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(54) Title: AN APPARATUS AND A METHOD FOR TREATING MINED MATERIAL

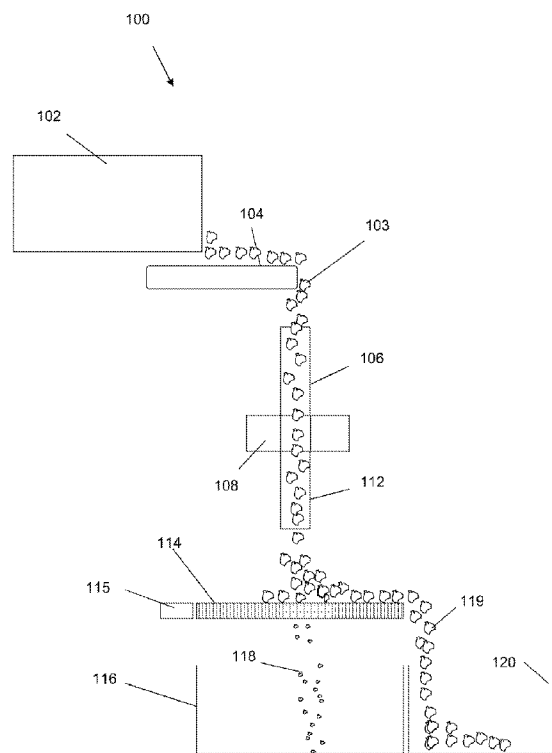


Fig. 1

(57) Abstract: An apparatus for treating mined material is described. The apparatus comprises a source for generating electromagnetic radiation, and a radiation applicator for exposing fragments of the mined material to the electromagnetic radiation in a manner such that fractures are formed within at least some of the fragments of the mined material that include valuable material. The apparatus also comprises a surface arranged such that fragments of the mined material that exit the radiation applicator are moved by gravity against, or to the proximity of, the surface. A resulting impact force causes breaking of at least a portion of the fractured fragments of the mined material that include the valuable material. The apparatus also comprises a sorting arrangement for sorting broken fragments of the mined material as a function of diameter of the broken fragments of the mined material.



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AN APPARATUS AND A METHOD FOR TREATING MINED MATERIAL

Field of the Invention

- 5 The present invention relates to an apparatus and a method for treating mined material, and relates particularly, although not exclusively, to an apparatus and a method for treating mined materials with microwave radiation and sorting the treated material.
- 10 The term "mined" material is understood herein to include metalliferous material and non-metalliferous material. Iron-containing and copper-containing ores are examples of metalliferous material. Coal is an example of a non-metalliferous material. The term "mined" material is also
- 15 understood herein to include (a) run-of-mine material and (b) run-of-mine material that has been subjected to at least primary crushing or similar size reduction after the material has been mined and prior to being sorted. Further, the term "mined" material includes mined material
- 20 that is in stockpiles.

The present invention also relates to recovering valuable material from mined material and relates particularly, although not exclusively, to treating mined material at high throughputs.

25

Background of the Invention

It has recently been proposed to treat mined material with high intensity microwave radiation to cause formation of cracks in fragments of mined material. The fragments may

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include gangue and valuable material (such as copper or iron containing minerals) and the exposure of the fragments to high power-density electric fields related to the high intensity microwave radiation causes preferential heating and resultant thermal expansion of some of the components of the fragments, which results in formation of micro-cracks and macro-cracks. The formation of the cracks is directly related to the value and rate of development of a temperature differential that is created during the application of the high intensity microwave radiation.

Summary of the Invention

The present invention provides in a first aspect an apparatus for treating mined material, the apparatus comprising:

a source for generating electromagnetic radiation;

a radiation applicator for exposing fragments of the mined material to the electromagnetic radiation in a manner such that fractures are formed within at least some of the fragments of the mined material that include valuable material;

a surface arranged such that fragments of the mined material that exit the radiation applicator are moved by gravity against, or to the proximity of, the surface and a resultant impact force causes breaking of at least a portion of the fractured fragments of the mined material that include the valuable material; and

a sorting arrangement for sorting broken fragments of the mined material as a function of diameter.

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The inventors have discovered that fragments of mined material that contain valuable material and that are fractured as a consequence of treatment using suitable electromagnetic radiation, such as suitable microwave
5 radiation, break into smaller fragments when exposed to suitable impact forces. Consequently, it is possible to separate at least a portion of the fragments that include valuable material from remaining fragments based on the smaller size of the broken fragments.

10 The apparatus may be arranged such that the fragments of the mined material are moved from the radiation applicator to the surface exclusively by gravity and broken fragments of the mined material are moved through the sorting arrangement exclusively by gravity.

15 In one embodiment, the sorting arrangement comprises a screen and the surface may be a surface of the screen. The screen may also be separate from the surface and the apparatus may be arranged such that the fragments of the mined material are moved against the surface before being
20 directed to the screen.

The screen may have apertures that have a diameter that is larger than a diameter of at least a portion of the broken fragments of the mined material, and smaller than at least a portion of unbroken fragments of the mined material;

25 wherein the apparatus is arranged such that a portion of the broken fragments of the mined material pass through the apertures by gravity, whereby at least a portion of the fragments that include valuable material are separated from remaining mined material.

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The impact force may be a consequence of a direct impact of the fragments of the mined material with the surface and/or may be a consequence of an impact with other fragments of the mined material in the proximity of the surface. The surface may be stationary and the apparatus may be arranged such that the impact force is exclusively a result of kinetic energy of the mined material as moved by gravity. However, in one embodiment the surface is arranged for moving, such as vibrating, and the apparatus may be arranged such that the vibration of the surface contributes to the impact force.

The diameter of the apertures may be smaller than that of at least a portion on unbroken fragments of the mined material. For example, the apertures may have a diameter in the range 10mm - 20mm, 20mm - 30mm, 40mm - 50mm, 50mm - 60mm, 60mm - 70mm, 70 - 80mm.

Embodiments of the present invention provide the advantage that sorting of the mined material by separating at least a portion of the fragments that include valuable material from remaining fragments is possible in a simplified manner and may not require grinding or milling of the fragments in which micro-cracks have formed as a consequence of the radiation treatment.

