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(71) Applicant: **LINDE AKTIENGESELLSCHAFT**
[DE/DE]; Klosterhofstr. 1, 80331 München (DE).

(72) Inventor; and

(71) Applicant (for US only): **FENG, Tao** [CN/CN]; 39-502,
No.1728, Wulian Road, Shanghai (CN).

(74) Agent: **SHANGHAI PATENT & TRADEMARK LAW
OFFICE, LLC**; 435 Guiping Road, Shanghai 200233
(CN).

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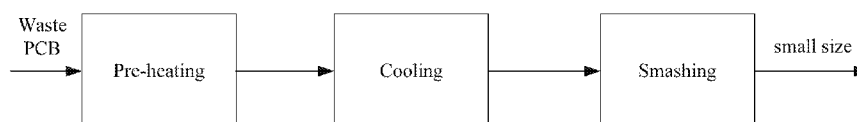


FIG. 3

(57) Abstract: A method and an apparatus of cryo-smashing waste PCB are provided. The method comprises pre-heating the PCB, cooling the pre-heated PCB, and smashing the cooled PCB.



CRYO-SMASHING OF WASTE PCB

TECHNICAL FIELD

5 The disclosure relates to a method and apparatus for cryo-smashing waste printed circuit board (PCB).

BACKGROUND

10 In recent decades, the waste electric and electronic equipment (WEEE) keeps increasing world widely. Recycling of WEEE becomes more and more important not only from the point of environment concern but also from point of the recovery of valuable materials.

15 Waste PCB recycling is a major part in the WEEE industry. Generally, the recycling process includes: 1) selectively disassembly: removing the components attached on PCB, such as capacitors; 2) upgrading & refining: using mechanical, chemical and/or metallurgical processing to upgrade desirable material contents, then refining to recover materials return to their life cycle; 3) final treatment for waste.

20 Before the refining steps in either mechanical or chemical way, a smashing process is a quite critical pre-treatment. The smashing process typically cracks the boards into small particles, e.g., 1×1 mm or even smaller. The conventional process for waste PCB treatment is shown in FIG.1. This process generally includes roughly cutting the bare PCB into 10-20mm size, cooling the cut PCB with liquid nitrogen, and then performing fine smashing.

25 With reference to FIG.2, a typical smashing machine is shown. To gain a finer particle size, a liquid nitrogen spray nozzle is provided at the material entry of the smashing machine. The boards are cooled and frozen before being loaded into the smashing chamber. In addition, there could also be another liquid nitrogen spray nozzle provided in the chamber to cool the cutter and the loaded boards.

30 There are many disadvantages in the prior art. For example, the cooling effect cannot be well controlled, and the nitrogen consumption for cooling is generally

very high. An additional disassembly step is required for removing the components, which is not healthy. Moreover, a rough cutting step is involved to cut the boards into intermediate size for further fine smashing.

One of objects of present disclosure is to address the above and other problems
5 in the prior art.

SUMMARY

In one aspect, present disclosure may generally provide a method of cryo-smashing waste PCB, comprising: pre-heating the PCB; cooling the
10 pre-heated PCB; and smashing the cooled PCB.

In another aspect, an apparatus for cryo-smashing waste PCB is also disclosed herein, comprising: a heater configured to pre-heat one or more PCB; a cooler coupled to the heater and configured to cool the pre-heated one or more PCB; a smasher coupled to the cooler and configured to smash the cooled one or more
15 PCB.

BRIEF DESCRIPTION OF THE DRAWINGS

The benefits, features, and advantages of the present disclosure will become better understood with regard to the following description and accompanying
20 drawings, in which:

FIG.1 illustrates the conventional smashing process in prior art;

FIG.2 illustrates the typical smashing machine in prior art;

FIG.3 is a block diagram showing a cryo-smashing process according to an embodiment of present disclosure;

25 FIG.4 is a block diagram showing a cryo-smashing apparatus according to an embodiment of present disclosure;

FIG.5 illustrates an embodiment of the cryo-smashing apparatus using liquid nitrogen bath; and

FIG.6 illustrates another embodiment of the cryo-smashing apparatus using
30 liquid nitrogen spray.

DETAILED DESCRIPTION

FIG.3 is a block diagram showing a cryo-smashing process according to an embodiment of present disclosure. As shown in FIG.3, this smashing process may include pre-heating the loaded waste PCB, cooling the pre-heated PCB, and smashing the cooled PCB into required size, such as less than 1×1 mm.

