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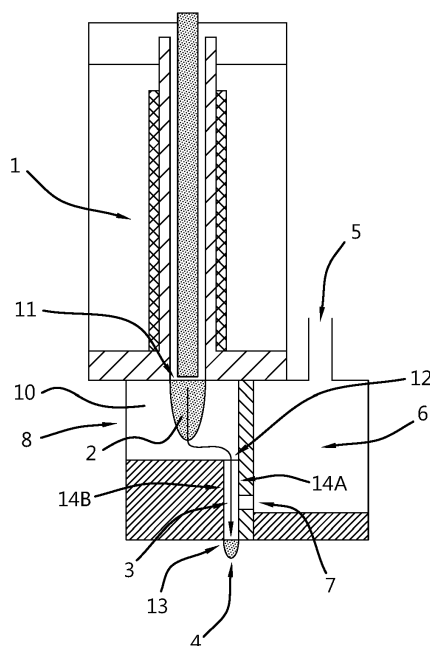
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(54) **PLASMA COATING METHOD AND APPARATUS FOR PROFILES**

(57) The present invention concerns a plasma coating apparatus for plasma coating a profile, the plasma coating apparatus comprising a plasma jet system with a plasma jet system outlet and a set of at least one plasma nozzle, wherein each plasma nozzle comprises an internal nozzle chamber and a mixing channel, whereby the internal nozzle chamber comprises a jet inlet in fluid connection with the plasma jet system jet outlet, whereby the mixing channel comprises a precursor inlet and a channel outlet comprising a channel outlet cross section, and whereby the internal nozzle chamber and the mixing

channel are in fluid communication via a passage opening comprising a passage opening cross section, whereby the mixing channel comprises a duct extending between the passage opening to the channel outlet and defined by a set of side walls, whereby at least one side wall of said set of side walls comprises said precursor inlet, whereby said passage opening cross section and said channel outlet cross section are configured such that a plasma afterglow can flow laminarly from the passage opening through the mixing channel to the channel outlet.

Fig. 1



Description

Technical field

[0001] The present invention concerns a plasma coating method and apparatus for profiles, i.e. objects having a constant cross section along a length direction. The present invention allows high-volume and high-speed plasma coating of profiles with an intricately shaped cross section. The coating is hereby homogeneous. The plasma coating method of the present invention relates to a plasma process performed at atmospheric or near-atmospheric pressures.

Background

[0002] Profiles are objects having a fixed cross section along a length direction and are widely used, for instance in construction, decoration, vehicles, etc. They can be made of a wide range of materials, such as metal, plastic, wood or composites thereof. The cross section may be simple, e.g. a circular cross section for a rod-shaped profile or a rectangular cross section for a beam-shaped profile, but may also be intricate, such as a profile which is used to construct a window frame. The latter type of profile is not always easily provided with a coating due to the presence of a multitude of corners and bends in the profile.

[0003] A painting or spraying technique has been used in the past for providing a coating on profiles. Such techniques are commonly called 'wet coating'. Such wet coating techniques suffer from a number of problems: typically wet coatings lead to relatively thick coatings of 1 micrometer or thicker, furthermore, homogeneous application is very difficult to achieve in practice, e.g. due to dripping effects, a lot of the coating material gets lost in the process, the coating liquid cannot reach everywhere in case of an intricately shaped profile, etc.

[0004] Plasma coatings offer an improvement over wet coatings, in that the resulting coating can be kept much thinner, e.g. 1 micrometer or less, and can usually be applied over the full surface of a profile, even if the profile is intricately shaped. A particular way of applying a plasma coating to an object can e.g. be found in WO2019243631A1.

