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(54) **METHOD AND APPARATUS FOR APPLYING A METAL COATING**

VERFAHREN UND VORRICHTUNG ZUM AUFBRINGEN EINER METALLBESCHICHTUNG

PROCÉDÉ ET APPAREIL POUR APPLIQUER UN REVÊTEMENT MÉTALLIQUE

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Description

[0001] The invention relates to a method for applying a metal coating or metal based coating on a surface of a substrate. The invention also relates to an apparatus for applying a metal coating or metal based coating on a surface of a substrate.

[0002] Metal coatings or metal based coatings (hereafter together referred to as metal coatings unless indicated otherwise) are often applied by electroplating or dipping in a melt. Especially for coating large surfaces, such as metal strips, hot dip coating is used to apply a zinc or aluminium coating, or an alloy thereof, since electroplating is more expensive and less practical on AHSS (advanced high strength steel) because of hydrogen embrittlement. The metal strip, usually a steel strip, is first continuously annealed and thereafter directly guided through a bath with molten metal. The coating on the strip is relatively thick and has to be removed partly, for which gas knives are used.

[0003] Hot dip coating however has the disadvantage that iron-aluminium alloy and oxide pollutions in the metal bath build up to large quantities and lead to surface defects in the coating. Moreover, the speed of coating is limited because when speed increases, the amount of metal to be removed increases too. To do so, the gas flow of the gas knives has to increase as well, which causes splashes, affecting the surface of the coating. In addition, the coating thickness of the coating often varies due to strip vibrations.

[0004] Other coating techniques have been developed, but these all have their disadvantages. For instance, physical vapour deposition (PVD) requires much energy and needs a high investment; PVD is therefore generally used for very thin coating layers. Thermal spraying of zinc is known, but this is usually done to cover e.g. corners of profiled products or welds. Typically thick layers are produced, having a poor quality; the coating is porous and has an unattractive optical appearance. A. Jaworek, Journal of Materials Sciences, vol. 42, n°1, pages 266-297, 2006, reviews electrospray methods and devices including liquid metal ion sources, used for thin film deposition.

[0005] It is an object of the invention to provide a method for applying a metal coating on a surface of a substrate (or a part of that surface), whereby the production speed of the coating process can be increased.

[0006] It is another object of the invention to provide a method for applying a metal coating on a surface of a substrate providing an improved surface quality compared to hot dip coatings.

[0007] It is a further object of the invention to provide a method for applying a metal coating on a surface of a substrate which coating can be thinner than usually applied by hot dip coating.

[0008] It is yet another object of the invention to provide a method for applying a metal coating on a surface of a substrate that has a better quality than a coating made

by hot dip coating.

[0009] Furthermore, it is an object of the invention to provide an apparatus that can be used to implement the method according to the invention.

[0010] One or more of the objects of the invention are obtained by a method for applying a metal coating or metal based coating on a surface of a substrate or a part of that surface, wherein the surface of the substrate is electrically conductive, wherein the surface of the substrate is provided with a temperature that is suitable for applying the coating, wherein metal droplets are generated from a surface of a metal melt, wherein an inert gas is present in the area of the metal melt and the droplets and the surface of the substrate, and wherein a high voltage of between 1 and 30 kV is applied between the metal melt and the surface of the substrate, whereby the metal droplets impinge on the surface of the substrate to form a coating.

[0011] The inventors have found that a metal coating layer of good quality can be provided when liquid metal droplets are generated from a melt and these droplets are pulled towards the surface of the substrate. This surface has to be electrically conductive so a high voltage can be applied between the metal melt and the surface. The droplets will be electrically charged and thereby pulled to the surface; to be able to do so over time, the electrical charge of the droplets has to be discharged by the electrically conductive surface once the droplets impinge on the surface. The droplets must be created and travel in an inert hot surrounding, otherwise the droplets will oxidise and solidify. The surface of the substrate has to have a suitable temperature so the droplets will stick on the surface and spread out by wetting. During their travel to the surface the charges on the droplets will prevent coagulation of the droplets and the droplets will be homogeneously dispersed in the inert gas as well.

[0012] By using the method according to the invention it is possible to apply a thin coating, for instance a coating having a thickness between 1 and 5 μm , at a high speed, having a smooth surface without defects, and having a constant thickness. It is also possible to apply thicker coatings.

[0013] According to a preferred embodiment the droplets have a diameter of at most 30 μm , preferably a diameter of at most 20 μm . Droplets of a small size in a high density spread out well on the surface of the substrate, and provide a coating with a uniform thickness. The inventors expect that droplets having a diameter of 1 to 5 μm are most preferred.

[0014] Preferably, the substrate is moving relative to the metal melt. In this way a coating having a constant thickness is provided on the substrate while the droplets are generated at a constant quantity, when the substrate is moving with a constant velocity. When the velocity is changed, either the coating thickness changes and/or the quantity of droplets has to be changed.

[0015] According to the invention the droplets are formed from the surface of the metal melt by applying

high-frequency ultrasonic energy to the metal melt. The high-frequency ultrasonic energy excites the surface of the metal melt, whereby a standing wave is formed on the surface, from which droplets are released when the amplitude is high enough. The magnitude of the frequency determines the size and quantity of the droplets that are formed.

