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(54) Title: VAPOUR NOZZLE FOR JVD

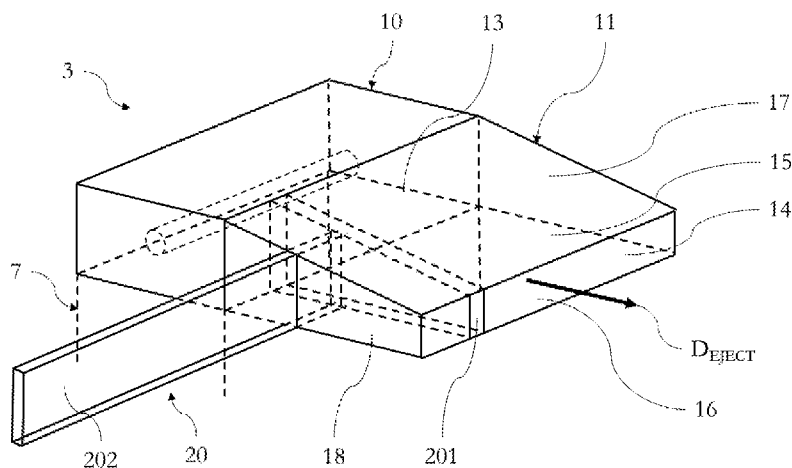


Figure 1

(57) Abstract: The invention relates to a sonic vapour jet coater, for depositing coatings formed of metal or metal alloy on a metallic running substrate, comprising : - a repartition chamber, - a vapour outlet duct, connected to said repartition chamber and able to spray a metal alloy vapour along a main ejection direction, formed by - an adjustable jet width system comprising a separator wall, a rod, and a displacement system wherein - said separator wall being in said duct, configured to closely fit said top wall and bottom wall, and extending essentially from the entry opening to the exit opening, - said rod linking said separator wall to said displacement system, and configured to closely fits said top wall and bottom wall and passing through a lateral wall, - said displacement system being able to displace said rod along the length of the exit opening.



VAPOUR NOZZLE FOR JVD

The present invention relates to a sonic vapour jet coater and a vacuum deposition facility for continuously depositing coatings formed from metal or metal alloys on a metallic substrate.

5 This invention also relates to a depositing method of such coatings.

The invention is particularly intended for depositing a zinc or zinc-magnesium based coatings onto a running steel strip without being limited thereto. Such coated steel strip can then be cut and shaped, for example by stamping, bending or shaping, to form a part that can then be painted.

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Several coating methods exist such as hot-dip coating and electrocoating. However, these conventional methods do not provide a satisfying coating for steel grades containing high level of oxidizable elements such as Si, Mn, Al, P, Cr or B. Consequently, new methods have been developed e.g. vacuum deposition technologies such as JVD (Jet Vapour Deposition).

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In a Jet Vapour Deposition, a metallic vapour spray, propelled at a supersonic speed, comes into contact with the substrate as described in WO97/47782 and WO2009/047333.

EP2048261 discloses a vapour generator for depositing a coating on a metallic substrate, and comprises a vacuum chamber in the form of an enclosure provided with a unit to ensure a state of depression with respect to the external environment and a unit allowing entry and exit of the substrate. The enclosure comprises a head for vapour deposition, and an ejector for creating a metal vapour jet at the sonic speed in the direction of and perpendicular to the substrate surface. The ejector is sealably connected with a crucible by a supply pipe. The crucible contains a mixture of metals in liquid form, and is located outside the vacuum chamber and fed by pumping or by barometric effect of the melt obtained from a melting furnace placed at atmospheric pressure. A unit is arranged to regulate flow, pressure and/or speed of the metal vapour in the ejector. The regulation unit comprises a butterfly type proportional valve and/or a pressure drop device arranged in the pipe. The ejector comprises a longitudinal slit as sonic collar for vapour exit extending on the whole width of the substrate, and a sintered filter medium or a pressure loss body for standardizing and correcting the velocity of the vapour exiting from the ejector.

