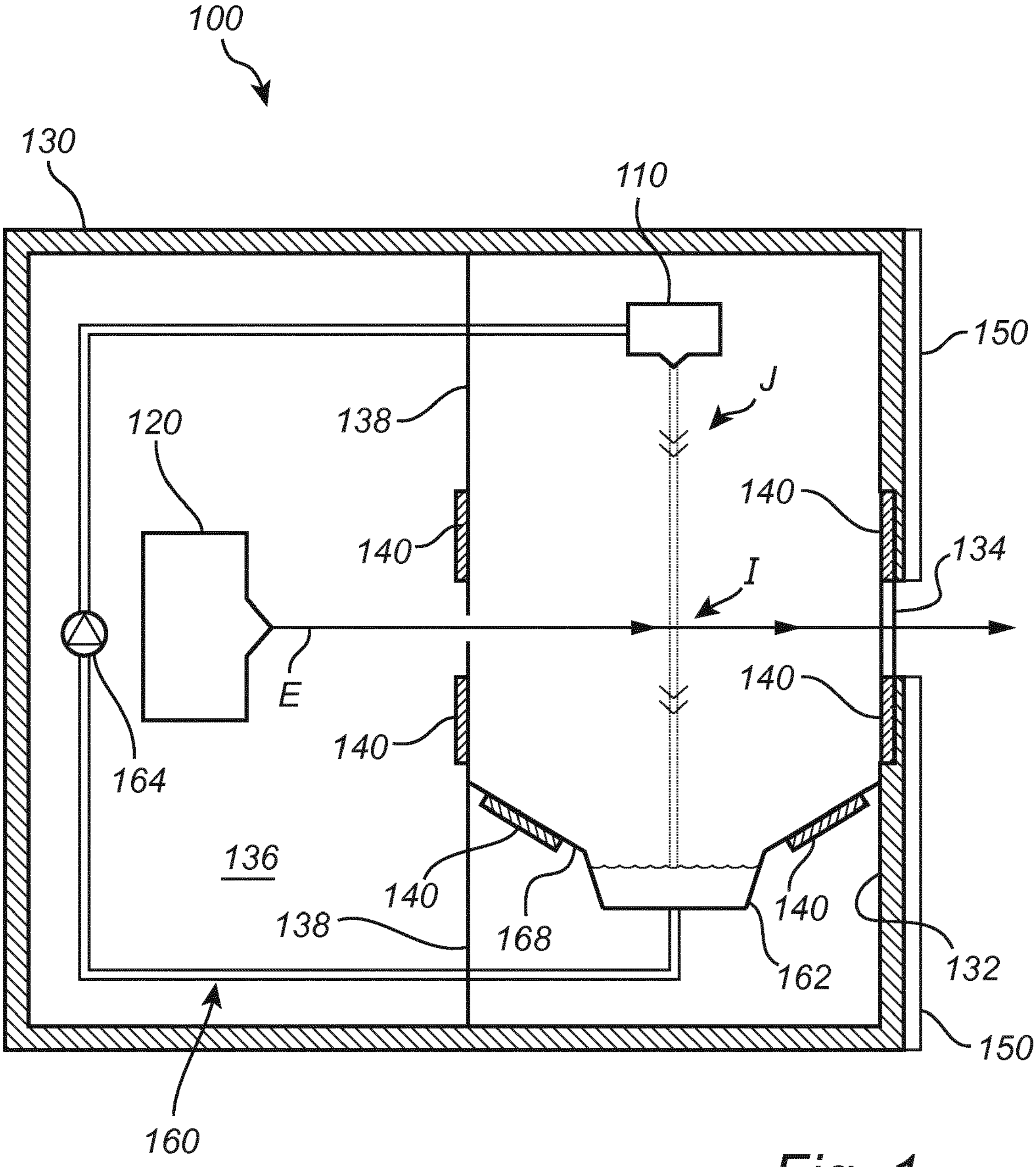
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Fig. 1

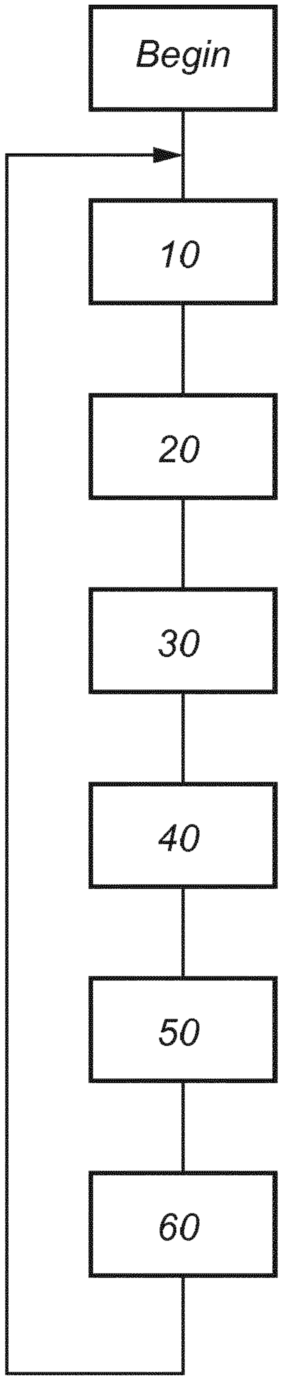

Fig. 2

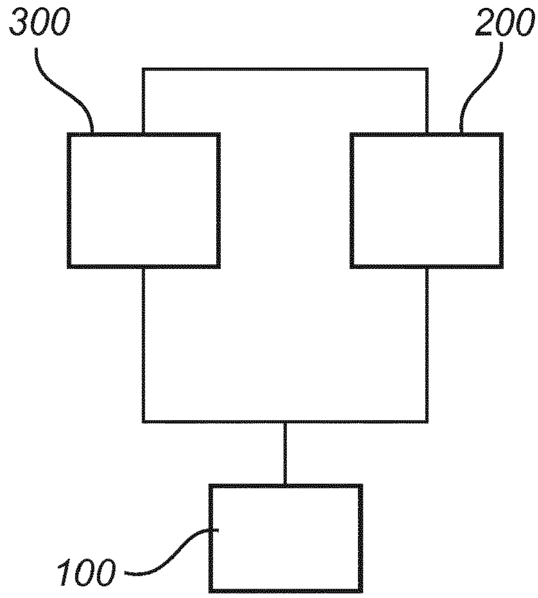

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 6517

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Place of search	Date of completion of the search	Examiner
Munich	11 December 2017	Krauss, Jan

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