In an embodiment, the PCB may be pre-heated to a temperature between about 150°C and about 200°C . The pre-heating step could, for example, enhance the cryo-treatment effect and reduce the adhesion between multiple layers so as to facilitate the following process. The pre-heating may include electrical heating, thermal heating and other heating techniques. Present disclosure is not limited in this aspect.

As shown in FIG.3, the pre-heated PCB may be cooled to a required temperature, such as between about -50°C and -100°C , and then smashed into particles of small size. Cooling the pre-heated PCB could be implemented in various ways including, but not limited to, cooling with coolant, such as liquid nitrogen and liquid CO_2 , or mechanical cooling.

The cryo-treatment after pre-heating may, for example, provide a stronger thermal strike and thus embrittle the PCB. In particular, the strong heat shock may, for example, create a lot of inter-layer delamination, internal stress and make the board brittle, which helps on finer particle size after the smashing. In some embodiments, the temperature gap between the heating and cooling of the PCB may range from about 200°C to 300°C .

In addition, in some embodiments, under the cooling effect, the liquid electrolyte in the components on the PCB could be frozen, such as to a temperature between about -5°C and about -55°C . Thus, unlike the prior art, there is no need to remove the components, such as capacitor, before the smashing. Moreover, the process shown in FIG.3 may eliminate the rough cutting step of the PCB before smashing in the prior art. Therefore, the smashing process disclosed herein may advantageously simplify the prior art process.

FIG. 4 is a block diagram illustrating a cryo-smashing apparatus according to present disclosure. As shown in FIG.4, the cryo-smashing apparatus

100 may includes a heater 110, a cooler 120 coupled to the heater 110 and a smasher 130 coupled to the cooler 120.

The heater 110 may be configured to pre-heat the waste PCB loaded to the heater 110. In some embodiments, the PCB could be pre-heated to a temperature ranging from about 150°C to about 200°C, which could, for example, reduce the adhesion between multiple layers. In various embodiments, the heater 110 may include any type of heating devices, such as an electrical heater, a thermal heater and others. For example, the heater 110 may be a normal heating mesh belt furnace.

The pre-heated PCB then may be provided from the heater 110 to the cooler 120. The cooler 120 may cool the pre-heated PCB to a required temperature, such as between about -50°C and -100°C. In various embodiments, the cooler may be of any suitable form, such as a coolant bath, a coolant nozzle, a cooling compressor and others. The coolant may be, but not limited to, liquid nitrogen.

The cooled PCB may be conveyed to the smasher 130 which smashes the PCB into suitable size, such as less than 1×1mm. As mentioned above, the cryo-treatment after pre-heating may, for example, provide a stronger thermal strike and embrittle the PCB, which helps on finer particle size after the smashing.

FIG.5 illustrates an embodiment of the cryo-smashing apparatus 200 using liquid nitrogen bath. As shown in Fig.5, waste PCB to be smashed may be loaded into a pre-heating furnace 210. The pre-heated PCB then may be dropped into a liquid nitrogen bath 220 via, for example, a belt conveyor. Of course, other conveyors could be used alternatively. Then, the pre-heated PCB may be immersed in the liquid nitrogen. The temperature ramp rate of the PCB may be about 40 to 80°C/min, or even higher. The strong heat shock may make the PCB brittle. Then, the PCB cooled in the liquid nitrogen bath may be conveyed into a smashing chamber 230 where the PCB is smashed into particles of fine size, such as less than 1×1mm.

To further reduce the temperature, in some embodiments, an additional liquid nitrogen is provided in the smashing chamber 230 and controlled to spray therein, as shown in FIG.5. For example, in an embodiment, a thermal sensor is provided

to monitor the temperature inside the chamber 230, and then the liquid nitrogen injection rate is controlled.

Fig.6 illustrates another embodiment of the cryo-smashing apparatus 300 using liquid nitrogen spray. As shown, one or more PCB may be conveyed to a cryo-chamber after pre-heating in the furnace 310. An array of nozzles 320 is provided in the cryo-chamber, spraying liquid nitrogen to the PCB. In one embodiment, the spray rate of the liquid nitrogen is controlled. The temperature ramp rate of the PCB may be about 40 to 80°C/min, or even higher. In such way, every board may be efficiently cooled to a required temperature, such as between about -50°C and -100°C. The cooled board then may be dropped into a smashing chamber 330.