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However, such an installation needs to homogeneously coat metallic substrate of various width. To this effect, EP 2 048 261 discloses a generator comprising a simple system for adjusting the vapour jet slot to the width of the strip by rotation of the ejector around its axis. Thus, the edges of the vapour jet and the edges of the substrate are in same plans, i.e. the distances between

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edges of the vapour jet and the edges of the substrate are equal to 0 mm. The generator can comprise two ejectors located on both side of the metallic substrate.

Nevertheless, by using such system, there is a risk that during the deposition process, a thermal gradient is formed along the strip width leading to elastic deformation due to the fact that the coating is firstly applied from one edge of the strip. This thermal gradient can lead to quality issue and reliability issues.

The aim of the present invention is to remedy the drawbacks of the facilities and processes of the prior art.

Other characteristics and advantages will become apparent from the following detailed description of the invention.

The invention will be described, in a non-limitative way, in reference to the following drawings.

Figure 1 is an embodiment of a sonic vapour jet coater according to the invention.

Figure 2 is a cross sectional view of an embodiment of a vapour outlet duct and an adjustable jet width system according to the invention.

Figure 3 is a cross sectional view of a second embodiment of a vapour outlet duct and an adjustable jet width system according to the invention.

Figure 4 is a second embodiment of a sonic vapour jet coater according to the invention.

Figure 5 is an embodiment of a vacuum deposition facility according to the invention.

The invention relates, as illustrated in Figure 1, to a sonic vapour jet coater 3, for depositing coatings formed of metal or metal alloy on a metallic running substrate, comprising :

- a repartition chamber 10 comprising at least one reheating means 12 and configured to be connectable to an evaporation pipe 7,
- a vapour outlet duct 11, connected to said repartition chamber 10 and able to spray a metal alloy vapour at a supersonic speed along a main ejection direction D_{EJECT} , formed by
 - a entry opening 13,
 - a exit opening 14,
 - a top wall 15 and a bottom wall 16,
 - two lateral walls (17, 18),

- an adjustable jet width system 20 comprising a separator wall 201, a rod 202, and a displacement system wherein

- said separator wall 201 being in said duct, configured to closely fit said top wall 15 and said bottom wall 16, and extending essentially from the entry opening 13 to the exit opening 14,

- said rod 202 linking said separator wall 201 to said displacement system, and configured to closely fits said top wall 15 and said bottom wall 16 and passing through a lateral wall 18,

- said displacement system being able to move said rod along the length of the exit opening.

The sonic vapour jet coater is a coater capable of generating a vapour jet of sonic velocity at the exit opening. This type of deposition is also usually referred to as a JVD, standing for Jet Vapour Deposition, device. The reader may refer to the patent applications W097/47782 and W02009/047333 for a fuller description of the details of this type of device.

The sonic vapour jet coater ejects the metallic vapour at a supersonic speed along a main ejection plan. This main ejection plan is preferably perpendicular to the path of the metallic running substrate to be coated.

The metallic running substrate is preferably a steel running substrate.

As embodied in Figure 1, the sonic vapour jet coater 3 comprises a repartition chamber 10 provided with a vapour outlet duct 11. Figure 1 does not exhibit the casing of the sonic vapour jet coater 3.

The repartition chamber 10 allows the metallic vapour to be homogeneously distributed along the entry opening 12 of the vapour outlet duct 11.

The repartition chamber 10 comprises at least one reheating means 12. Such reheating means permit to reheat the metallic vapour coming from the evaporation pipe after its expansion when entering the vapour outlet duct preventing condensation in the vapour outlet duct.

Preferably, the reheating means extends along the length of the entry opening. It is preferably in the form of a heating cartridge. The number and position of the reheating means can be adjusted to optimize the reheating of the vapour.

This chamber may for example be made of graphite.

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As illustrated in Figure 1, the entry opening is cut in the wall of the repartition chamber 10 so as to allow a flow of vapour from the repartition chamber 10 to the vapour outlet duct 11. The entry opening is preferably rectangular, as illustrated in Figure 1. The exit opening 13 is preferably rectangular 14, as illustrated in Figure 1.

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The vapour can exit in the deposition chamber through the exit opening 14 which is preferably located in a plan parallel to the path of the metallic running substrate P so that the vapour is more homogeneously deposited on the substrate.