[0016] Preferably the surface of the metal melt is formed at the end face of a nozzle tip. When a standard (pressure) nozzle is used this nozzle usually has an entrance opening to a cavity filled with molten metal. A transducer coupled to this cavity can provide ultrasonic energy to the molten metal, whereby the surface of the molten metal will vibrate and release droplets. Molten metal has to be fed into the cavity of the nozzle continuously to keep the cavity filled. Usually the surface of the outlet opening of the nozzle has a diameter of approximately 3 mm. Another embodiment uses a series of coupled acoustic horns vibrating at resonance, whereby the molten metal covers the end face of the last horn, which has a diameter of approximately 1 mm. This leads to a monodisperse droplet distribution of diameters between 1 and 5 μm for MHz frequencies. Reference is made to the article "Faraday instability-based micro droplet ejection for inhalation drug delivery" by C.S. Tsai, R.W. Mao, S.K. Lin and S.C. Tsai, describing the forming of water droplets.

[0017] According to a first preferred embodiment the temperature of the surface of the substrate is higher than the melting temperature of the metal. The droplet impinging on the surface of the substrate thus remains molten and will spread out well over that surface, often increasing its diameter with approximately a factor ten compared to the diameter of the original droplet.

[0018] According to a second preferred embodiment the temperature of the surface of the substrate is lower than the melting temperature of the metal and the surface of the substrate is heated to a temperature that is higher than the melting temperature of the metal coating, after the metal coating has been applied. Using this method, the droplet that impinged on the surface of the substrate will directly solidify on the surface of the substrate, thus preventing bounce-off, and therefore not spread out over that surface initially. Since the droplets impinge at random on the surface, a locally uneven coating surface will be formed. To create a smooth, even surface of the coating, the surface of the substrate has to be heated to a temperature that is higher than the melting temperature of the metal coating, so the metal coating will melt and a smooth surface is formed due to the interfacial (wetting) tension between the coating and the surface of the substrate. Heating of the coating can be performed in any suitable way, such as induction heating.

[0019] Preferably the metal coating is formed from a metal having a low melting point, such as zinc, aluminium, tin, copper or an alloy thereof, wherein the alloying elements are for instance aluminium or magnesium, or wherein the metal based coating is formed from a metal

coating with solid particles, for instance nano particles. It is expected that the method according to the invention is very suitable for applying a zinc or zinc based coating, since it is desired to produce zinc (alloy) coatings with a thickness of less than 5 μm which are difficult to produce with hot dip coating. Moreover, the coating velocity can be higher than the maximum practical velocity for hot dip coating, and it is possible to apply a coating at only one side of the substrate. However, the method is also perfectly suited to apply an aluminium, tin, copper or other metal (alloy) coating. Furthermore, using the method of the invention it is possible to apply a metal based coating by introducing solid particles in the metal melt. These solid particles can for instance be nano particles or other small particles, which are (very) small relative to the diameter of the droplets. In the method of the invention, it is easier to introduce these solid particles in the coating, whereas using for instance hot dip coating these particles will easily clog the molten metal bath.

[0020] According to a preferred embodiment the substrate is a moving strip, preferably a moving metal strip, more preferably a moving steel strip. The method according to the invention is very suitable for coating a metal or steel strip, in the same way as a steel strip can be coated with zinc or aluminium by hot dip coating, directly after the annealing line. The method according to the invention has the advantage that coatings with practically any thickness can be applied, and that a very high velocity of the strip can be used. Vibrations of the strip will not influence the coating thickness, and the guiding of the strip is easier because no molten metal bath is needed through which the strip has to be guided. No dross is formed in the method according to the invention.

[0021] Preferably, the moving steel strip has a temperature of 350°C to 500°C when the metal droplets consist of zinc or a zinc alloy. The strip thus has a temperature above the melting temperature of zinc, or slightly below the melting temperature, but is thus easy to heat above the melting temperature, as is described above.

[0022] According to a second aspect of the invention an apparatus for applying a metal coating or metal based coating on a surface of a substrate or a part of that surface is provided, the apparatus having a container for keeping an inert gas and for containing the surface of the substrate to be coated, or a part of that surface, wherein means for generating metal droplets from the surface of a metal melt are present in the container, and wherein means to apply a high voltage of between 1 and 30 kV between the metal melt and the surface of the substrate to be coated are present.

[0023] This apparatus can be used to implement the method according to the first aspect of the invention as described above. The container is needed to keep the inert gas in the area where the droplets are formed and travel and impinge on the surface of the substrate. The high voltage is needed to pull the droplets to the surface of the substrate.

[0024] It is possible that means are present to heat the

surface of the substrate to be coated. Whether these means are needed depends on the use that is made of the apparatus according to the invention. When a steel strip has to be coated using the method of the invention, and the apparatus is placed directly after the continuous annealing line, it is possible that the strip has a temperature that is still high enough to coat it, without use of additional heating means. This also depends on the coating to be applied. If the apparatus is used as stand-alone equipment, a strip will have to be heated before it can be coated using the method according to the invention and heating means are needed for the apparatus.