[0005] The present invention is particularly related to an indirect plasma coating process and apparatus. Hereby, the object which is to be coated, does not pass through an active plasma zone, i.e. a region wherein plasma is actively induced. In particular, the object does not pass in between plasma-inducing electrodes. In the present invention, a process fluid, preferably a process gas, is introduced in a plasma jet apparatus. While flowing through a plasma channel of the plasma jet apparatus, the process fluid is plasmized, preferably using a set of electrodes in and/or around the plasma channel. A precursor can be introduced into the plasmized process gas, thereby obtaining a precursor-comprising plasma

gas. The precursor can be introduced within the plasma zone and/or downstream of the plasma zone in the plasma afterglow. As indicated above, the plasma zone refers to the zone wherein plasma is actively induced in the process gas. The plasma afterglow is a region downstream of the active plasma zone wherein the plasma gas still comprises excited species such as excited atoms, excited molecules, ions, excited ions, etc. Introducing the precursor in the plasma afterglow has the advantage that the precursor is excited via secondary processes, which tend to be softer than direct excitation processes. As such, the functionalities of the precursor tend to be better preserved, leading to better functionalities of the resulting coating.

[0006] The present invention is also related to atmospheric or near-atmospheric pressure plasma processes. Hereby, no vacuum pumps or other vacuum techniques are required to obtain a low-pressure environment at the position of the object which is to be coated. This allows easy and/or continuous coating of the object or objects. Operating pressures in the present invention are at least 600 mbar, and preferably between 800 mbar and 1600 mbar. In order to create a flow in the plasma, a slight overpressure can typically be created, e.g. of between 1050mbar and 1500mbar to ensure that the plasma flows in the intended direction and one does not have to worry about gas flowing into the plasma nozzle or plasma jet from the outlet.

[0007] The document WO2019243631A1 discloses a method for plasma coating an object comprising an object profile, comprising the steps of: a) manufacturing a replaceable shield comprising a jet inlet, a nozzle outlet and a sidewall extending from the jet inlet to the nozzle outlet, wherein the nozzle outlet comprises an edge essentially congruent to at least part of the object profile; b) detachably attaching the replaceable shield to a jet outlet of a plasma jet generator; c) placing the object at the nozzle outlet such that the object profile fits closely to the nozzle outlet edge, thereby minimizing a gap between the nozzle outlet and the object; d) plasma coating the object with a low-temperature, oxygen-free plasma at an operating pressure which is higher than the atmospheric pressure, preferably by at most 10%, by providing a plasma jet in the shield via the plasma jet generator and injecting coating precursors in the plasma jet in the shield, thereby creating said operating pressure, thereby plasma coating the object in an oxygen-depleted plasma zone.

[0008] However, the applicant has found that for profiles having an intricate shape, a homogeneous coating layer is not so easily achieved, possibly due to a divergent flow of the plasma once it leaves the plasma nozzle. The present invention aims to overcome this problem and to provide a manner of improving homogeneity in the resulting coating.

Summary of the Invention

[0009] The present invention concerns a plasma coating apparatus for plasma coating a profile, comprising an atmospheric plasma jet system (1) with a plasma jet system outlet and a plasma nozzle (8), wherein the plasma nozzle comprises an internal nozzle chamber (2) and a mixing channel (3), whereby the internal nozzle chamber (2) comprises a jet inlet (11) in fluid connection with the plasma jet system jet outlet, whereby the mixing channel (3) comprises a precursor inlet (7) and a channel outlet (13) comprising a channel outlet cross section, and whereby the internal nozzle chamber (2) and the mixing channel (3) are in fluid communication via a passage opening (12) comprising a passage opening cross section, whereby the mixing channel (3) comprises a duct extending between the passage opening (12) to the channel outlet (13) and defined by a set of at least two side walls (14A, 14B), whereby at least one side wall (14A) of said set of side walls comprises said precursor inlet (7), whereby said passage opening cross section and said channel outlet cross section are configured such that a plasma afterglow can flow laminarly from the passage opening through the duct to the channel outlet.

[0010] Note that in order to obtain the best results for the homogeneous coating, the cross section of the channel outlet may preferably be configured taking into account at least a portion of a profile shape of the profile which is to be treated. Typically, the channel outlet may have a rectangular shape, which may preferably be a flat rectangular shape or a bent rectangular shape, preferably depending on the shape of the portion of the profile which is intended to be treated E.g. if the portion of the profile is flat, a flat rectangular shape is preferred for the channel outlet cross section, and if the portion of the profile is bent, then a bent rectangular shape is preferred. Preferably, the cross-section passage opening can then be configured taking into account the channel outlet cross section. In order to achieve laminar flow, many flow simulation packages are available to assist the skilled person to select or configure the cross sections of the channel outlet and the passage opening.