As illustrated in Figure 1 and Figure 2, the top wall 15 and the bottom wall 16 link the length of the entry opening 13 and the length of the exit opening 14. The two lateral walls (17, 18) link the width of the entry opening 13 and the width of the exit opening 14.

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Preferably, the top wall 15 and the bottom wall 16 of the vapour outlet duct converge toward each other in the direction of the exit opening 14. By “converging toward each other”, it is meant that the exit opening width of the vapour outlet duct is smaller than the entry opening width. It in no way limits the shape of the sides, which can be for example straight lines, curved lines or combinations of both.

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The reader may refer to the patent application WO2018/239314 for a fuller description of the details of this type of vapour outlet duct.

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Alternatively, the top wall and the bottom wall of the vapour outlet duct may form two sections, a first section wherein said sides converge toward each other in the direction of the second section, and a second section wherein said sides diverge from each other in the direction of the exit opening.

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As illustrated in Figure 1 and in Figure 2, the vapour jet orifice comprises an adjustable jet width system 20 which comprises a separator wall 201, a rod 202, and a displacement system.

The separator wall 201 extends essentially from the entry opening 13 to the exit opening 14 of the vapour outlet duct 11. A passage is defined from the separator wall 201 to the opposite lateral wall 17. The length of this passage is smaller than the length of the exit opening 14.

As illustrated in Figure 1, the separator wall 201 is configured to fit closely the top wall 15 and the bottom wall 16. Preferably, the separator wall is configured such that there is a little clearance, from 1 to 9 tenths of a millimetre, between the separator wall 201 and the top wall 15 as well as between the separator wall 201 and the bottom wall 16 when in operation. A smaller clearance will lead to friction and a greater clearance will allow the metallic vapour to pass through.

As illustrated in Figure 1 and Figure 2, the length of the separator wall 201 is preferably along the main ejection direction

As illustrated in Figure 1, the rod 202 passes through a lateral wall 18 of the vapour outlet duct 11. One end of the rod 202 is linked to the separator wall 201 so as to move said separator wall 201 when the rod 202 is moved. The other end of the rod 202 is linked to the system able to move the rod.

As illustrated in Figure 1, the rod 202 is configured to fit closely the top wall and the bottom wall (15, 16) of the vapour outlet duct. Preferably, the rod is configured such that there is a little clearance, from 1 to 9 tenths of a millimetre, between the rod 202 and the top wall 15 as well as between the rod 202 and the bottom wall 16 when in operation. A smaller clearance will lead to friction and a greater clearance will allow the metallic vapour to pass through.

The section of the rod is not limited. For example, the rod can have a round, a rectangular or a triangular section. Also, the section can vary along the length of the rod.

The system able to displace the rod, which is not represented, can be any suitable system. For example, it can be a brushless electric motor able to work under vacuum for low tension which can drive a screw system moving the rod forwards or backwards.

This system permits to displace the rod 202 and thus the separator wall 201 in a direction along the length of the exit opening 16.

Preferably, the adjustable jet width system comprises heating means able to heat said separator wall 201. Even more preferably, the adjustable jet width system comprises heating means able to heat said separator wall 201 and said rod 202. It has surprisingly been found that if the separator wall is not heated, it could lead to a quality issue of the coating. The addition of this

heating means permits to reduce the risk of condensation, on the separator wall 201 and/or on the rod 202, of the metallic vapour.

5 The separator wall 201 and the rod 202 can be made of graphite or of ceramic being resistant to metallic vapour, especially zinc metallic vapour. Graphite is the preferred option as is permits to reduce the friction when the adjustable jet width system is moved.

10 As illustrated in Figure 2 and in Figure 3, this invention allows to modify the length of the opening where the metallic sonic vapour exit the sonic vapour jet coater and thus the length of the spray exiting the vapour outlet duct. Advantageously, compared to the existing prior art, the length of the sprayed sonic vapour jet can be different from the length of the duct which permits to coat metallic running substrate having different width with a satisfying homogeneity. This is illustrated in Figure 3, wherein the length of the opening, from the separator wall 201 to the lateral wall 17, where the metallic sonic vapour can exit the sonic vapour jet coater is smaller than the length of
15 the exit opening 14.