In some embodiments, the cold nitrogen gas may flow into the smashing chamber 310, and/or additional liquid nitrogen may be controlled to spray in the smashing chamber 330 to further reduce the temperature if required.

With the liquid nitrogen bath 220 of FIG.5 or the array of liquid nitrogen spray nozzles 320 of FIG.6, the pre-heated PCB may suffer quick and sufficient cooling to embrittle the PCB while the usage of liquid nitrogen can be well controlled in a consumption effective way. Thus, the overall nitrogen consumption may be significant reduced over prior art.

Although specific embodiments have been illustrated and described herein in considerable details, it should be appreciated that any other arrangement to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. It is to be understood that the above description has been made in an illustrative, not a restrictive, fashion. Combinations of the above embodiments, and other embodiments not specifically described herein will be apparent to those of skill in the art upon reviewing the above description. Thus, those of skill in the art should appreciate that they can readily use the disclosed conception and specific embodiments as a basis for designing or modifying other structures without departing from the spirit and scope of the disclosure as defined by the following claim(s).

CLAIMS

1. A method of cryo-smashing waste printed circuit board (PCB), comprising:
pre-heating the PCB;

5 cooling the pre-heated PCB; and
smashing the cooled PCB.

2. The method of claim 1 wherein the pre-heating comprises pre-heating the
PCB up to about 150-200°C, and/or the cooling comprises cooling the PCB to
10 about -50°C to -100°C.

3. The method of claim 1 wherein the cooling comprises immersing the
pre-heated PCB in liquid nitrogen.

15 4. The method of claim 1 wherein the cooling comprises spraying liquid
nitrogen to the pre-heated PCB.

5. The method of claim 4 wherein the spraying liquid nitrogen to the
pre-heated PCB comprising spraying liquid nitrogen to a plurality of pre-heated
20 PCB with a plurality of nozzles.

6. The method of claim 3 or 4 wherein the cooling temperature ramp rate of
the PCB is about 40 to 80°C/min.

25 7. The method of claim 1 wherein the temperature gap between the
pre-heating and cooling of the PCB ranges from about 200°C to 300°C.

8. The method of claim 1 wherein the cooling comprises freezing the liquid
electrolyte in components on the PCB to a temperature between about -5°C and
30 about -55°C.

9. The method of claim 1 wherein the smashing comprises placing the PCB into a smashing chamber and controlling the injection rate of liquid nitrogen to spray in the smashing chamber.

5 10. The method of claim 1 wherein the smashing comprises smashing the PCB into particles of size less than $1\times 1\text{mm}$.

11. An apparatus of cryo-smashing waste printed circuit board (PCB), comprising:

10 a heater configured to pre-heat one or more PCB;

 a cooler coupled to the heater and configured to cool the pre-heated one or more PCB; and

 a smasher coupled to the cooler and configured to smash the cooled one or more PCB.

15

12. The apparatus of claim 11 wherein the heater is configured to pre-heat the one or more PCB up to about $150\text{-}200^{\circ}\text{C}$, and/or the cooler is configured to cool the PCB to about -50°C to -100°C .

20 13. The apparatus of claim 11 wherein the cooler comprises a liquid nitrogen bath in which the pre-heated one or more PCB is immersed.

14. The apparatus of claim 11 wherein the cooler comprises an array of nozzles for spraying liquid nitrogen to the pre-heated one or more PCB.

25

15. The apparatus of claim 13 or 14 wherein the cooling temperature ramp rate of the one or more PCB is about 40 to $80^{\circ}\text{C}/\text{min}$.

30 16. The apparatus of claim 11 wherein the temperature gap between the pre-heating and cooling of the one or more PCB ranges from about 200°C to 300°C .

17. The apparatus of claim 11 wherein the cooler is configured to freeze the liquid electrolyte in components on the PCB to a temperature between about -5°C and about -55°C.

5

18. The apparatus of claim 11 wherein the smasher comprises a smashing chamber and a liquid nitrogen nozzle for controlling the injection rate of liquid nitrogen to spray in the smashing chamber when the PCB is placed into the smashing chamber.