[0011] A plasma flow from a jet system may be turbulent. Furthermore, the jet apparatus may have a jet outlet comprising a specific cross-sectional shape, e.g. circular or rectangular, which does not correspond to the shape of the cross section of the outlet of the nozzle. This may increase the likeliness of turbulence. Without wishing to be bound by theory, the inventors believe that such a turbulent plasma flow may lead to inhomogeneous coating on the substrate and that a laminar flow is preferred. Note that this could be deemed counter-intuitive since adding the precursor in a turbulent flow could be expected to lead to a better mixing of the precursor in the plasma flow. Nevertheless, the inventors have found that it is better to first create a laminar flow within a duct and then mixing the precursor in the laminar flow in order to obtain a homogeneous coating on a profile. In order to create

such a laminar flow, the inventors have found that the plasma afterglow from the plasma jet can be made to relax in an internal chamber, after which the plasma afterglow can be made to flow essentially laminarly through a duct with a passage opening and a channel outlet which have cross sections configured to allow such a laminar flow. The term 'relax' herein refers to a relaxation of the turbulence in the flow. Note that hereby, the inventors have also found that the plasma afterglow resulting from the plasma jet, continues to have excited species for long enough, such that the time spent by the plasma afterglow in the internal chamber is short enough to ensure that the plasma afterglow still comprises enough excited species to ensure a good coating.

[0012] In an embodiment, the duct comprises a minimal duct length between the passage opening and the channel outlet, said minimal duct length preferable being at least 3mm, and/or at most 100mm.

[0013] Preferably the precursor inlet is located closer to the channel outlet than to the passage opening. Preferably the duct comprises a minimal duct length between the passage opening and the channel outlet, and the precursor inlet is located within 50% of the minimal duct length from the channel outlet, more preferably within 40% of the minimal duct length from the channel outlet, such as within 35%, within 30%, within 25% or even within 20% of the minimal duct length.

[0014] In an embodiment, the precursor inlet is located at least 5% of the minimal duct length from the channel outlet, preferably at least 10%.

[0015] In an embodiment, the duct comprises a duct width as defined by the distance between the at least two side walls (14A, 14B) which is at least 0.1 mm and/or which is at most 5mm. Preferably said duct width is essentially constant along a duct length stretching from the passage opening to the channel outlet.

[0016] Preferably the precursor is provided to the precursor inlet in the form of a gas or an aerosol, most preferably an aerosol. It is one of the advantages of the present system that a large variety and combination of molecules can be used as precursor. The indirect excitation process, wherein a plasma gas is first plasmized and the precursor is mixed into the plasma afterglow, allows using even intricate molecules which could otherwise fragmentate when being plasmized directly.

[0017] In an embodiment, the precursor inlet comprises a precursor inlet height as measured in the longitudinal direction of the duct, i.e. essentially from the passage opening to the channel outlet, which is at least 0.1mm and/or at most 15mm.

[0018] In an embodiment, the precursor inlet comprises a precursor inlet width as measured perpendicular to the longitudinal direction of the duct and essentially within the plane defined by the side wall in which the precursor inlet is located, said precursor inlet width preferably being at least 1mm and/or at preferably at most 15mm.

[0019] In an embodiment, the plasma nozzle comprises an internal precursor chamber, which can preferably

be fed with chemical precursors through a precursor chamber inlet. The precursors in the precursor chamber (6) are preferably sucked into the plasma afterglow flow in the mixing channel (3) through the precursor inlet (7) of the mixing channel (3) by a Venturi effect.