Alternatively, the sonic vapour jet coater comprises two adjustable jet width system and, one on each side. In this alternative a first rod passes through a first lateral wall and a second rod
20 passes through a second lateral wall.

The running metallic substrate might not be centred or aligned with the desired running path. Such a sonic vapour jet coater permits to adapt the sprayed metallic vapour to the position of the running metallic substrate and thus improve the coating quality along the substrate width for a wider range of metallic running substrate ranges.

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The invention also relates, as illustrated in Figure 5, to a vacuum deposition facility 1 for continuously depositing, on a running substrate (S), coatings formed from metal or metal alloy, said facility 1 comprising successively :

- an evaporation crucible 4 suited to supply metal or metal alloy vapour
- 30 - an evaporation pipe 7,
- a deposition chamber 2 suited to have said substrate S run through along a given path and
- at least one sonic vapour jet coater 3 according to the invention.

The sonic vapour jet coater 3 of the present invention can be used in a vacuum deposition facility as embodied in Figure 1. The vacuum deposition facility 1 comprises a deposition chamber 2 which is a hermetically sealable box preferably kept at a pressure between from 10^{-8} to 10^{-3} bar. It has an entry lock and an exit lock, which are not shown, between which a metallic substrate S can run along a given path P. The metallic substrate can be for example a steel strip. The substrate may be made to run by any suitable means such as a rotary support roller.

In the deposition chamber 2, a vapour sonic jet coater 3 is beside a face of the substrate S to be coated. This coater is suited to spray, onto the running substrate S, a metal alloy vapour from an evaporation crucible.

The sonic vapour jet coater is mounted, directly or not, on the evaporation crucible 4. The latter is suited to contain a metal or metal alloy bath generating the vapour to be deposited on the substrate and suited to feed the sonic vapour jet coater with the metallic vapour. The evaporation crucible 4 is preferably located in the deposition chamber 2.

The evaporation crucible 4 mainly consists of a pot 5, a cover 6 and an evaporation pipe 7. The latter is connected on one side on the cover 6 and on the other side on the sonic vapour jet coater 3. Preferably, a valve placed between the evaporator and the ejector controls the metallic vapour flow. These different parts may for example be made of graphite.

The evaporation crucible is provided with heating means 8 enabling the metallic vapour to form and to feed the sonic vapour jet coater. The evaporation crucible is advantageously provided with an induction heater which has the advantage of making the stirring and the composition homogenisation of the metal alloy bath easier.

The invention also relates to a method for continuously depositing, on a running substrate (S), coatings formed from at least one metal inside a vacuum deposition facility according to the invention, wherein the method comprises a step in which a metallic vapour is ejected through at least one vapour outlet duct, towards a side of said running substrate and a layer of at least one metal is formed.

The depositing method may also have the optional features listed below, considered individually or in combination :

- in said vacuum chamber having a pressure P_{VACUUM} , said metallic vapour is ejected through at least one vapour outlet duct at a pressure P_{EJECTED} , wherein $(P_{\text{EJECTED}} / P_{\text{VACUUM}})$ is from 2 to 15,
- the vacuum chamber has pressure P_{VACUUM} from 10^{-8} to 10^{-3} bar.

CLAIMS

1. A sonic vapour jet coater (3), for depositing coatings formed of metal or metal alloy on a metallic running substrate, comprising :

- a repartition chamber (10) comprising at least one reheating means (12) and configured to be connectable to an evaporation pipe (7),

- a vapour outlet duct (11), connected to said repartition chamber (10) and able to spray a metal alloy vapour at a supersonic speed along a main ejection direction D_{EJECT} , formed by

- a entry opening (13),

- a exit opening (14),

- a top wall (15) and a bottom wall (16),

- two lateral walls (17, 18),

- an adjustable jet width system (20) comprising a separator wall (201), a rod (202), and a displacement system wherein

- said separator wall (201) being in said duct, configured to closely fit said top wall (15) and said bottom wall (16), and extending essentially from the entry opening (13) to the exit opening (14),

- said rod (202) linking said separator wall (201) to said displacement system, and configured to closely fits said top wall (15) and said bottom wall (16), and passing through a lateral wall (18),

- said displacement system being able to move said rod along the length of the exit opening.