[0025] According to a preferred embodiment the means for generating the metal droplets from the surface of a metal melt are one or more nozzles, wherein the surface of the metal melt is formed at the end face of a nozzle tip. The use thereof has been described above.

[0026] According to the invention, means are present for applying high-frequency ultrasonic energy to the surface of the metal melt. The forming of droplets using high-frequency ultrasonic energy has been described above.

[0027] According to a preferred embodiment the container contains an entry gas lock system and an outlet gas lock system for coating a moving substrate. The moving substrate, for instance a steel strip or steel wire, can enter the container through the entry gas lock system and leave the container after it has been coated and preferably after the coating has solidified through the outlet gas lock system. The entry and outlet gas lock systems are needed to keep the inert gas inside the container, while making it possible to coat a moving substrate.

[0028] The invention will be elucidated with reference to an exemplary embodiment, as shown schematically in the figures.

Fig. 1 shows, in a very schematic way and while leaving out several required parts, an apparatus according to the invention for coating a moving strip using the method according to the invention.

Fig. 2a shows, in a schematic way, a standard pressure nozzle as can be used in the apparatus of Fig. 1, from the outside.

Fig. 2b shows in cross-section the pressure nozzle as schematically shown in Fig. 2a.

Fig. 3a shows, in a schematic way, another embodiment of nozzles placed in parallel, which can be used in the apparatus shown in Fig. 1.

Fig. 3b shows one of the nozzles of Fig. 3a in more detail.

[0029] Figure 1 shows a moving metal strip 1 that is fed horizontally from for instance an annealing furnace (not shown) and that is deflected in the vertical direction by a guiding roll 2. Above the guiding roll 2 a container (not shown) is placed, having an entry gas lock system in its lower part and an outlet gas lock system in its upper part (also not shown), so the moving strip 1 can enter and exit, respectively, the container. The gas lock sys-

tems are present so as to keep an inert gas inside the container.

[0030] Figure 1 shows a small, closed bath 5 containing molten metal 6 at each side of the metal strip 1. Each bath 5 has several outlet pipes 7 that are connected to nozzles 9. A valve 8 is present in each outlet pipe 7 to regulate the flow of molten metal to each nozzle 9. The baths 5 with molten metal 6 are replenished with additional molten metal at a moment in time and in a way as required, by means and measures that are not shown here. To replenish molten metal in baths is as such known in the art.

[0031] Between the strip 1 and the molten metal 6 a high voltage is applied, of for instance 6 kV (6000 Volt). The molten metal has the high voltage relative to the strip 1, which is connected to earth. Metal droplets are generated at the outlet openings of the nozzles 9. These droplets are generated at the surface of the metal melt at the outlet openings of the nozzle 9 by applying a high-frequency ultrasonic wave at the backside of the nozzles 9. The means for generating the high-frequency ultrasonic waves are not shown; the high frequency is for instance 3 MHz. The high-frequency ultrasonic waves generate a standing wave at the surface of the metal melt in the outlet opening of the nozzle 9, which standing waves produce droplets with an average diameter of less than 20 μm .

[0032] Due to the high voltage between the molten metal 6 the droplets become charged and are attracted towards the metal strip 1 and impinge thereon. When the metal strip 1 has a temperature that is higher than the melting temperature of the (molten) metal 6, the droplets remain molten and will spread out on the surface of the metal strip 1. In this way, a continuous, smooth, even metal coating will be formed on the strip 1, due to the interfacial (wetting) tension of the molten metal on the strip. The droplets are shown in Figure 1 as a dark cloud in front of the nozzles 9.

[0033] The nozzles 9 shown in Figure 1 are depicted in more detail in Figures 2a and 2b. Figure 2a shows a nozzle 9 having an outlet opening 10. Figure 2b shows that outlet opening 10 is the outlet opening of a cavity 11, which can be filled through entrance opening 12. The cavity 11 is filled with molten metal through entrance opening 12, and at the outlet opening 10 the surface of the molten metal is formed. A transducer 13 behind the cavity 11 in the nozzle 9 is set to vibrate using high-frequency ultrasonic energy, whereby the molten metal in the cavity 11 will vibrate. This vibration is increased towards the outlet opening 10. At the surface of the molten metal in the outlet opening 10 a standing wave is formed on the surface, from which droplets are released when the amplitude is high enough. The magnitude of the frequency determines the size and quantity of the droplets that are formed.

[0034] Instead of the nozzles 9 shown in Figure 1, 2a and 2b, it is also possible to use another type of nozzle as shown in Figure 3a and 3b to generate droplets of the

required size. The nozzles 15 shown in Figure 3a use a series of three small horns 16 in series, as shown in Figure 3b, which are induced to vibrate by high-frequency ultrasonic energy generated in a transducer 17. The horns 16 increase the amplitude of the vibration, such that the end face 18 of the last horn 16 has a high amplitude of a precise frequency. The end face 18 of the nozzle 15 has a surface of for instance 1 mm². Molten metal is fed to the end face 18 of the nozzle 15 through a pipe 19. Due to the precise frequency at the end face of the nozzle, droplets are formed within a narrow diameter range between 1 and 5 µm. These diameters are very suitable to form thin metal coatings in accordance with the invention.