[0020] In view of the above, the present invention also pertains to a plasma coating method for providing a plasma coating on a profile, comprising the steps of:

- creating a plasma jet comprising a plasma afterglow. This can be achieved using a plasma jet apparatus.
- relaxing the plasma afterglow to reduce turbulences. This can be achieved by allowing the plasma afterglow to relax in an internal nozzle chamber.
- creating an essentially laminar plasma afterglow flow. This can be achieved by first relaxing the plasma afterglow in the internal chamber and then passing the plasma afterglow into a duct via a passage opening.
- mixing a precursor into said laminar plasma afterglow flow, thereby obtaining a precursor-comprising plasma afterglow. This can be achieved through a precursor opening in a side wall of the duct.
- exposing a profile to said precursor-comprising plasma afterglow, thereby providing a coating onto a surface of said profile. This can be achieved by positioning the profile at a channel outlet.

[0021] Preferably, relaxing the plasma afterglow is performed by injecting the plasma jet and/or the plasma jet afterglow in an internal nozzle chamber, whereby an internal nozzle chamber pressure is maintained, said internal nozzle chamber pressure preferably at least 5% more than ambient pressure, and/or at most 50% more than ambient pressure, preferably between 10% and 25% more than ambient pressure.

Overview of the figures

[0022]

Figure 1 illustrates an apparatus according to an embodiment of the present invention, shown in cross section.

Figure 2 shows a perspective view of a plasma nozzle of an apparatus according to an embodiment of the present invention and **Figures 3A-B** show a perspective view of separate components of a plasma nozzle of an apparatus according to the same embodiment of the present invention as in Fig. 2.

[0023] An embodiment of the present invention with 3 plasma nozzles is illustrated in **Figures 4A and 4B**, and another embodiment, also with three plasma nozzles, is shown in **Fig. 5**.

[0024] **Figure 6** illustrates yet another embodiment of the present invention comprising two plasma nozzles.

Detailed description of the invention

[0025] The present invention is further discussed with reference to the figures, which serve to illustrate embodiments of the present invention.

[0026] Figure 1 illustrates an embodiment of an apparatus according to the present invention. The apparatus is the combination of a plasma jet apparatus (1) generating an indirect plasma afterglow under atmospheric pressure (2) and a plasma nozzle (8) comprising two zones. The first zone comprises an internal nozzle chamber (10) which receives the plasma afterglow (2), relaxes it, resulting in a slight compression of the plasma, and redirects the plasma afterglow through a passage opening (12) which may have a different geometrical shape (e.g. a rectangular slit) than the plasma afterglow (2) and/or the jet inlet (11) (e.g. a circular shape) in fluid connection with the plasma jet system jet outlet. The passage opening (12) serves as an inlet for the mixing channel (3) through which the plasma afterglow can flow.

[0027] In the shown embodiment, the plasma nozzle (8) comprises a second zone comprising an internal precursor chamber (6), which can be fed with chemical precursors (preferably in the form of a gas or an aerosol) through a precursor chamber inlet (5). The precursors in the precursor chamber (6) are basically sucked in by the Venturi effect in the plasma afterglow flow in the mixing channel (3) through the precursor inlet (7) of the mixing channel (3).

[0028] Figure 2 shows a perspective view of a plasma nozzle of an apparatus according to an embodiment of the present invention and Figures 3A-B show a perspective view of separate components of a plasma nozzle of an apparatus according to the same embodiment of the present invention as in Fig. 2, thereby illustrating how the plasma nozzle can be constructed in practice. Shown in Fig. 2 is the plasma nozzle (8) and a jet nozzle (20) of a plasma jet apparatus. It can be seen that in this embodiment, the jet nozzle (20) is shaped to deliver a plasma jet at the plasma jet system outlet with a circular shape due to the circular jet nozzle outlet (21) which can put be in fluid connection with the jet inlet (11) of the nozzle chamber (10). The plasma nozzle (8) further comprises a precursor chamber (6) with a precursor chamber outlet (5). The manner in which the plasma nozzle can be constructed, is illustrated in Figs. 3A and 3B. Fig. 3A shows a precursor chamber casing (26) comprising a precursor chamber inlet (5) and which defines a precursor chamber (6) together with a precursor side wall (28) attached to a precursor wall component (27). The attachment between precursor chamber casing (26) and precursor side wall (28) can be made fluid-tight using a gasket (29) and a set of fasteners (30, 39) such as bolts. The precursor side wall forms, in the shown embodiment and when the components are connected to form the plasma nozzle, a first side wall (14A) of the mixing channel (3). The first wall (14A, 28) thereto comprises a precursor inlet (7). Precursors can be fed into the precursor chamber (6) via