2. A sonic vapour jet coater 3, according to claim 1, wherein said top wall (15) and said bottom wall (16) converge toward each other in the direction of the exit opening.

3. A sonic vapour jet coater 3, according to claim 1, wherein said top wall and said bottom wall form two sections,

- a first section wherein said top wall and said bottom wall converge toward each in the direction of the second section, and

- a second section wherein said top wall and said bottom wall diverge from each other in the direction of the exit opening.

4. A sonic vapour jet coater 3, according to any one of the claims 1 to 3, wherein said adjustable jet width system (20) comprises heating means able to heat said separator wall (201).
5. A sonic vapour jet coater 3, according to any one of the claims 1 to 4, wherein said separator wall 201 and said rod (202) are made of graphite.
6. A sonic vapour jet coater 3, according to any one of the claims 1 to 5, wherein said vapour jet orifice comprises an adjustable jet width system (20, 20') on both sides.
- 10 7. A vacuum deposition facility (1) for continuously depositing, on a running substrate (S), coatings formed from metal or metal alloy, said facility (1) comprising successively :
 - an evaporation crucible (4) suited to supply metal or metal alloy vapour
 - an evaporation pipe (7),
 - a deposition chamber (2) suited to have said substrate (S) run through along a given path
 - 15 and
 - at least one sonic vapour jet coater (3), according to any one of the claims 1 to 6.
8. A method for continuously depositing, on a running substrate (S), coatings formed from at least one metal inside a vacuum deposition facility according to claim 7, wherein the method
- 20 comprises a step in which a metallic vapour is ejected at a supersonic speed through at least one vapour outlet duct towards a side of said running substrate and a layer of at least one metal is formed.
9. A method for continuously depositing, according to claim 8, wherein in said vacuum chamber
- 25 having a pressure P_{VACUUM} , said metallic vapour is ejected through at least one vapour outlet duct at a pressure P_{EJECTED} , wherein $(P_{\text{EJECTED}} / P_{\text{VACUUM}})$ is from 2 to 15.
10. A method for continuously depositing, according to claim 8 or 9, wherein the vacuum chamber has pressure P_{VACUUM} from 10^{-8} to 10^{-3} bar.