10

19. The apparatus of claim 11 wherein the smasher is configured to smash the cooled PCB into size of less than 1×1 mm.

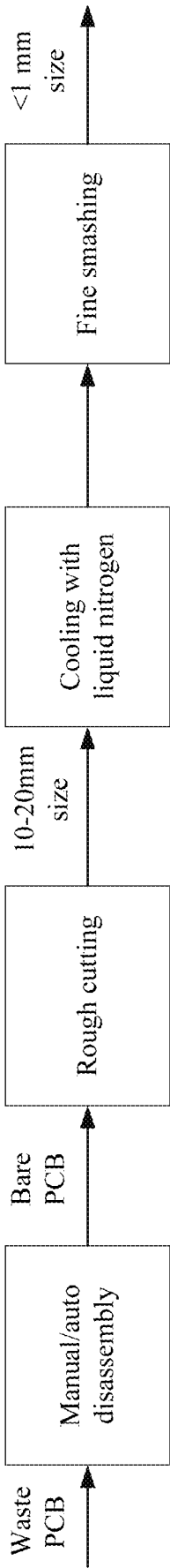
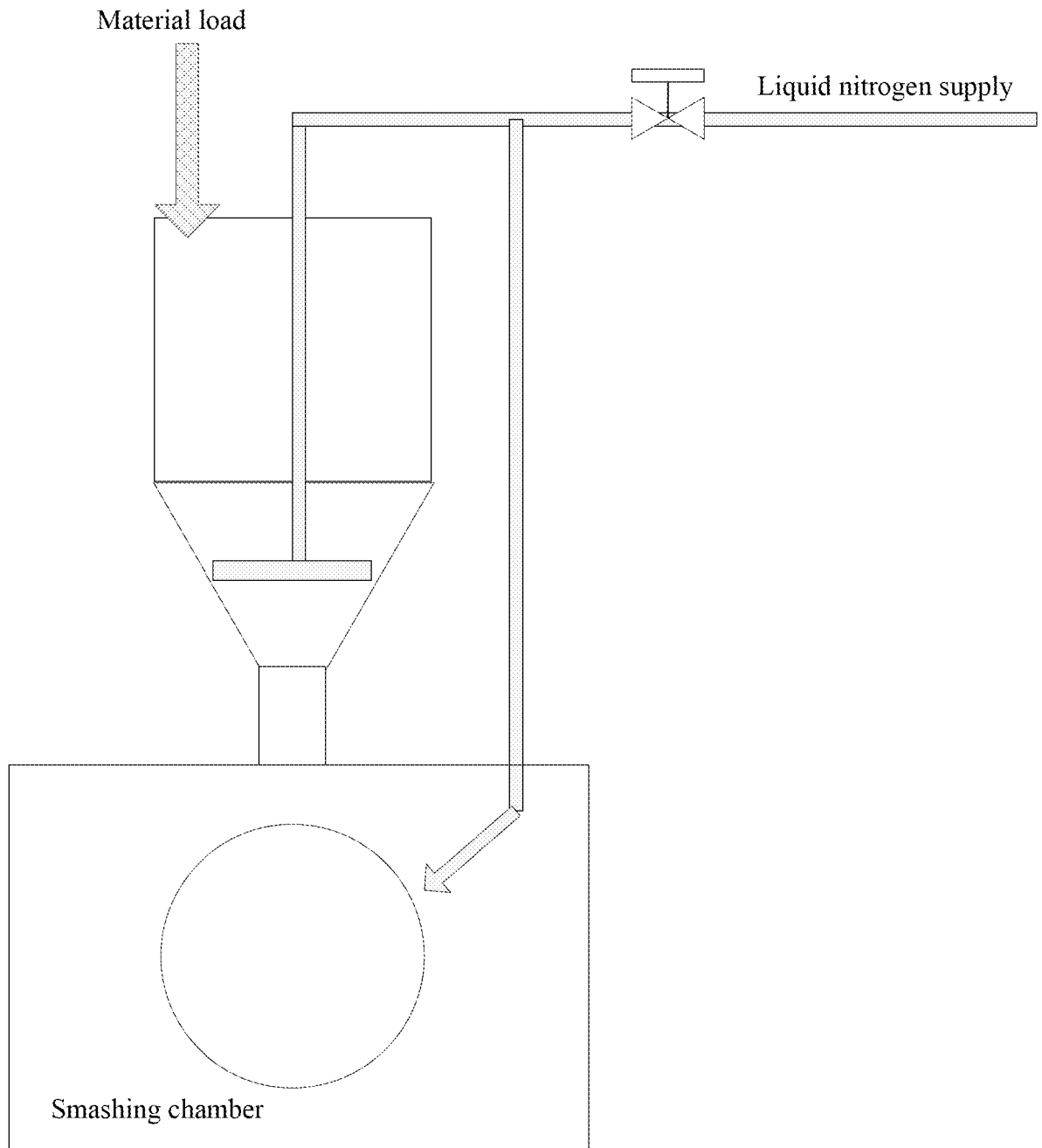