the precursor chamber inlet (5) which can be put in fluid connection with a precursor-providing system using a precursor chamber inlet connector (40). On the other side, an internal chamber casing (30) comprising a jet inlet (11) is shown, which defines the internal nozzle chamber (10) together with an inner chamber side wall (38) attached to a inner chamber wall component (31), preferably with a gasket (32) in between to ensure fluid-tightness. The inner chamber side wall forms, in the shown embodiment and when the components are connected to form the plasma nozzle, a second side wall (14B) of the mixing channel (3). The second side wall comprises a slit (12) which acts as a passage opening to bring the internal nozzle chamber (10) in fluid connection with the mixing channel (3). The mixing channel (3) and in particular the duct thereof, extends between passage opening (12) and channel outlet (13) and is essentially defined by the side walls (14A, 14B). This is illustrated in more detail in Fig. 3B, where one can see that a portion of the inner chamber side wall (38) comprises a sunken portion as seen in the corner (51) in Fig. 3B, the sunken portion thereby forming the second side wall (14B) of the mixing channel. Also shown in Fig. 3B are arrows which indicate the plasma afterglow flow prior to passing through the passage opening (60), while passing through the duct (61) and at the channel outlet (61). Note that at least in the duct (61) and at the channel outlet, the flow is laminar, while the flow before the passage opening, i.e. in the internal nozzle chamber, may comprise turbulences.

[0029] In an embodiment, the set of plasma nozzles comprises more than one plasma nozzle, such as 2, 3, 4, 5, 6, 7, 8, 9, 10 or more plasma nozzles. An embodiment with 3 plasma nozzles is illustrated in Figures 4A and 4B, and another embodiment, also with three plasma nozzles is shown in Fig. 5. The embodiment in Figs. 4A and 4B is particularly apt to coat a profile having a cross section (150) as shown in Fig. 5C, comprising three essentially flat portions (151A, 151B, 151C). Each of the three flat portions can be coated via a respective plasma nozzle having flat rectangular channel outlet cross sections (113A, 113B, 113C), each plasma nozzle comprising a precursor chamber inlet (105A, 105B, 105C) and a jet inlet (111A, 111B, 111C). Note that the jet inlets are preferably in connection with the plasma jet system outlet of the plasma jet system, allowing to provide plasma to each of the plasma nozzle of the set with a single plasma jet system. Furthermore, the different precursor inlets allow a user to choose which coating is intended to be applied on which portion of the profile, with respect to the type of precursor used, or the flow parameters of the precursor providing means whereby the thickness of the resulting coating may be controlled.

[0030] Fig. 5 illustrates a different embodiment, comprising a set of three plasma nozzles (208A, 208B, 208C), each comprising a jet inlet (211A, 211B, 211C) and a precursor chamber inlet (205A, 205C). The jet inlets may be put in fluid connection with a plasma jet system outlet

using a tubing system comprising a set of 3 tubes (220) connected to a single tubing inlet (210) which can be connected to the plasma jet system outlet. In this respect, the inventors have found that a plasma afterglow can persist for a considerable length after the jet outlet of the plasma jet system. However, it is also the inventors' merit to find out that it is better to transport the plasma afterglow without the precursor and to only mix in the precursor in the mixing channel of the plasma nozzle, which means close to the profile's surface. It is believed that mixing the precursor into the plasma afterglow in the mixing channel of the plasma nozzle, close to where the profile is exposed to the mixture rather than to mix in the precursor immediately in the plasma afterglow, prior to being transported to different nozzles, provides the advantages that:

- the precursors are excited within the plasma afterglow, but do not have the time to de-excite in the plasma afterglow prior to contacting the profile's surface, leading to better attachment of the coating resulting from the precursors to the surface;
- the type of precursor and the amount and/or flow rate can be independently controlled for different plasma nozzle, allowing providing a profile with a different coating on different portions of the profile with respect to e.g. type of coating and thickness.