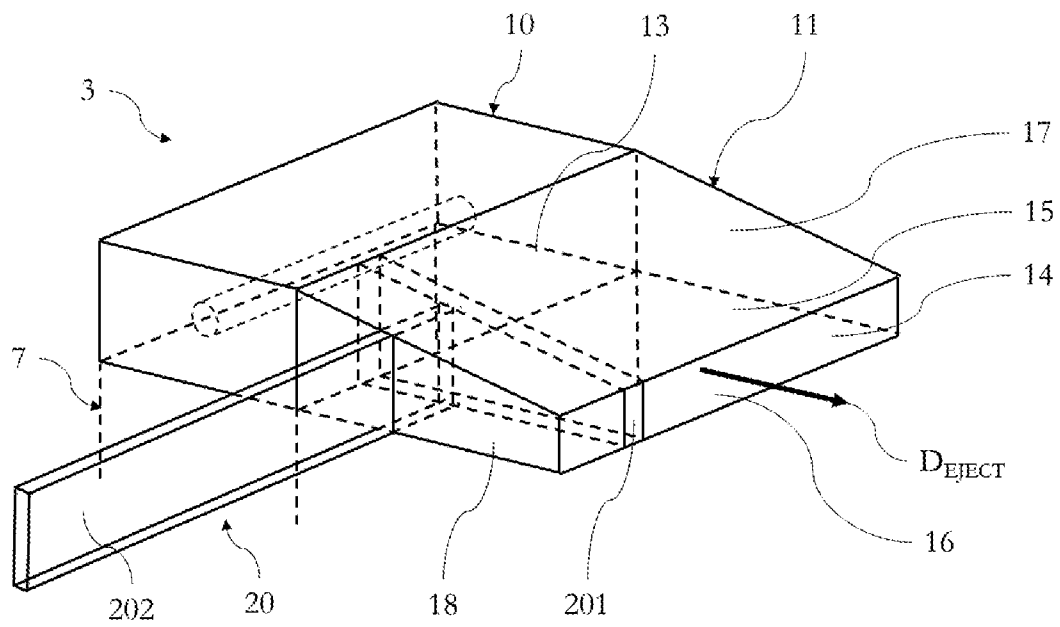


Figure 1

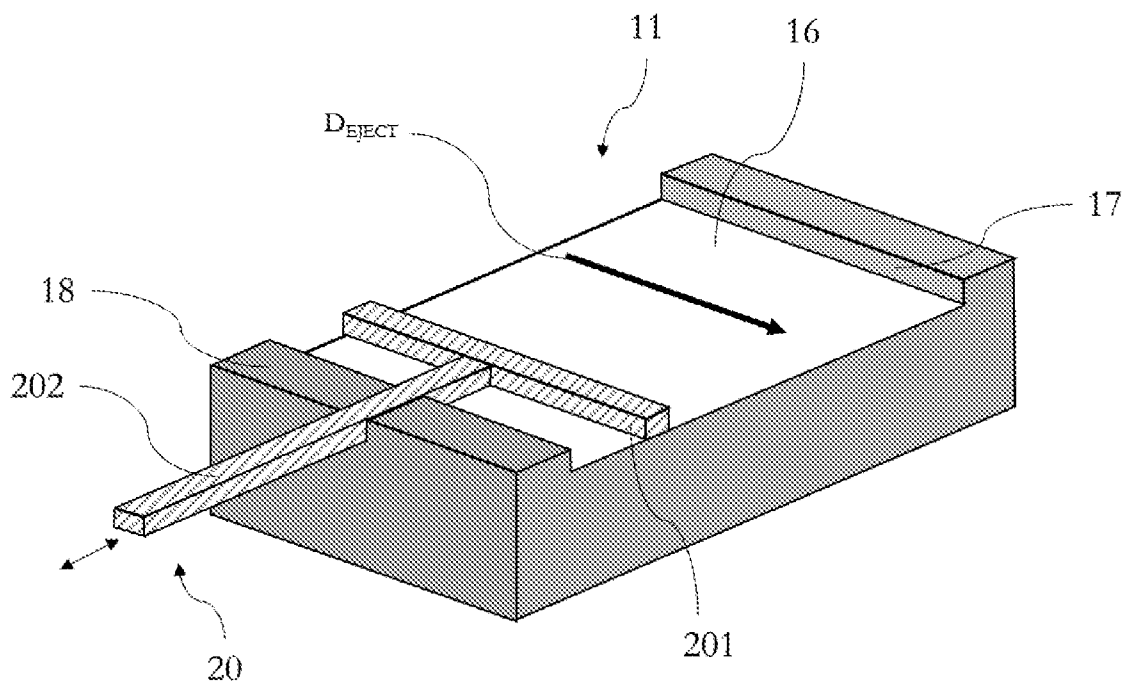