FIG. 1

**FIG. 2**

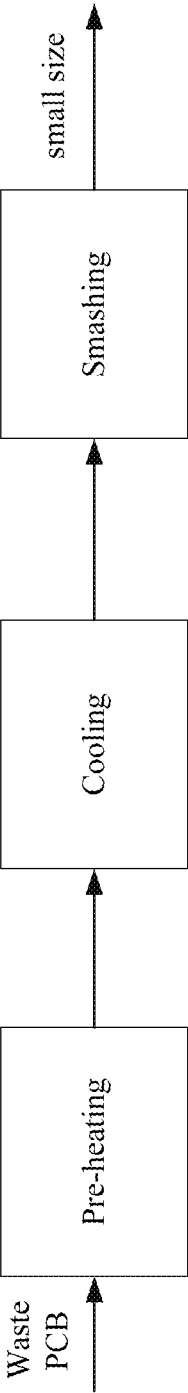


FIG. 3

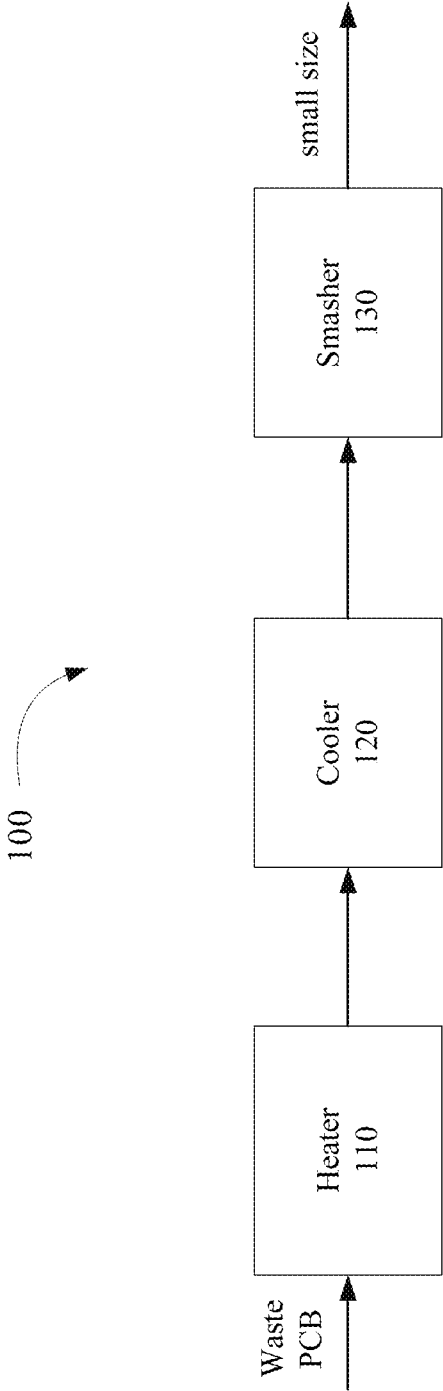


FIG. 4

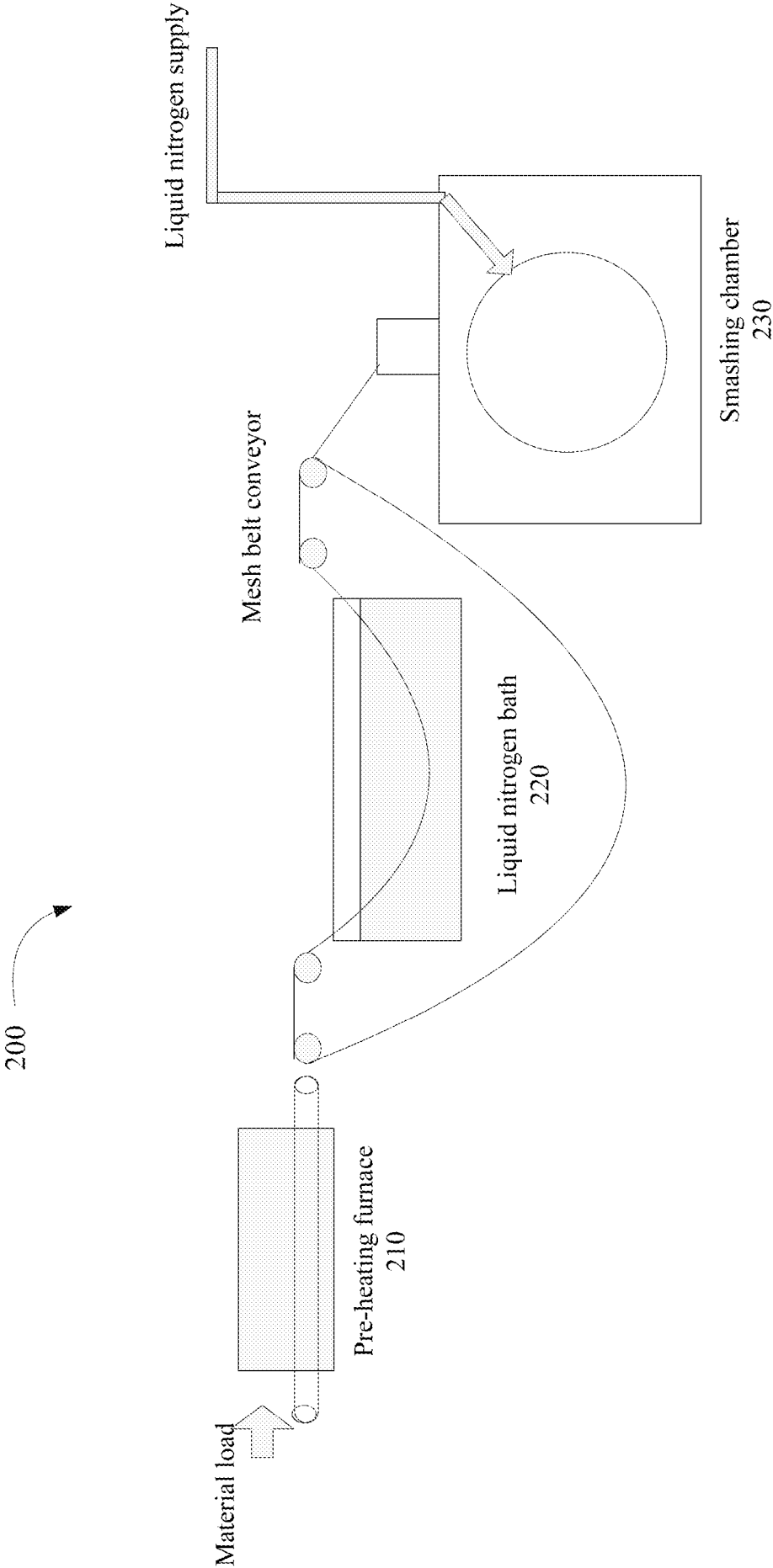


FIG. 5

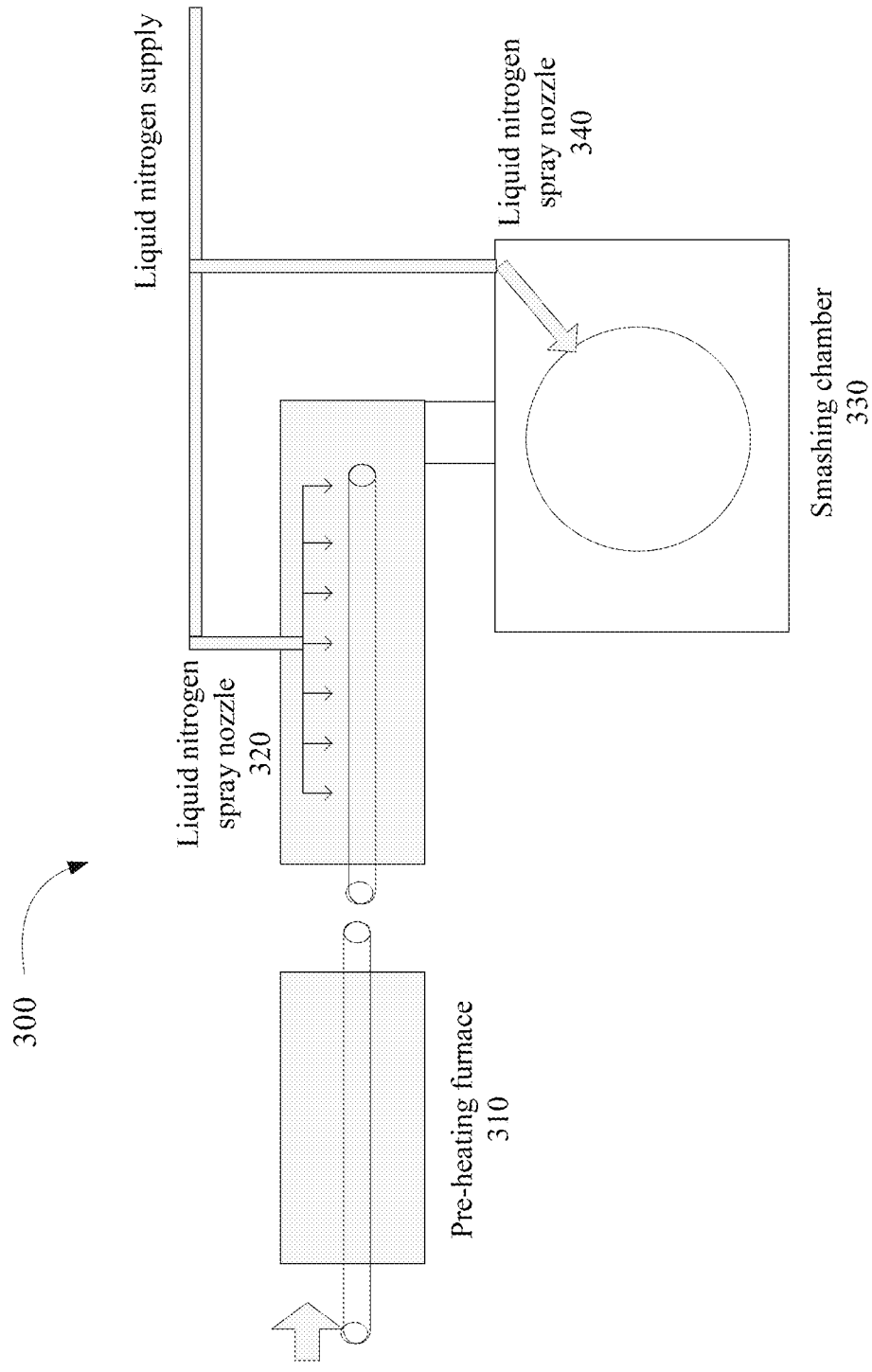


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/082823

A. CLASSIFICATION OF SUBJECT MATTER

B09B 3/00(2006.01)i

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)

B09B, B02C

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)

CNTXT,USTXT,DWPI,CNKI: waste, PCB,crush, smash, grind,liquid nitrogen, cool, heat, preheat

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 101642765A (UNIV BEIJING AERONAUTICS & ASTRONAUTICS) 10 February 2010 (2010-02-10) specification: page 4, line 8- page 6, the last line	1, 3-5, 9, 11, 13, 14, 18
A	US 5683040A (DAIMLER BENZ AG) 04 November 1997 (1997-11-04) the whole document	1-19
A	JP 07140871A (ASMO CO LTD) 02 June 1995 (1995-06-02) the whole document	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

“A”	document defining the general state of the art which is not considered to be of particular relevance	“T”	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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“L”	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	“Y”	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“O”	document referring to an oral disclosure, use, exhibition or other means	“&”	document member of the same patent family
“P”	document published prior to the international filing date but later than the priority date claimed		

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P.R.CHINA(ISA/CN)
6,Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088 China

Authorized officer

ZHI,Yue

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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Patent document cited in search report		Publication date (day/month/year)	Patent family member(s)		Publication date (day/month/year)
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			GB	2300827B	05 February 1997
			JP	2779787B2	23 July 1998
			NL	1003120C2	12 February 1997
			FR	2734177A1	22 November 1996
JP	07140871A	02 June 1995	None		