[0035] It will be clear to the person skilled in the art that means have to be provided to keep the molten metal 6 in the baths 5 at a required temperature, and also that means can be needed to heat the steel strip before it enters the container, such that the strip has the required temperature when the droplets impinge upon it, as described hereinabove. It may also be necessary to use heating means after the coating has been applied, to melt the coating consisting of impinged droplets, such that a smooth surface of the coating is obtained. Further means for controlling the flow of molten metal through the pipes 7 may be required, and also means to apply inert gas to the container.

[0036] Some droplets will become uncharged and float through the inert gas in the container, therefore the container walls should have a temperature such that the droplets reaching the container walls will remain liquid and flow downwards in the container, where the molten metal can be tapped off.

[0037] The metal that can be applied as coating is the usual coating metal such as zinc, aluminium, tin and copper, or alloys thereof, such as aluminium and magnesium for zinc, and silicon for aluminium. However, also other metals and their alloys could be used. The substrate to be coated will usually be a metal strip, preferably a steel strip, such as a steel used for automotive purposes or for building purposes. However, it is also possible to coat other substrates, as long as the surface of the substrate to be coated is electrically conductive. It is also possible to coat other types of substrates in the way as described above, such as metal wires and even metal pipes (having a small diameter). It is also possible to coat a substrate with a metal coating for instance larger diameter pipes and other long products in a semi-continuous way using the method according to the invention, and using the apparatus according to the invention after small modifications.

[0038] The metal coating described hereinabove also encompasses metal based coatings, wherein solid particles are introduced in the molten metal that is deposited on the surface of the substrate using the method according to the invention.

Claims

1. Method for applying a metal coating or metal based coating on a surface of a substrate or a part of that surface, wherein the surface of the substrate is electrically conductive, wherein the surface of the substrate is provided with a temperature that is suitable for applying the coating, wherein metal droplets are generated from a surface of a metal melt, wherein an inert gas is present in the area of the metal melt and the droplets and the surface of the substrate, and wherein a high voltage of between 1 and 30 kV is applied between the metal melt and the surface of the substrate and the droplets are formed from the surface of the metal melt by applying high-frequency ultrasonic energy to the metal melt, whereby the metal droplets impinge on the surface of the substrate to form a coating.
2. Method according to claim 1, wherein the droplets have a diameter of at most 30 µm, preferably a diameter of at most 20 µm.
3. Method according to claim 1 or 2, wherein the substrate is moving relative to the metal melt.
4. Method according to any one of the preceding claims, wherein the surface of the metal melt is formed at the end face of a nozzle tip.
5. Method according to any one of claims 1 - 4, wherein the temperature of the surface of the substrate is higher than the melting temperature of the metal.
6. Method according to any one of claims 1 - 4, wherein the temperature of the surface of the substrate is lower than the melting temperature of the metal and the surface of the substrate is heated to a temperature that is higher than the melting temperature of the metal coating, after the metal coating has been applied.
7. Method according to any one of the preceding claims, wherein the metal coating is formed from a metal having a low melting point, such as zinc, aluminium, tin, copper or an alloy thereof, wherein the alloying elements are for instance aluminium or magnesium, or wherein the metal based coating is formed from a metal coating with solid particles, for instance nano particles.
8. Method according any one of the preceding claims, wherein the substrate is a moving strip, preferably a moving metal strip, more preferably a moving steel strip.
9. Method according to any one of the preceding claims, wherein the moving steel strip has a temper-

ature of 350°C to 500°C when the metal droplets consist of zinc or a zinc alloy.

10. Apparatus for applying a metal coating or metal based coating on a surface of a substrate or a part of that surface, the apparatus having a container for keeping an inert gas and for containing the surface of the substrate to be coated, or a part of that surface, wherein means for generating metal droplets from the surface of a metal melt are present in the container, wherein means to apply a high voltage of between 1 and 30 kV between the metal melt and the surface of the substrate to be coated are present, and wherein means are present for applying high-frequency ultrasonic energy to the surface of the metal melt. 5 10
11. Apparatus according to claim 10, wherein means are present to heat the surface of the substrate to be coated. 20
12. Apparatus according to claim 10 or 11, wherein the means for generating the metal droplets from the surface of a metal melt are one or more nozzles, each having an outlet opening for forming the surface of the metal melt, or the end faces of one or more nozzle tips. 25
13. Apparatus according to any one of claims 10 - 12, wherein the container contains an entry gas lock system and an outlet gas lock system for coating a moving substrate. 30