The apparatus may comprise an arrangement for vibrating the screen to facilitate movement of the broken fragments of the mined material through the apertures.

The surface may be of any suitable shape and may for example have a rounded cross-sectional shape or a trough-like cross-sectional shape. In one specific embodiment the surface has a flat shape. The surface may have any suitable transversal orientation relative to a direction

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of gravity. For example, the surface may be oriented substantially perpendicular relative to a direction of gravity. Alternatively, the surface may have a suitable inclined orientation.

- 5 The source may be arranged to generate microwave radiation. The microwave radiation may have any suitable wavelength in the range of 300 MHz - 300 GHz, 500 MHz - 30 GHz or 600 MHz - 3 GHz, for example 2450 MHz or 915 MHz.

10 In one embodiment the apparatus is arranged such that the microwave radiation causes heating of the fragments of the mined material in the radiation applicator such that an associated power-density in the heated fragments of the mined material is at least 1×10^9 W/cm³, 1×10^{10} W/cm³, typically at least 1×10^{11} W/cm³.

- 15 The apparatus may comprise a first conduit for directing the fragments of the mined material to the radiation applicator and may also comprise a second conduit for directing the fragments from the radiation applicator to the surface.

- 20 The first conduit may comprise a reflective structure that is arranged such that propagation of the electromagnetic radiation from the radiation applicator through the first conduit is reduced in a manner such that the fragments of the mined material entering the radiation applicator
25 experience an increase in electric field intensity at a rate of at least 15 dB/m. Further, the second conduit may comprise a suitable reflective structure that is arranged to reflect microwave radiation that penetrates from the cavity into the second conduit.

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The present invention provides in a second aspect a method for treating mined material, the method comprising the steps of:

directing fragments of the mined material to a
5 radiation applicator for treating the fragments of the mined material with electromagnetic radiation;

exposing the fragments of the mined material to the electromagnetic radiation in a manner such that fractures are formed within at least some of the fragments of the
10 mined material that include valuable material; and thereafter

allowing gravity to direct the fragments of the mined material against, or to the proximity of, a surface such that a resultant impact force breaks at least some of the
15 fractured fragments that include the valuable material; and

directing broken fragments of the mined material through a sorting arrangement for sorting the broken fragments of the mined material as a function of diameter.

20 The impact force may be a consequence of a direct impact of the fragments of the mined material with the surface and/or may be a consequence of an impact with other fragments of the mined material in the proximity of the surface. The surface may be stationary and the impact
25 force may exclusively be result of the kinetic energy of the mined material as moved by gravity. Alternatively, the surface may be arranged for moving, such as vibrating, and the vibration of the surface may contribute to the impact force.

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The method may comprise moving fragments of the mined material from the radiation applicator to the surface exclusively by gravity and moving broken fragments of the mined material through the sorting arrangement exclusively
5 by gravity.

In one embodiment, the method further comprises the step of providing a screen. The surface may be a surface of the screen. Alternatively, the surface may be separate from the screen and the fragments may be directed to the screen
10 after being directed against, or to the proximity of, the surface.

The screen may have apertures that have a diameter that is larger than a diameter of at least a portion of the broken fragments of the mined material, and smaller than at least
15 a portion of unbroken fragments of the mined material, and wherein the step of directing the at least a portion of the broken fragments through the sorting arrangement comprises directing the at least a portion of the broken fragments through the apertures by gravity, whereby at
20 least a portion of the fragments that include valuable material are separated from remaining mined material.

The diameter of the apertures may be smaller than that of at least a portion on unbroken fragments of the mined material. For example, the apertures may have a diameter
25 in the range of 10mm - 20mm, 20mm - 30mm, 40mm - 50mm, 50mm - 60mm, 60mm - 70mm, 70 - 80mm. In this embodiment the step of separating includes allowing gravity to direct at least a portion of the broken fragments through the apertures of the screen.

30 The electromagnetic radiation may be microwave radiation. The microwave radiation may have any suitable wavelength

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in the range of 300 MHz - 300 GHz, 500 MHz - 30 GHz or 600 MHz - 3 GHz, for example 2450 MHz or 915 MHz.

The step of exposing the fragments of the mined material to the electromagnetic radiation may comprise exposing the fragments of the mined material to microwave radiation thereby causing heating of the fragments of the mined material in the radiation applicator such that an associated power-density in the heated fragments of the mined material is at least 1×10^9 W/cm³, 1×10^{10} W/cm³, typically at least 1×10^{11} W/cm³.

As mentioned above, the method may also comprise vibrating the screen to facilitate movement of the broken fragments through the apertures.

The present invention provides in a third aspect a method for sorting mined material, the method comprising the steps of:

providing the mined material, the mined material including first and second types of fragments, the fragments of the first type including valuable material and having fractures;

directing the fragments against or to the proximity of a surface such that an impact force breaks at least some of the fragments of the first type into smaller fragments; and

separating at least a portion of the broken fragments from remaining fragments of the mined material.

The impact force may be a consequence of a direct impact of the fragments of the mined material with the surface

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and/or may be a consequence of an impact with other fragments of the mined material in the proximity of the surface. The surface may be stationary and the impact force may exclusively be a result of kinetic energy of the mined material as moved by gravity. Alternatively, the surface may be arranged for moving, such as vibrating and the vibration of the surface may contribute to the impact force.

The step of providing the mined material including the first and second types of fragments may comprise exposing the fragments of the mined material to the electromagnetic radiation in a manner such that the fractures are formed within at least some of the fragments of the mined material that include valuable material. The electromagnetic radiation may be microwave radiation. The microwave radiation may have any suitable wavelength in the range of 300 MHz - 300 GHz, 500 MHz - 30 GHz or 600 MHz - 3 GHz, for example 2450 MHz or 915 MHz. Exposing the fragments of the mined material to the electromagnetic radiation may comprise exposing the fragments of the mined material to microwave radiation thereby causing heating of the fragments of the mined material in the radiation applicator such that an associated power-density in the heated fragments of the mined material is at least 1×10^9 W/cm³, 1×10^{10} W/cm³, typically at least 1×10^{11} W/cm³.