[0031] Figure 6 illustrates yet another embodiment of the present invention comprising two plasma nozzles. Note that only the mixing channels (303A, 303B) of the plasma nozzles are shown for illustration purposes. Fig. 6 illustrates how the present invention can be used to coat a profile having both bent portions (370, 372) and straight portions (371).

[0032] Hereto, the system comprises a first plasma nozzle with a first mixing channel (303A) to coat a first bent portion (370) of the profile (300). The first mixing channel (303A) receives a plasma afterglow (360A) coming from a first internal nozzle chamber via a first passage opening (312A). The first mixing chamber is (303A) configured such that the plasma afterglow flow within the duct (361A) is laminar. Hereto, the channel outlet (313A) of the first mixing channel is configured to closely fit the shape of the bent portion (370) of the profile and hereby comprises the shape of a bent rectangle. The passage opening (312A) in a side wall of the mixing chamber comprises a cross section in a shape which is or resembles an annulus sector. Note that if the bent portion (370) of the profile has a circular shape, the passage opening may preferably comprise a cross section having the shape of a circular annulus sector. If the bent portion is not exactly circular, but e.g. is elliptic or has a more intricate shape, the channel outlet and passage opening may be configured accordingly. As indicated before, many flow simulation packages exist which allow a skilled person to design a mixing channel with a channel outlet and a passage opening configured such that essentially

a laminar flow can be achieved in the duct. The mixing channel (303A) also comprises a precursor inlet (307A) through which the precursor can be mixed into the plasma afterglow flow in the duct. The precursor inlet may also preferably have a cross section which is configured taking into account the shape of the cross section of the channel outlet, and may in the presented example comprise a shape of an annulus sector. The precursor inlet (307A) is located closer to the channel outlet (313A) than to the passage opening (312A). The precursor-comprising plasma afterglow (362A) coming from the channel outlet can be used to provide a homogenous coating onto the bent portion (370) of the profile. Hereto, the profile (300) can be moved in a direction (310), preferably essentially perpendicular to the precursor-comprising plasma afterglow flow (362A), to coat the portion along the length of the profile.

[0033] The system further comprises a second plasma nozzle with a second mixing channel (303B) to coat a second, flat portion (371) of the profile (300). The second mixing channel (303B) receives a plasma afterglow (360B) coming from a second internal nozzle chamber via a second passage opening (312B). The second mixing chamber is (303B) configured such that the plasma afterglow flow within the duct (361B) is laminar. Hereto, the channel outlet (313B) of the second mixing channel is configured to closely fit the shape of the flat portion (371) of the profile and hereby comprises the shape of a flat rectangle. The passage opening (312B) in a side wall of the mixing chamber comprises a cross section in a shape which is essentially rectangular. The mixing channel (303B) also comprises a precursor inlet (307B) through which a precursor can be mixed into the plasma afterglow flow in the duct. The precursor inlet may also preferably have a cross section which is configured taking into account the shape of the cross section of the channel outlet, and may in the presented example comprise a rectangular. The precursor inlet (307B) is located closer to the channel outlet (313B) than to the passage opening (312B). The precursor-comprising plasma afterglow (362B) coming from the channel outlet can be used to provide a homogenous coating onto the flat portion (371) of the profile. Hereto, the profile (300) can be moved in a direction (310), preferably essentially perpendicular to the precursor-comprising plasma afterglow flow (362B), to coat the portion along the length of the profile.

[0034] The plasma jet system of the present invention may be any type of atmospheric plasma jet system creating a plasma afterglow. Preferred systems are commercially available from the applicant of the present patent application, Molecular Plasma Group SA, such as the PlasmaSpot and PlasmaLine systems.