Patentansprüche

1. Verfahren zum Aufbringen eines Metallüberzugs oder metallischen Überzugs auf eine Oberfläche eines Substrats oder einen Teil dieser Oberfläche, wobei die Oberfläche des Substrats elektrisch leitend ist, wobei die Oberfläche des Substrats mit einer Temperatur bereitgestellt wird, die zum Aufbringen des Überzugs geeignet ist, wobei Metalltröpfchen von einer Oberfläche einer Metallschmelze erzeugt werden, wobei ein Inertgas im Bereich der Metallschmelze und der Tröpfchen und der Oberfläche des Substrats vorhanden ist, und wobei eine Hochspannung zwischen 1 und 30 kV zwischen der Metallschmelze und der Oberfläche des Substrats angelegt wird und die Tröpfchen von der Oberfläche der Metallschmelze durch ein Anwenden von hochfrequenter Ultraschallenergie auf die Metallschmelze gebildet werden, wobei die Metalltröpfchen auf die Oberfläche des Substrats aufprallen, um einen Überzug zu bilden. 40 50
2. Verfahren nach Anspruch 1, wobei die Tröpfchen einen Durchmesser von höchstens 30 µm, vorzugs-

weise einen Durchmesser von höchstens 20 µm aufweisen.

3. Verfahren nach Anspruch 1 oder 2, wobei sich das Substrat bezogen auf die Metallschmelze bewegt. 5
4. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Oberfläche der Metallschmelze an der Stirnfläche einer Düsen Spitze gebildet wird. 10
5. Verfahren nach einem der Ansprüche 1 bis 4, wobei die Oberflächentemperatur des Substrats höher als die Schmelztemperatur des Metalls ist. 15
6. Verfahren nach einem der Ansprüche 1 bis 4, wobei die Oberflächentemperatur des Substrats niedriger als die Schmelztemperatur des Metalls ist und die Oberfläche des Substrats auf eine Temperatur erwärmt wird, die höher als die Schmelztemperatur des Metallüberzugs ist, nachdem der Metallüberzug aufgebracht wurde. 20
7. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Metallüberzug aus einem Metall mit einem niedrigen Schmelzpunkt wie zum Beispiel Zink, Aluminium, Zinn, Kupfer oder einer Legierung derselben gebildet wird, wobei die legierenden Elemente zum Beispiel Aluminium oder Magnesium sind, oder wobei der metallische Überzug von einem Metallüberzug mit Feststoffteilchen, zum Beispiel Nanoteilchen, gebildet wird. 25
8. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Substrat ein beweglicher Streifen, vorzugsweise ein beweglicher Metallstreifen, besonders bevorzugt ein beweglicher Stahlstreifen ist. 30 35
9. Verfahren nach einem der vorhergehenden Ansprüche, wobei der bewegliche Stahlstreifen eine Temperatur von 350 °C bis 500 °C aufweist, wenn die Metalltröpfchen aus Zink oder einer Zinklegierung bestehen. 40
10. Vorrichtung zum Aufbringen eines Metallüberzugs oder metallischen Überzugs auf eine Oberfläche eines Substrats oder einen Teil dieser Oberfläche, wobei die Vorrichtung einen Behälter zum Aufbewahren eines Inertgases und zum Aufnehmen der Oberfläche oder eines Teils dieser Oberfläche des zu beschichtenden Substrats aufweist, wobei Mittel zum Erzeugen von Metalltröpfchen von der Oberfläche einer Metallschmelze in dem Behälter vorhanden sind, wobei Mittel vorhanden sind, eine Hochspannung zwischen 1 und 30 kV zwischen der Metallschmelze und der Oberfläche des zu beschichtenden Substrats anzulegen, und wobei Mittel zum Anwenden von hochfrequenter Ultraschallenergie auf die Oberfläche der Metallschmelze vorhanden sind. 45 50 55

11. Vorrichtung nach Anspruch 10, wobei Mittel vorhanden sind, die Oberfläche des zu beschichtenden Substrats zu erwärmen.
12. Vorrichtung nach Anspruch 10 oder 11, wobei die Mittel zum Erzeugen der Metalltröpfchen von der Oberfläche einer Metallschmelze eine oder mehrere Düsen, wobei jede eine Auslassöffnung zum Bilden der Oberfläche der Metallschmelze aufweist, oder die Stirnflächen von einer oder mehrerer Düsenspitzen sind.
13. Vorrichtung nach einem der Ansprüche 10 bis 12, wobei der Behälter ein Einlassgassperrsystem und ein Auslassgassperrsystem zum Überziehen eines beweglichen Substrats enthält.

Revendications

1. Procédé permettant l'application d'un revêtement métallique ou d'un revêtement à base de métaux sur une surface d'un substrat ou une partie de cette surface, ladite surface du substrat étant électroconductrice, ladite surface du substrat étant fournie à une température appropriée en vue de l'application du revêtement, des gouttelettes métalliques étant produites à partir d'une surface d'un métal en fusion, un gaz inerte étant présent dans la zone du métal en fusion et des gouttelettes et de la surface du substrat, et une haute-tension comprise entre 1 et 30 kV étant appliquée entre le métal en fusion et la surface du substrat et lesdites gouttelettes étant formées à partir de la surface du métal en fusion en appliquant une énergie ultrasonore à haute fréquence sur le métal en fusion, moyennant quoi les gouttelettes métalliques heurtent la surface du substrat pour former un revêtement.
2. Procédé selon la revendication 1, lesdites gouttelettes possédant un diamètre inférieur ou égal à 30 μm , de préférence un diamètre inférieur ou égal à 20 μm .
3. Procédé selon la revendication 1 ou 2, ledit substrat étant en déplacement par rapport au métal en fusion.
4. Procédé selon l'une quelconque des revendications précédentes, ladite surface du métal en fusion étant formée au niveau de la face d'extrémité d'un embout de buse.
5. Procédé selon l'une quelconque des revendications 1 à 4, ladite température de la surface du substrat étant supérieure à la température de fusion du métal.
6. Procédé selon l'une quelconque des revendications 1 à 4, ladite température de la surface du substrat étant inférieure à la température de fusion du métal

et ladite surface du substrat étant chauffée à une température supérieure à la température de fusion du revêtement métallique, après que le revêtement métallique a été appliqué.