In one embodiment the surface is a surface of a screen. In an alternative embodiment the method comprises the step of directing the fragments to a screen after directing the fragments against the surface.

The screen may have apertures having a diameter that is larger in diameter than a diameter of at least a portion

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of broken fragments of the mined material. Further, the diameter of the apertures may be smaller than that of at least a portion on unbroken fragments of the mined material. For example, the apertures may have a diameter
5 in the range of 10mm - 20mm, 20mm - 30mm, 40mm - 50mm, 50mm - 60mm, 60mm - 70mm, 70 - 80mm. The step of separating at least a portion of the broken fragments from remaining fragments may include allowing gravity to direct at least a portion of the broken fragments of the mined
10 material through the apertures of the screen. The method may also comprise vibrating the screen to facilitate movement of the broken fragments of the mined material through the apertures.

The invention will be more fully understood from the
15 following description of specific embodiments of the invention. The description is provided with reference to the accompanying drawings.

Brief Description of the Drawings

20 Figures 1 to 3 are schematic representations of an apparatus for treating mined material in accordance with an embodiment of the present invention; and

Figure 4 is a flow chart of a method of treating mined
25 material in accordance with an embodiment of the present invention.

Detailed Description of Specific Embodiments

Embodiments of the present invention relate to an apparatus and a method for treating and sorting fragments of mined material. The fragments of the mined material are directed to a microwave applicator and exposed to microwave radiation that generates a microwave power density within the fragments that is sufficiently large such that micro-cracks are formed in the fragments that include valuable material. Gravity is then allowed to direct the fragments to a suitable surface, such as the surface of a screen, in a manner such the fragments having the micro-cracks break into smaller fragments. In one embodiment the screen has apertures that are sufficiently large such that the broken (smaller) fragments pass through the apertures, but are sufficiently small such that at least a significant portion of the unbroken fragments will not pass through the apertures whereby the broken fragments that include the valuable material are separated from remaining mined material.

Referring initially to Figures 1 and 2, apparatus 100, 200, which are used for treating mined material in accordance with specific embodiments of the present invention, are now described. The apparatus 200 is related to the apparatus 100 and the same reference numerals are used for like components. The apparatus 100, 200 comprise a crusher 102 that is arranged to receive mined material. The mined material may be run of mine ore, such as a copper, nickel or iron containing ore or another suitable ore. The crusher 102 is in this embodiment arranged to crush the mined material such that fragments 103 of the mined material have a particle size in the range of 50 - 100mm (such as of the order of 75mm),

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but may alternatively also have other suitable sizes.

The fragments 103 of the mined material are then directed by conveyor belt 104 into chute 106. The chute 106 provides a vertical passage through which the fragments 103 fall by gravity in the form of a packed bed. The chute 106 is a conduit that surrounds the falling fragments 103 and directs the fragments 103 to a radiation applicator 108. The radiation applicator 108 is arranged to expose the fragments 103 to microwave radiation and the apparatus 100, 200 also comprise a microwave generator (not shown) that is arranged to generate high-intensity microwave radiation. The radiation applicator 108 is positioned such that the fragments 103 are exposed to the microwave radiation when the fragments 103 fall through the microwave applicator 108 by gravity. The fragments 103 exit through an exit portion of the radiation applicator 108 and chute 112 directs the falling fragments 103 to a screen 114 of the apparatus 100 or a screen 118 of the apparatus 200.

The microwave generator generates microwave radiation which by interaction with mined material, such as ore, induces the microwave absorbing phase such that a resulting power-density in the microwave absorbent phase of the ore is in the region of 10^6 - 10^{14} W/m³. Different types of materials have a different receptiveness for microwave radiation (depending on their dielectric properties) and different thermal expansion coefficients. For example, minerals, silicates or similar that form rock have a thermal expansion coefficient that is different to that of copper or iron containing minerals and also absorb a different amount of energy when exposed to the microwaves. Consequently, when for example copper-

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containing minerals are surrounded by gangue and are exposed to such treatment, fractures (micro-cracks) form due to the differential expansion between the hot mineral and the cold gangue. The micro-cracks typically form
5 around the boundaries of the hot mineral phase enclosed in the gangue, which facilitates material separation.

The screen 114 of the apparatus 100 has a plurality of apertures. Each aperture has in this embodiment a diameter of the order of 20 - 30mm. Further, the screen
10 114 comprises an arrangement 115 for vibrating the screen 114. The fragments 103 fall from the chute 112 directly onto the screen 114 or collide with other fragments 103 in the proximity of the screen 114. As mentioned above, micro-cracks form in the fragments 103 that include the
15 valuable material. Due to the formed micro-cracks impact forces are sufficient to break the fragments 103 that include valuable material into smaller fragments 118. The impact forces are a consequence of kinetic energy that the falling fragments gained and a consequence of the
20 vibrations of the vibrating screen 114. However, in one specific embodiment the portion of the impact force that is a result of the kinetic energy of the mined material is significantly larger than the portion provided by the vibration of the screen 114 (which typically is $\ll 0.1$
25 kW/t).

The apertures of the screen 114 are sized such that the smaller broken fragments 118 ("accepts") pass through the apertures and are then collected by a sorting bin 116 for further processing. The screen 114 has an arrangement for
30 vibrating 115 that vibrates the screen 114 in a horizontal direction in order to facilitate the passing of the broken fragments 118 through the apertures of the screen

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114. The unbroken fragments 119 ("rejects") that are too large to pass through the apertures of the screen 114 then pass into bin 120 and may be stockpiled.

The apparatus 200 comprises a surface 113 that is in this embodiment inclined and that is provided in addition to the screen 114. Again, micro-cracks will form in the fragments 103 that include valuable material when these fragments 103 are exposed to the microwave radiation in the radiation applicator 108. The fragments then fall onto the surface 113 and at least a significant portion of the fragments 103 in which micro-cracks have formed will break up into smaller fragments 119 as a consequence of the impact force on the surface 113. The screen 114 separates the smaller broken fragments 118 ("accepts") from the larger unbroken fragments 119 ("rejects"). The broken fragments are collected in the bin 116 and the unbroken fragments are collected in the bin 120.