Claims

1. A plasma coating apparatus for plasma coating a profile, the plasma coating apparatus comprising a

plasma jet system with a plasma jet system outlet and a set of at least one plasma nozzle, wherein each plasma nozzle comprises an internal nozzle chamber and a mixing channel,

whereby the internal nozzle chamber comprises a jet inlet in fluid connection with the plasma jet system jet outlet,

whereby the mixing channel comprises a precursor inlet and a channel outlet comprising a channel outlet cross section, and

whereby the internal nozzle chamber and the mixing channel are in fluid communication via a passage opening comprising a passage opening cross section,

whereby the mixing channel comprises a duct extending between the passage opening to the channel outlet and defined by a set of side walls, whereby at least one side wall of said set of side walls comprises said precursor inlet, whereby said passage opening cross section and said channel outlet cross section are configured such that a plasma afterglow can flow laminarly from the passage opening through the mixing channel to the channel outlet.

2. A plasma coating apparatus according to any of the previous claims, whereby the plasma nozzle comprises an internal precursor chamber, which can preferably be fed with chemical precursors through a precursor chamber inlet.

3. A plasma coating apparatus according to any of the previous claims, whereby the cross section of the channel outlet is configured taking into account at least a portion of a profile shape of the profile and whereby the cross-section passage opening is configured taking into account the channel outlet cross section.

4. A plasma coating apparatus according to any of the previous claims, whereby the duct comprises a minimal duct length between the passage opening and the channel outlet, said minimal duct length preferably being at least 3mm, and/or at most 100mm.

5. A plasma coating apparatus according to any of the previous claims, whereby the duct comprises a minimal duct length between the passage opening and the channel outlet, and the precursor inlet is located within 50% of the minimal duct length from the channel outlet, more preferably within 40% of the minimal duct length from the channel outlet, such as within 35%, within 30%, within 25% or even within 20% of the minimal duct length.

6. A plasma coating apparatus according to any of the previous claims, whereby the duct comprises a min-

imal duct length between the passage opening and the channel outlet, and the precursor inlet is located at least 5% of the minimal duct length from the channel outlet, preferably at least 10%.

7. A plasma coating apparatus according to any of the previous claims, whereby the duct comprises a duct width as defined by the distance between the at least two side walls (14A, 14B) which is at least 0.1mm and/or which is at most 5mm, preferably said duct width being essentially constant along a duct length stretching from the passage opening to the channel outlet.
8. A plasma coating apparatus according to any of the previous claims, whereby the precursor inlet comprises a precursor inlet height as measured in the longitudinal direction of the duct, which is at least 0.1mm and/or at most 15mm.
9. A plasma coating apparatus according to any of the previous claims, whereby the precursor inlet comprises a precursor inlet width as measured perpendicular to the longitudinal direction of the duct and essentially within the plane defined by the side wall in which the precursor inlet is located, said precursor inlet width being at least 1mm and/or at most 15mm.
10. A plasma coating apparatus according to claim 1, whereby the precursor inlet comprises a precursor inlet cross section extending over a fraction of a width of said at least one side wall, said fraction being at least 50%, more preferably at least 90%.
11. A plasma nozzle for a plasma coating apparatus according to any of the claims 1 to 10, comprising an internal nozzle chamber and a mixing channel,

whereby the internal nozzle chamber comprises a jet inlet,
whereby the mixing channel comprises a precursor inlet and a channel outlet comprising a channel outlet cross section, and
whereby the internal nozzle chamber and the mixing channel are in fluid communication via a passage opening comprising a passage opening cross section,
whereby the mixing channel comprises a duct extending between the passage opening to the channel outlet and defined by a set of side walls, whereby at least one side wall of said set of side walls comprises said precursor inlet,
whereby said passage opening cross section and said channel outlet cross section are configured such that a plasma afterglow can flow laminarily from the passage opening through the mixing channel to the channel outlet.

12. A plasma coating method for providing a plasma coating on a profile, comprising the steps of:

- creating a plasma jet comprising a plasma afterglow;
- relaxing the plasma afterglow to reduce turbulences;
- creating an essentially laminar plasma afterglow flow;
- mixing a precursor into said laminar plasma afterglow flow, thereby obtaining a precursor-comprising plasma afterglow;
- exposing a profile to said precursor-comprising plasma afterglow, thereby providing a coating onto a surface of said profile.