7. Procédé selon l'une quelconque des revendications précédentes, ledit revêtement métallique étant formé à partir d'un métal à faible point de fusion, tel que le zinc, l'aluminium, l'étain, le cuivre ou un alliage de ceux-ci, lesdits éléments d'alliage étant par exemple de l'aluminium ou du magnésium, ou ledit revêtement à base de métaux étant formé à partir d'un revêtement métallique avec des particules solides, par exemple des nanoparticules.
8. Procédé selon l'une quelconque des revendications précédentes, ledit substrat étant une bande en déplacement, de préférence une bande métallique en déplacement, idéalement une bande d'acier en déplacement.
9. Procédé selon l'une quelconque des revendications précédentes, ladite bande d'acier en déplacement possédant une température allant de 350°C à 500°C lorsque les gouttelettes métalliques sont constituées de zinc ou d'un alliage de zinc.
10. Appareil destiné à l'application d'un revêtement métallique ou d'un revêtement à base de métaux sur une surface d'un substrat ou d'une partie de cette surface, ledit appareil possédant un récipient destiné à conserver un gaz inerte et destiné à contenir la surface du substrat à revêtir ou une partie de cette surface, des moyens pour générer des gouttelettes métalliques à partir de la surface d'un métal en fusion étant présents dans le récipient, des moyens pour appliquer une haute tension comprise entre 1 et 30 kV entre le métal en fusion et la surface du substrat à revêtir étant présents, et des moyens étant présents pour appliquer une énergie ultrasonore à haute fréquence à la surface du métal en fusion.
11. Appareil selon la revendication 10, des moyens étant présents pour chauffer la surface du substrat à revêtir.
12. Appareil selon la revendication 10 ou 11, lesdits moyens pour générer les gouttelettes métalliques à partir de la surface d'un métal en fusion étant une ou plusieurs buses, chacune possédant une ouverture de sortie pour former la surface du métal en fusion, ou les faces d'extrémité d'un ou de plusieurs embouts de buses.
13. Appareil selon l'une quelconque des revendications 10 à 12, ledit récipient contenant un système de verrouillage de gaz d'entrée et un système de verrouillage de gaz de sortie pour revêtir un substrat en déplacement.