Figure 2

Figure 3

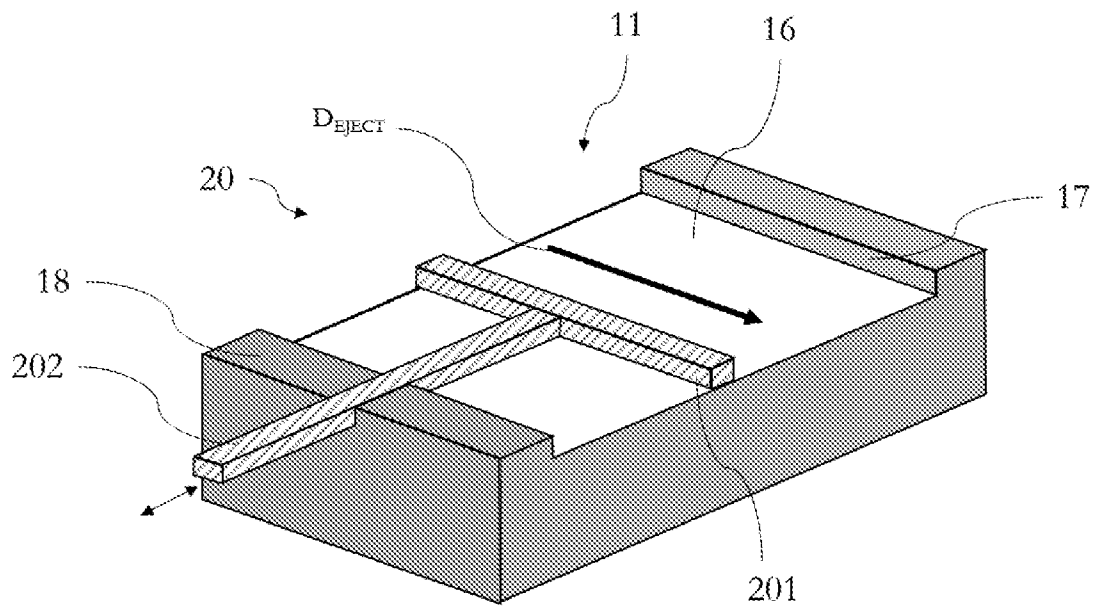
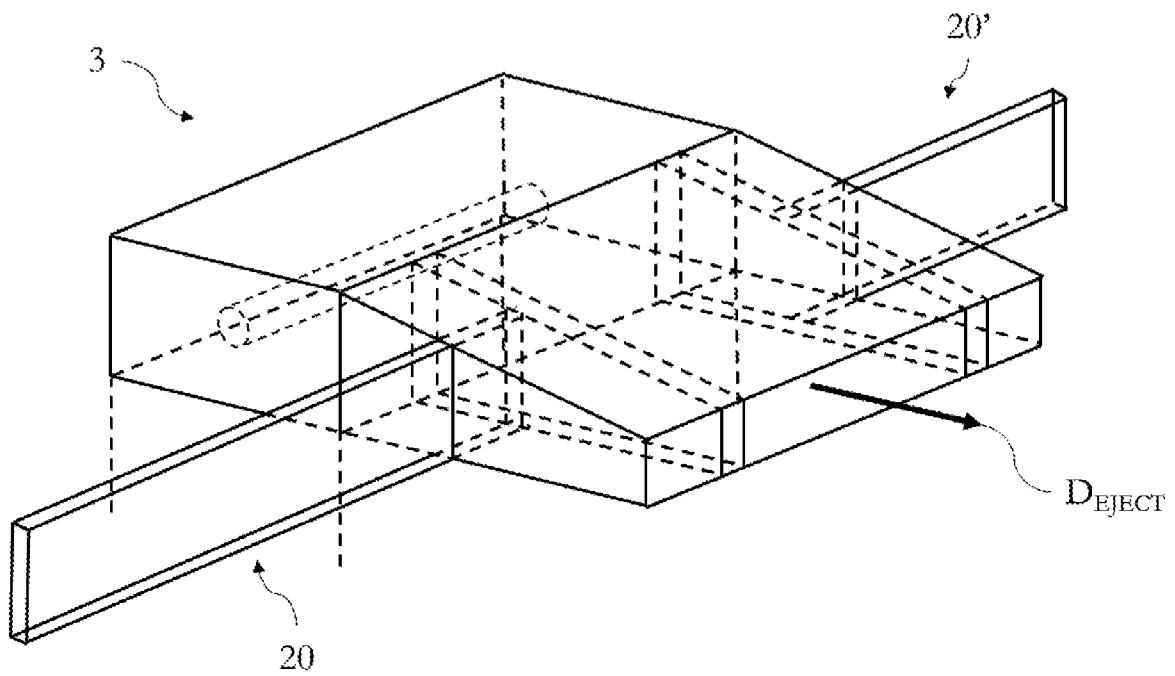