It will be appreciated by a person skilled in the art that various variations of the apparatus 100 and 200 are possible. For example, the screens 114 and 118 may not necessarily be planar screens, but may have any other suitable shape.

Referring now to Figure 3, a portion of an apparatus 300 for treating and sorting mined material is now described. The apparatus 300 also comprises the same components as the apparatus 100 described above, but only the radiation applicator 108, the chutes 106, 112 and a microwave source 302 are shown and now described in further detail.

The chutes 106 and 112 comprise confining chokes 304, 306, respectively. The confining chokes 304, 306 are arranged to restrict via reflection the propagation of the

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electromagnetic field and thus microwave radiation out of the radiation applicator 108 such that 90% of the electric field is confined over a set distance within the radiation applicator 108. The confining chokes 304 are effective to provide an abrupt change in electric field intensity as fragments of the mined materials (ores) move from the choke 304 into the applicator. The highly localised increase in temperature due to the abrupt change in electrical field intensity results in uneven thermal expansion that in turn provides a higher degree of fracture. A further benefit of the confining chokes 304, 306 is that the loss of energy through the chute portion is reduced, which increases the energy available in the radiation applicator 108 and consequently further increases the efficiency.

The confining chokes 304, 306 are arranged such that the electric field intensity decreases at a rate of 15 dB/m (typically at least 20 or 30 dB/m) in directions away from the radiation applicator 108.

Referring now to Figure 4, a method of treating and sorting fragments of mined material in accordance with a specific embodiment of the present invention is now described. The method 400 comprises an initial step 402 of directing run of mine ore to a crusher for fragmentation. The resulting fragments typically have a diameter in the range of 50 - 100mm, such as of the order of 75mm. Step 404 directs the fragments of the mined material to a radiation applicator for treating the fragments of the mined material with microwave radiation that is sufficient such that micro-cracks form in fragments of the mined material that include valuable material.

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Step 406 exposes the fragments of the mined material to the microwave radiation in a manner such that the fractures are formed. Step 407 directs the exposed fragments of the mined material against a surface using gravity and an impact forces breaks at least some of the fractured fragments. Step 408 allows broken fragments to pass through apertures of a vibrating screen and separates the broken (accepted) fragments from unbroken (rejected) fragments. Flotation or leaching (step 412) is used to extract the valuable material from the accepted fragments and the valuable material is then concentrated (step 414). Rejected fragments are stockpiled (step 410). In a possible variation of the described embodiment the broken (accepted) fragments may be grinded such that even smaller fragments are formed and the even smaller fragments are then treating using leaching or flotation.

It is to be appreciated that various variations of the described embodiments are possible. For example, the apparatus 100, 200 or 300 may be arranged to generate microwave radiation having any suitable frequency. Further, the chute portion 106 may not necessarily be arranged vertically and may have any suitable cross-sectional shape, diameter and length. Further, the chute portions 106 and 112 may not necessarily comprise the described confining chokes 304, 306.

It will be understood to persons skilled in the art of the invention that many modifications may be made without departing from the spirit and scope of the invention.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary

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implication, the word "comprise" or variations such as
"comprises" or "comprising" is used in an inclusive sense,
i.e. to specify the presence of the stated features but
not to preclude the presence or addition of further
5 features in various embodiments of the invention.

The Claims defining the Invention are as Follows:

1. An apparatus for treating mined material, the apparatus comprising:

5 a source for generating electromagnetic radiation;

a radiation applicator for exposing fragments of the mined material to the electromagnetic radiation in a manner such that fractures are formed within at least some of the fragments of the mined material that include
10 valuable material;

a surface arranged such that fragments of the mined material that exit the radiation applicator are moved by gravity against, or to the proximity of, the surface and a resultant impact force causes breaking of at least a
15 portion of the fractured fragments of the mined material that include the valuable material; and

a sorting arrangement for sorting broken fragments of the mined material as a function of diameter.

2. The apparatus of claim 1, wherein the apparatus is
20 arranged such that the fragments of the mined material are moved from the radiation applicator to the surface exclusively by gravity and broken fragments of the mined material are moved through the sorting arrangement exclusively by gravity.

25 3. The apparatus of claim 1 or 2 wherein the sorting arrangement comprises a screen and the surface is a surface of the screen.

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4. The apparatus of claim 1 or 2, wherein the sorting arrangement comprises a screen and the surface is separate from the screen and wherein the apparatus is arranged such that the fragments of the mined material are moved against the surface before being directed to the screen.

5. The apparatus of claim 3 or 4 wherein the screen has apertures that have a diameter that is larger than a diameter of at least a portion of the broken fragments of the mined material, and smaller than at least a portion of unbroken fragments of the mined material;

wherein the apparatus is arranged such that a portion of the broken fragments of the mined material pass through the apertures by gravity, whereby at least a portion of the fragments that include valuable material are separated from remaining mined material.

6. The apparatus of any one of claims 3 to 5, wherein the apertures have a diameter in the range of 10mm - 20mm.

7. The apparatus of any one of claims 3 to 5, wherein the apertures have a diameter in the range of 20mm - 30mm.

8. The apparatus of any one of claims 3 to 5, wherein the apertures have a diameter in the range of 40mm - 50mm.

9. The apparatus of any one of claims 3 to 8, further comprising an arrangement for vibrating the screen to facilitate movement of the broken fragments of the mined material through the apertures.

10. The apparatus of any one of the preceding claims, wherein the surface is arranged for vibrating and the apparatus is arranged such that the vibration of the surface contributes to the impact force.

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11. The apparatus of any one of the preceding claims wherein the source is arranged to generate microwave radiation.

12. The apparatus of claim 11, wherein the apparatus is
5 arranged such that the microwave radiation causes heating of the fragments of the mined material in the radiation applicator such that an associated power-density in the heated fragments of the mined material is at least 1×10^9 W/cm³.