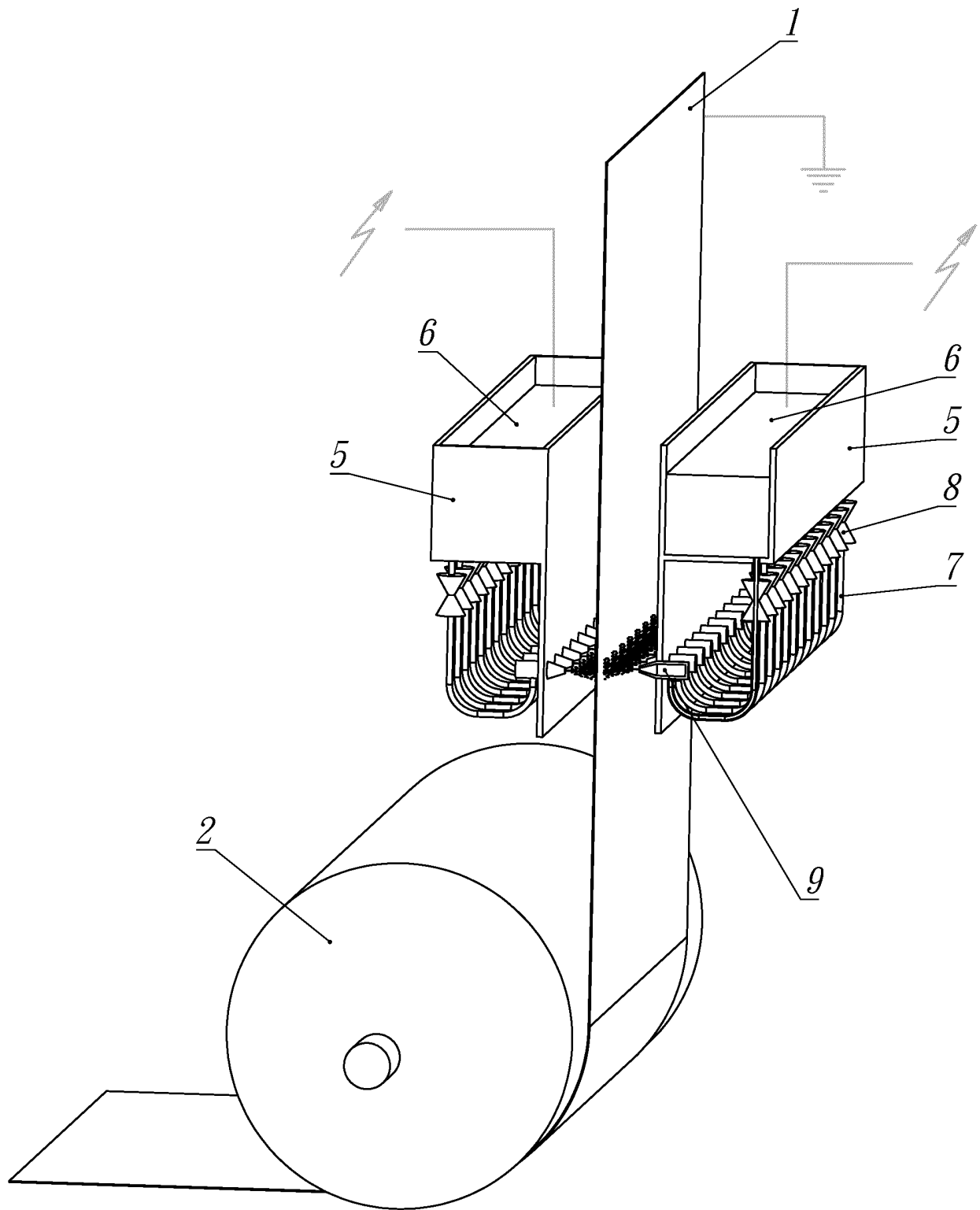


Fig 1

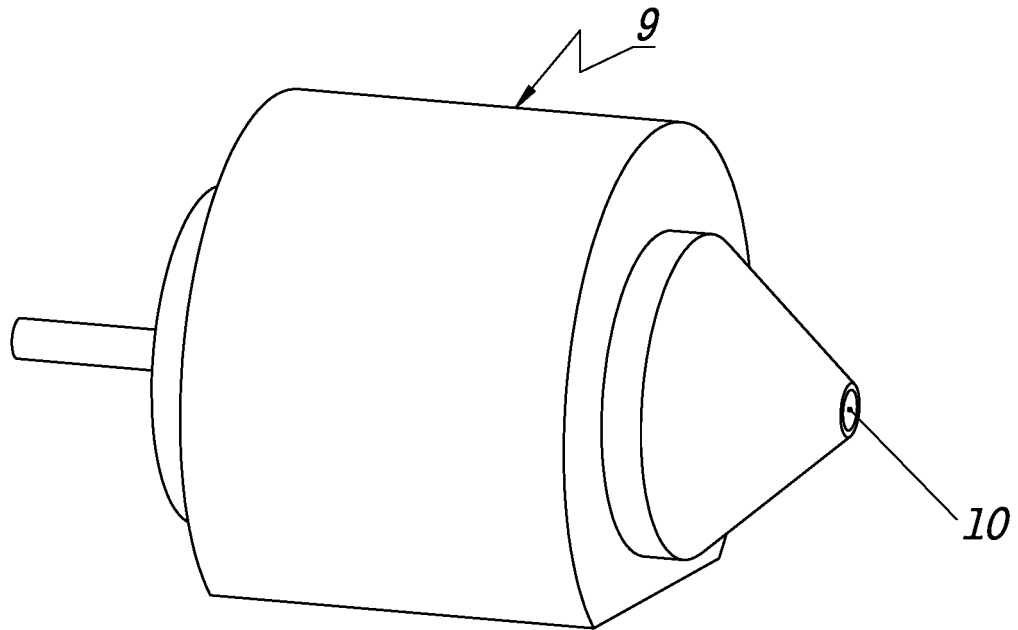


Fig 2a

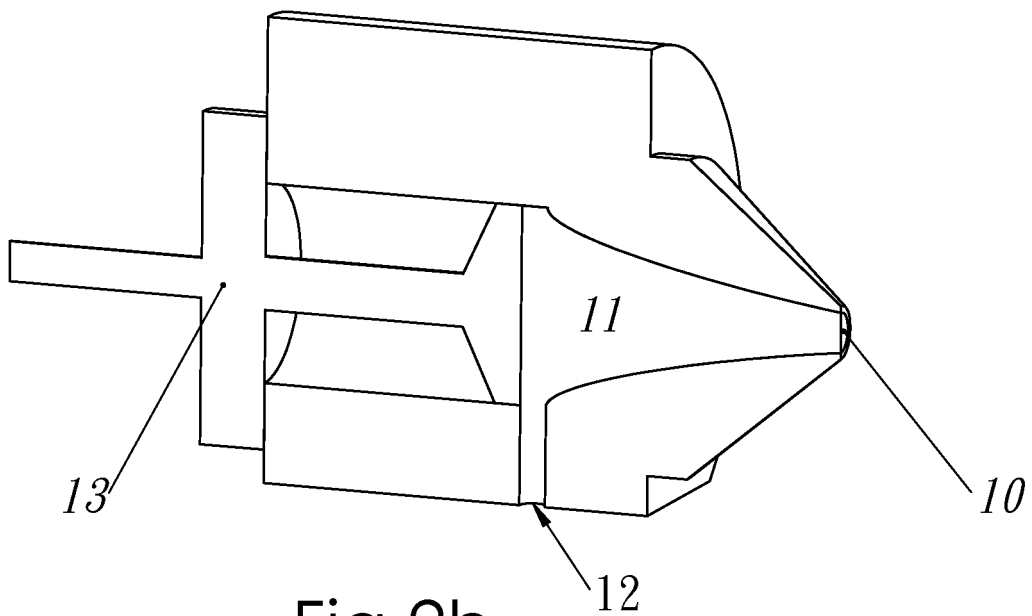


Fig 2b

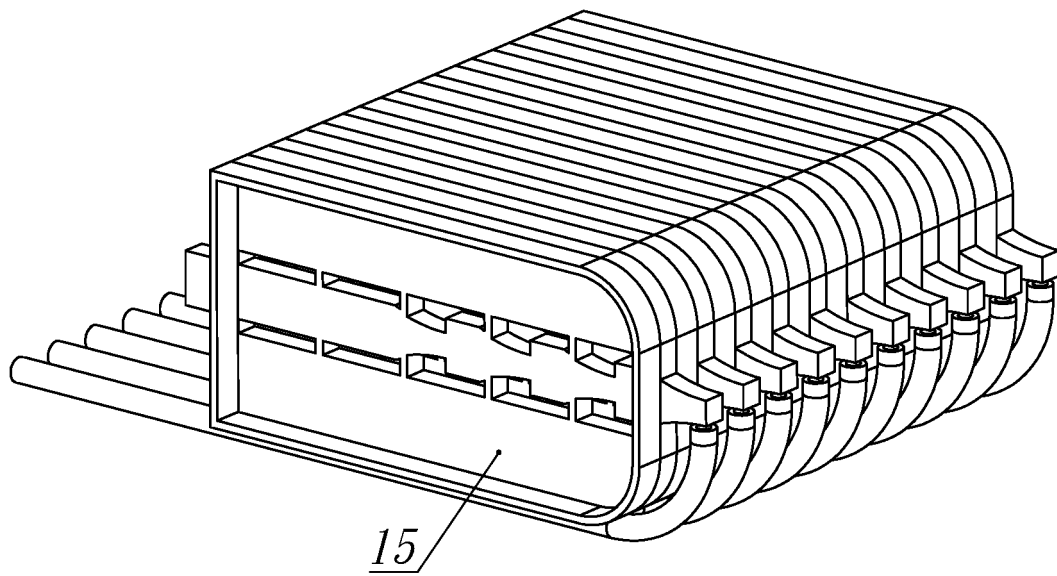