Figure 4



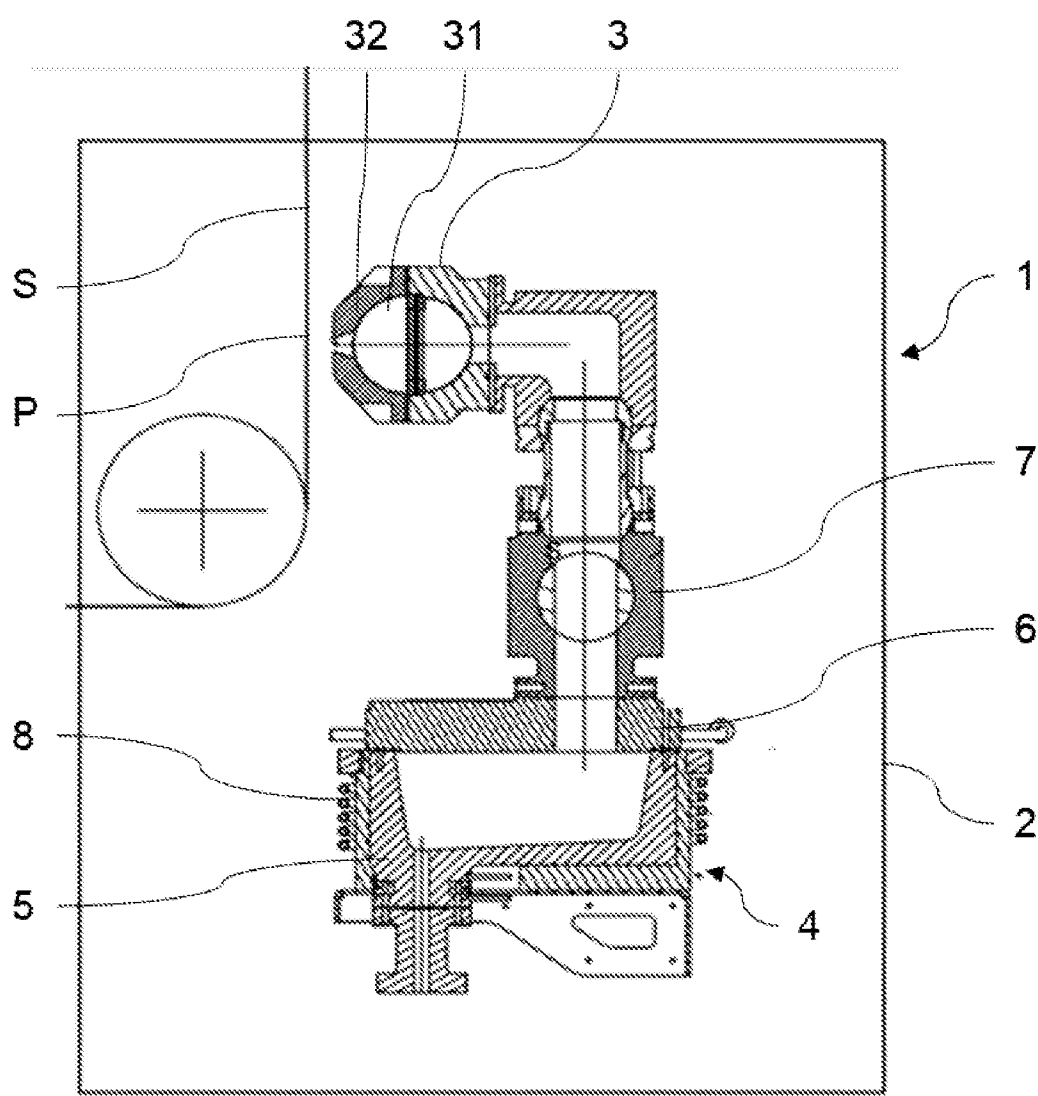


Figure 5

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER INV. C23C14/16 C23C14/24 C23C14/26 C23C14/56 ADD.		
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) C23C 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) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2021/238734 A1 (PACE SERGIO [BE] ET AL) 5 August 2021 (2021-08-05) page 1, paragraphs 7, 8, 9, 12, 26 - page 2, paragraphs 28, 32, 33, 34, 35 page 3, paragraph 49; figures 1-3 -----	1-10
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Y	WO 2023/062410 A1 (ARCELORMITTAL [LU]) 20 April 2023 (2023-04-20) page 2, line 14 - page 3, line 31; figures 2-4 ----- -/--	3
☒ 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 "E" earlier application or patent but published on or after the international filing date "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) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "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 "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "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 "&" document member of the same patent family		
Date of the actual completion of the international search 22 January 2024		Date of mailing of the international search report 02/02/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Boussard, Nadège

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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