10 13. The apparatus of any one of the preceding claims, comprising a first conduit for directing the fragments of the mined material to the radiation applicator and a second conduit for directing the fragments from the radiation applicator to the surface.

15 14. The apparatus of claim 13, wherein the first conduit comprises a reflective structure that is arranged such that propagation of the electromagnetic radiation from the radiation applicator through the first conduit is reduced in a manner such that the fragments of the mined material
20 entering the radiation applicator experience an increase in electric field intensity at a rate of at least 15 dB/m.

15. A method for treating mined material, the method comprising the steps of:

directing fragments of the mined material to a
25 radiation applicator for treating the fragments of the mined material with electromagnetic radiation;

exposing the fragments of the mined material to the electromagnetic radiation in a manner such that fractures are formed within at least some of the fragments of the

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mined material that include valuable material; and
thereafter

allowing gravity to direct the fragments of the mined
material against, or to the proximity of, a surface such
5 that a resultant impact force breaks at least some of the
fractured fragments that include the valuable material;
and

directing broken fragments of the mined material
through a sorting arrangement for sorting the broken
10 fragments of the mined material as a function of diameter.

16. The method of claim 15, comprising moving fragments
of the mined material from the radiation applicator to the
surface exclusively by gravity and moving broken fragments
of the mined material through the sorting arrangement
15 exclusively by gravity.

18. The method of claim 15 or 16, further comprising the
step of providing a screen, the screen having apertures
that have a diameter that is larger than a diameter of at
least a portion of the broken fragments of the mined
20 material, and smaller than at least a portion of unbroken
fragments of the mined material, and wherein the step of
directing the at least a portion of the broken fragments
through the sorting arrangement comprises directing the at
least a portion of the broken fragments through the
25 apertures by gravity, whereby at least a portion of the
fragments that include valuable material are separated
from remaining mined material.

19. The method of claim 18 wherein the surface is a
surface of the screen.

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20. The method of any one of claims 15 to 19, comprising the step of vibrating the screen so as to facilitate movement of the broken fragments of the mined material through the apertures.

5 21. The method of any one of claims 17 to 20, comprising the step of vibrating the surface such that the vibration of the surface contributes to the impact force.

22. The method of any one of claims 15 to 21, wherein the step of exposing the fragments of the mined material to
10 the electromagnetic radiation comprises exposing the fragments of the mined material to microwave radiation.

23. The method of claim 22, wherein the step of exposing the fragments of the mined material to the electromagnetic radiation comprises exposing the fragments of the mined
15 material to the microwave radiation and thereby causing heating such that an associated power-density in the heated fragments of the mined material is at least 1×10^9 W/cm³.

AMENDED CLAIMS**received by the International Bureau on 30 September 2014 (30.09.2014)**

The Claims defining the Invention are as Follows:

1. An apparatus for treating mined material, the apparatus comprising:

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a source for generating electromagnetic radiation;

a radiation applicator for exposing fragments of the mined material to the electromagnetic radiation in a manner such that fractures are formed within at least some of the fragments of the mined material that include valuable material;

a surface arranged such that fragments of the mined material that exit the radiation applicator are moved by gravity against, or to the proximity of, the surface and a resultant impact force causes breaking of at least a portion of the fractured fragments of the mined material that include the valuable material; and

20

a sorting arrangement for sorting broken fragments of the mined material as a function of diameter.

2. The apparatus of claim 1, wherein the apparatus is arranged such that the fragments of the mined material are moved from the radiation applicator to the surface exclusively by gravity and broken fragments of the mined material are moved through the sorting arrangement exclusively by gravity.

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3. The apparatus of claim 1 or 2 wherein the sorting arrangement comprises a screen and the surface is a surface of the screen.

4. The apparatus of claim 1 or 2, wherein the sorting arrangement comprises a screen and the surface is separate

from the screen and wherein the apparatus is arranged such that the fragments of the mined material are moved against the surface before being directed to the screen.

- 5 5. The apparatus of claim 3 or 4 wherein the screen has apertures that have a diameter that is larger than a diameter of at least a portion of the broken fragments of the mined material, and smaller than at least a portion of unbroken fragments of the mined material;

10

 wherein the apparatus is arranged such that a portion of the broken fragments of the mined material pass through the apertures by gravity, whereby at least a portion of the fragments that include valuable material
15 are separated from remaining mined material.

6. The apparatus of any one of claims 3 to 5, wherein the apertures have a diameter in the range of 10mm - 20mm.

- 20 7. The apparatus of any one of claims 3 to 5, wherein the apertures have a diameter in the range of 20mm - 30mm.

8. The apparatus of any one of claims 3 to 5, wherein the apertures have a diameter in the range of 40mm - 50mm.

25

9. The apparatus of any one of claims 3 to 8, further comprising an arrangement for vibrating the screen to facilitate movement of the broken fragments of the mined material through the apertures.

30

10. The apparatus of any one of the preceding claims, wherein the surface is arranged for vibrating and the apparatus is arranged such that the vibration of the surface contributes to the impact force.

35

11. The apparatus of any one of the preceding claims wherein the source is arranged to generate microwave radiation.

5 12. The apparatus of claim 11, wherein the apparatus is arranged such that the microwave radiation causes heating of the fragments of the mined material in the radiation applicator such that an associated power-density in the heated fragments of the mined material is at least 1×10^9
10 W/cm³.

13. The apparatus of any one of the preceding claims, comprising a first conduit for directing the fragments of the mined material to the radiation applicator and a
15 second conduit for directing the fragments from the radiation applicator to the surface.