Fig 3a

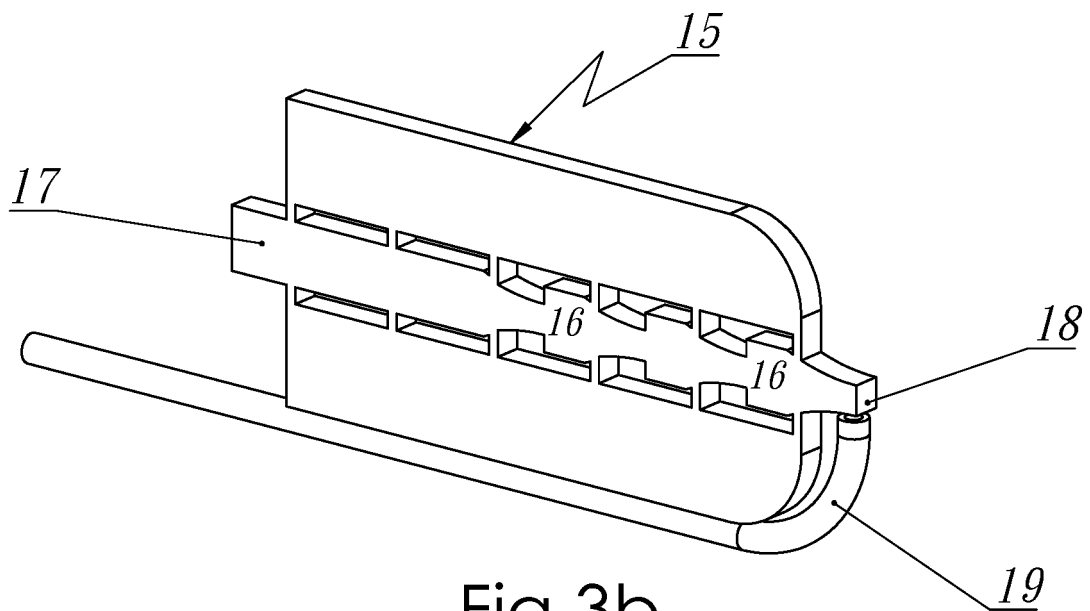


Fig 3b

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **A.JAWOREK.** *Journal of Materials Sciences*, 2006, vol. 42 (1), 266-297 [0004]