14. The apparatus of claim 13, wherein the first conduit comprises a reflective structure that is arranged such
20 that propagation of the electromagnetic radiation from the radiation applicator through the first conduit is reduced in a manner such that the fragments of the mined material entering the radiation applicator experience an increase in electric field intensity at a rate of at least 15 dB/m.
25

15. A method for treating mined material, the method comprising the steps of:

directing fragments of the mined material to a
30 radiation applicator for treating the fragments of the mined material with electromagnetic radiation;

exposing the fragments of the mined material to the electromagnetic radiation in a manner such that fractures
35 are formed within at least some of the fragments of the mined material that include valuable material; and thereafter

allowing gravity to direct the fragments of the mined material against, or to the proximity of, a surface such that a resultant impact force breaks at least some of the fractured fragments that include the valuable
5 material; and

directing broken fragments of the mined material through a sorting arrangement for sorting the broken fragments of the mined material as a function of diameter.
10 16. The method of claim 15, comprising moving fragments of the mined material from the radiation applicator to the surface exclusively by gravity and moving broken fragments of the mined material through the sorting arrangement exclusively by gravity.

15 17. The method of claim 15 or 16, further comprising the step of providing a screen, the screen having apertures that have a diameter that is larger than a diameter of at least a portion of the broken fragments of the mined
20 material, and smaller than at least a portion of unbroken fragments of the mined material, and wherein the step of directing the at least a portion of the broken fragments through the sorting arrangement comprises directing the at least a portion of the broken fragments through the
25 apertures by gravity, whereby at least a portion of the fragments that include valuable material are separated from remaining mined material.

18. The method of claim 18 wherein the surface is a
30 surface of the screen.

19. The method of any one of claims 15 to 19, comprising the step of vibrating the screen so as to facilitate movement of the broken fragments of the mined material
35 through the apertures.

20. The method of any one of claims 17 to 20, comprising the step of vibrating the surface such that the vibration of the surface contributes to the impact force.

5 21. The method of any one of claims 15 to 21, wherein the step of exposing the fragments of the mined material to the electromagnetic radiation comprises exposing the fragments of the mined material to microwave radiation.

10 22. The method of claim 22, wherein the step of exposing the fragments of the mined material to the electromagnetic radiation comprises exposing the fragments of the mined material to the microwave radiation and thereby causing heating such that an associated power-density in the
15 heated fragments of the mined material is at least 1×10^9 W/cm³.

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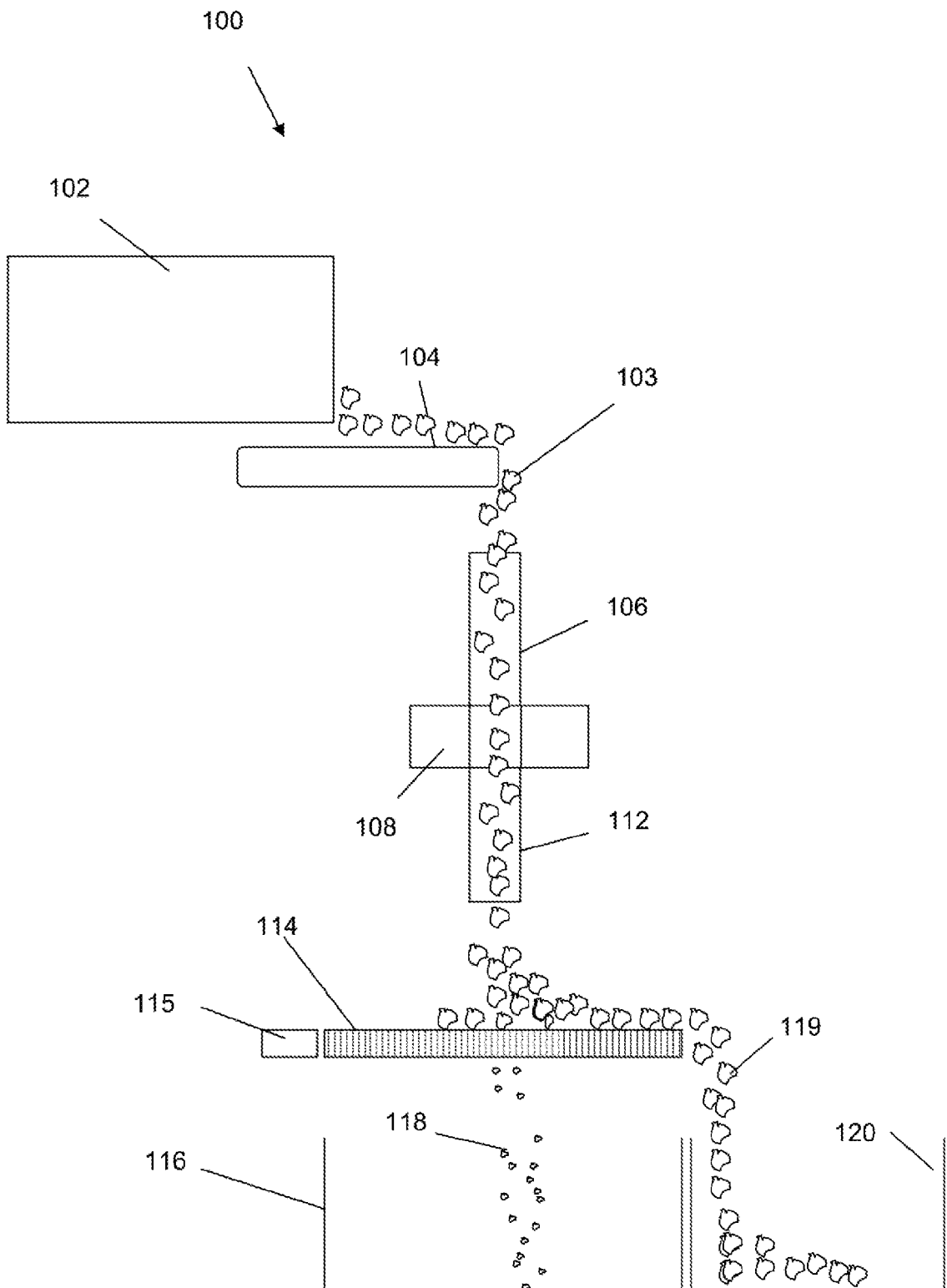


Fig. 1

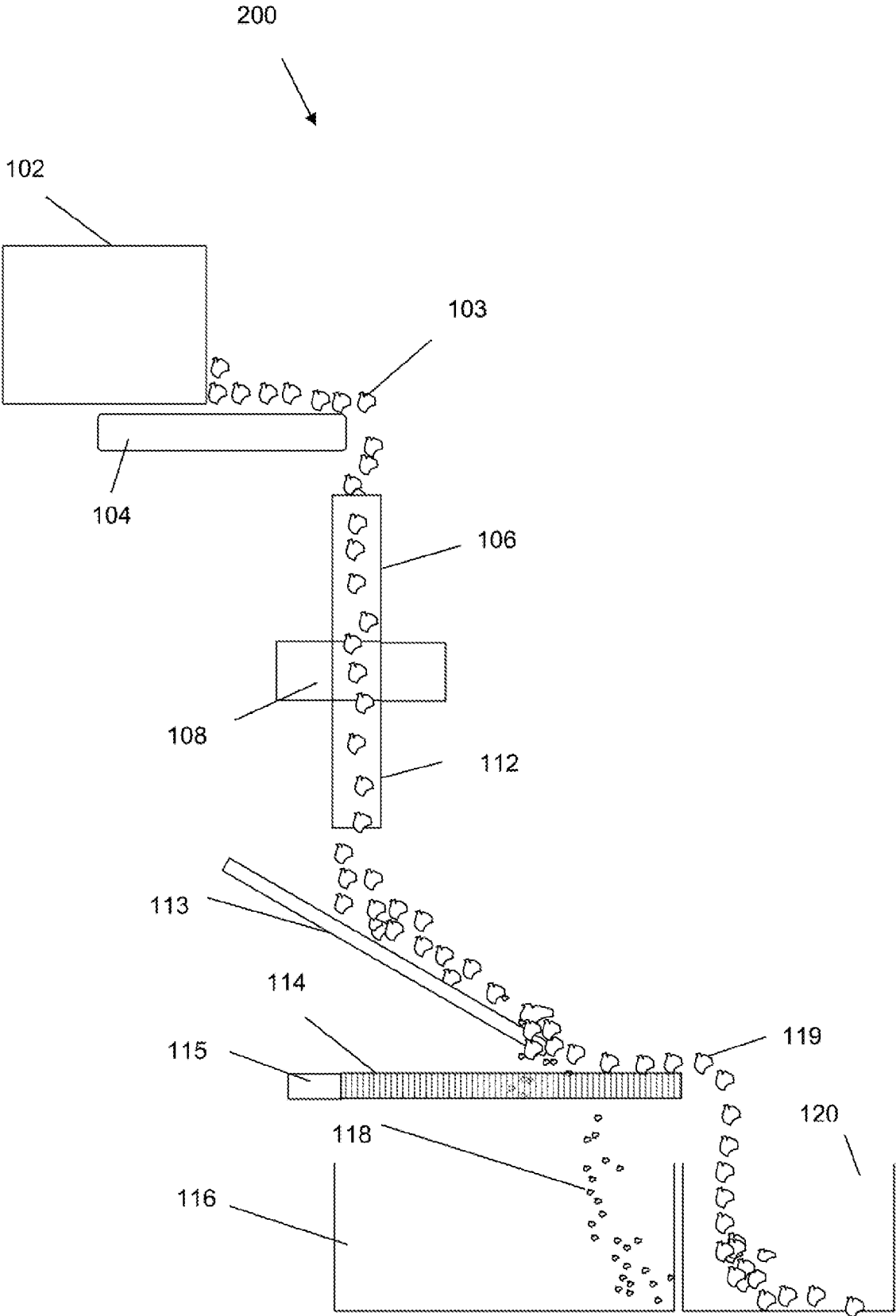


Fig. 2

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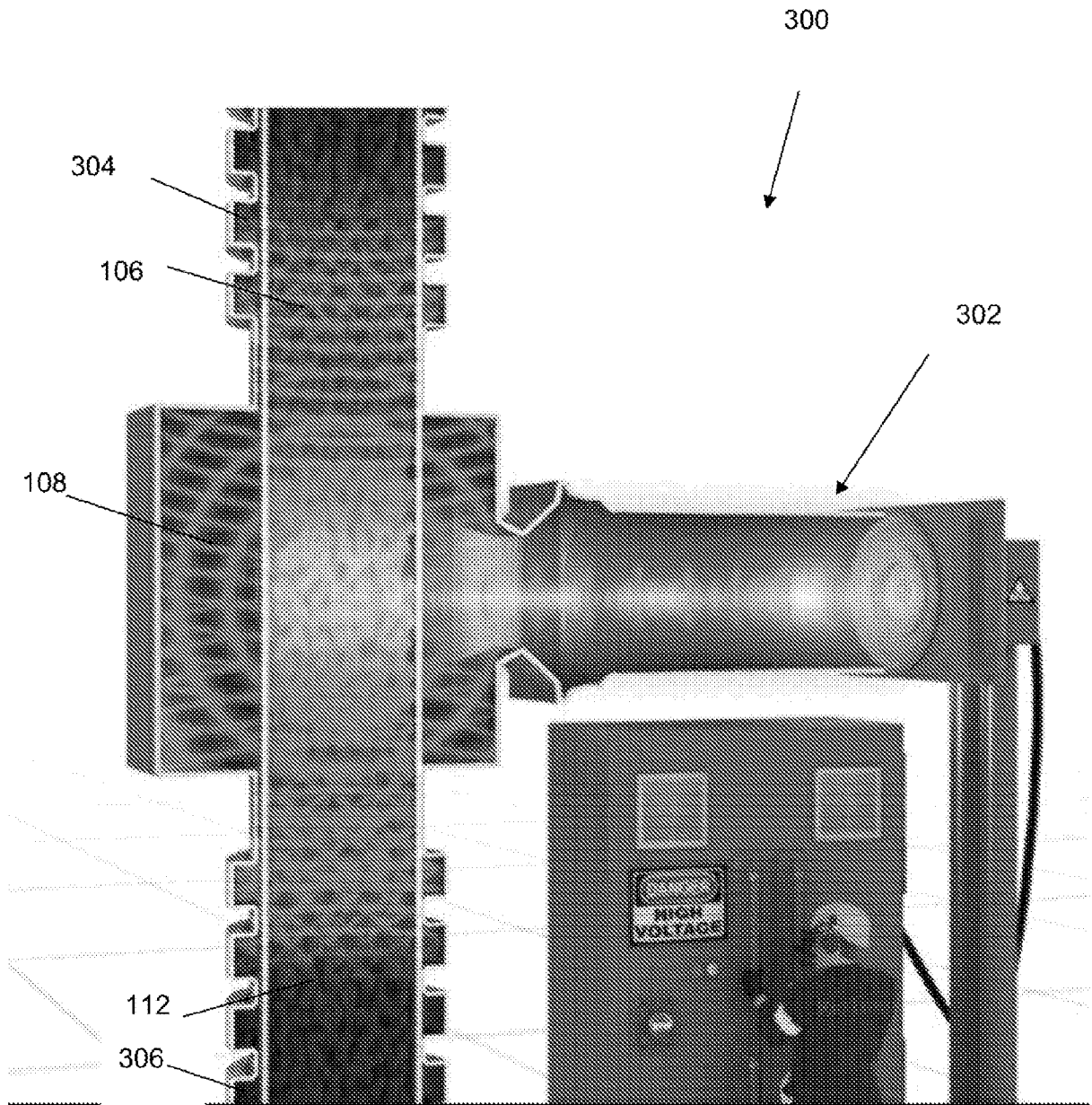
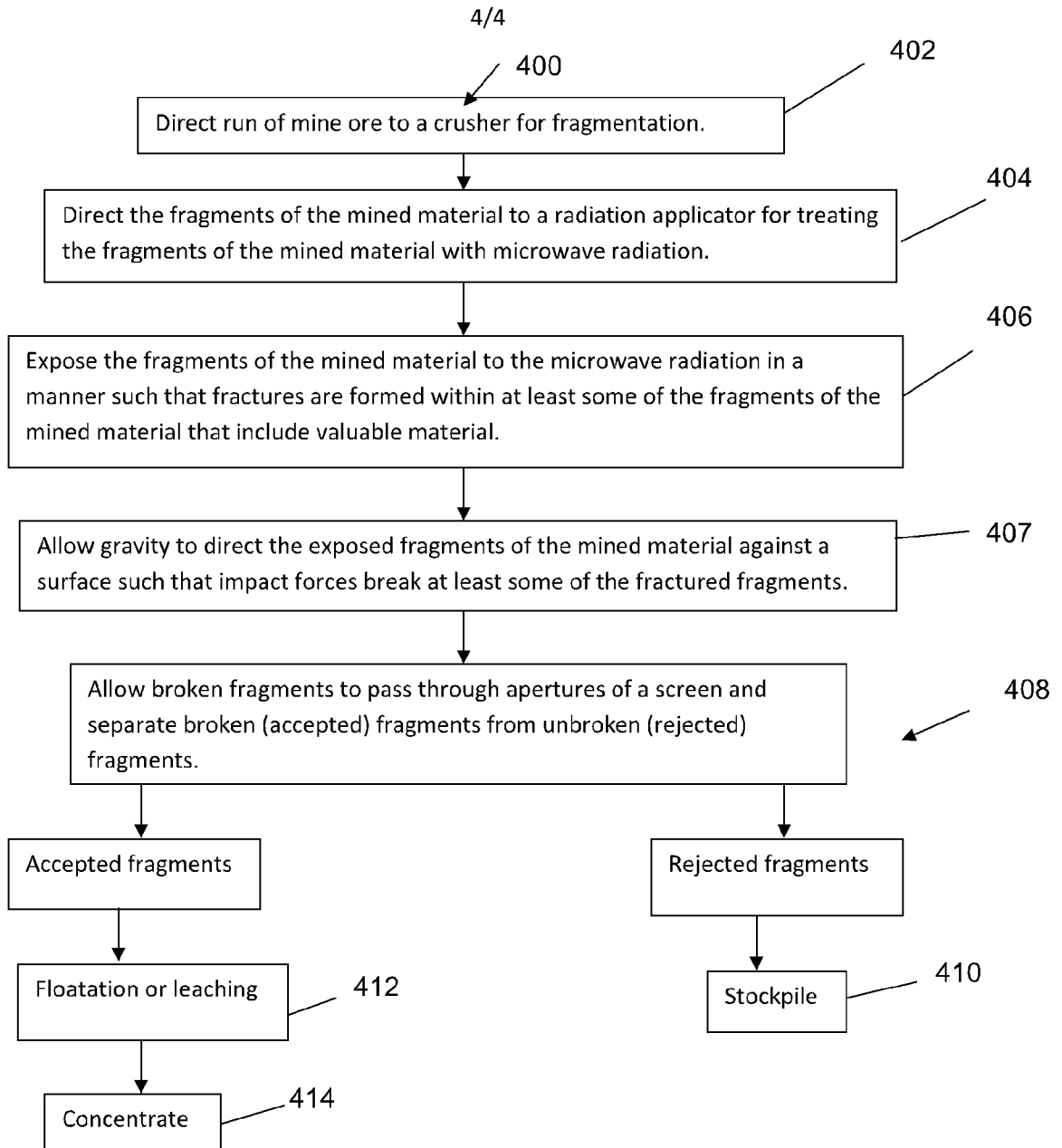


Fig. 3

**Fig. 4**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2014/000648

A. CLASSIFICATION OF SUBJECT MATTER

B02C 19/18 (2006.01) B02C 23/08 (2006.01) B02C 23/16 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI and EPODOC: /IC/CC: B02C19/18, B02C23/08, B02C23/16, B02C19/186; Keywords: microwave (with similar keywords); Google Patent, Esp@csnet, Patent Lens: ore, crack, microwave, radiation, gravity, screen, vibrate (with similar keywords)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:	
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"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
5 August 2014Date of mailing of the international search report
05 August 2014

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INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. PCT/AU2014/000648
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/ 0263483 A1 (Liubakka et al.) 21 October 2010 abstract, figure 1, paragraphs 0014-0020, claim 1	1-23

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INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2014/000648	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 2010/ 0263483 A1	21 October 2010	None	
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			