13. A plasma coating method according to claim 12, whereby the precursor is provided to the precursor inlet in the form of a gas or an aerosol, most preferably an aerosol.

14. A plasma coating method according to claim 12 or 13, whereby relaxing the plasma afterglow is performed by injecting the plasma jet and/or the plasma jet afterglow in an internal nozzle chamber, whereby an internal nozzle chamber pressure is maintained, said internal nozzle chamber pressure preferably at least 5% more than ambient pressure, and/or at most 50% more than ambient pressure, preferably between 10% and 25% more than ambient pressure.

15. A plasma coating method according to any of the claims 12 to 14, executed using a plasma coating apparatus according to any of the claims 1 to 10 and/or a plasma nozzle according to claim 11.

Fig. 1

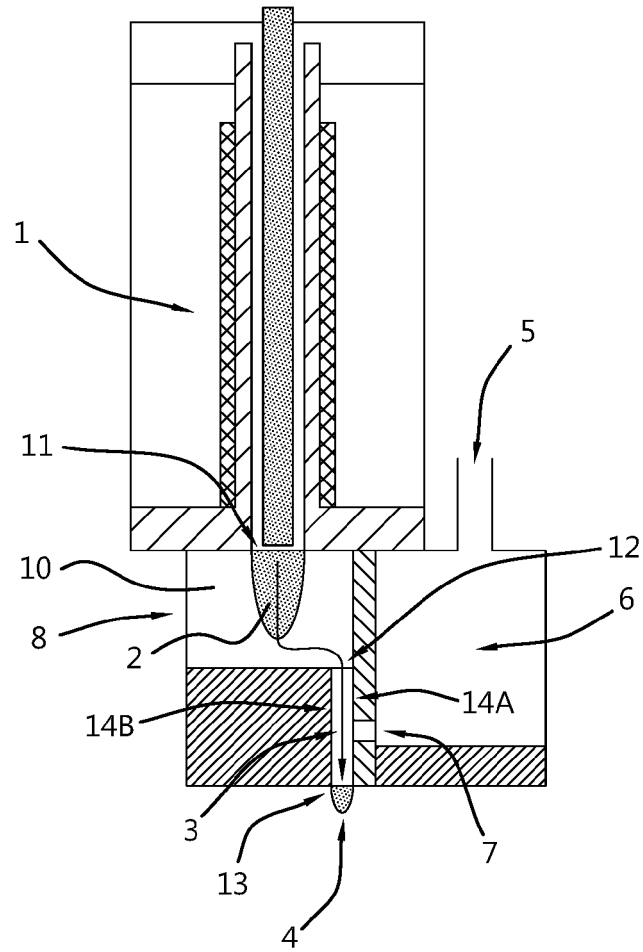


Fig. 2

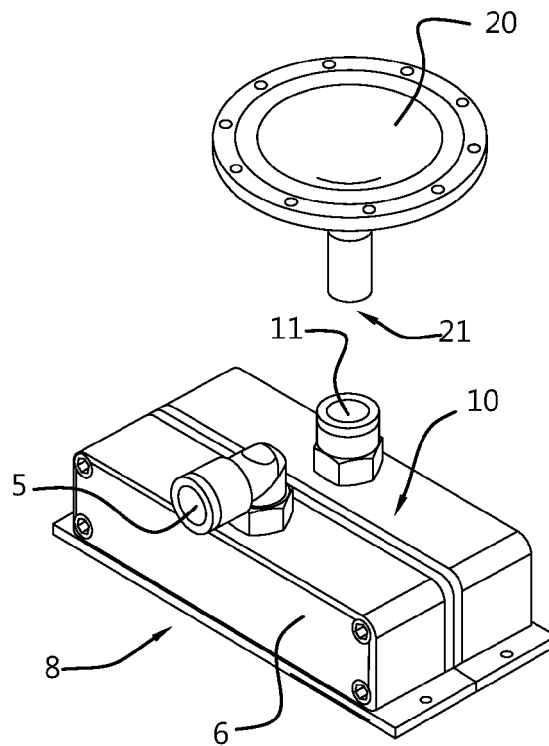


Fig. 3A

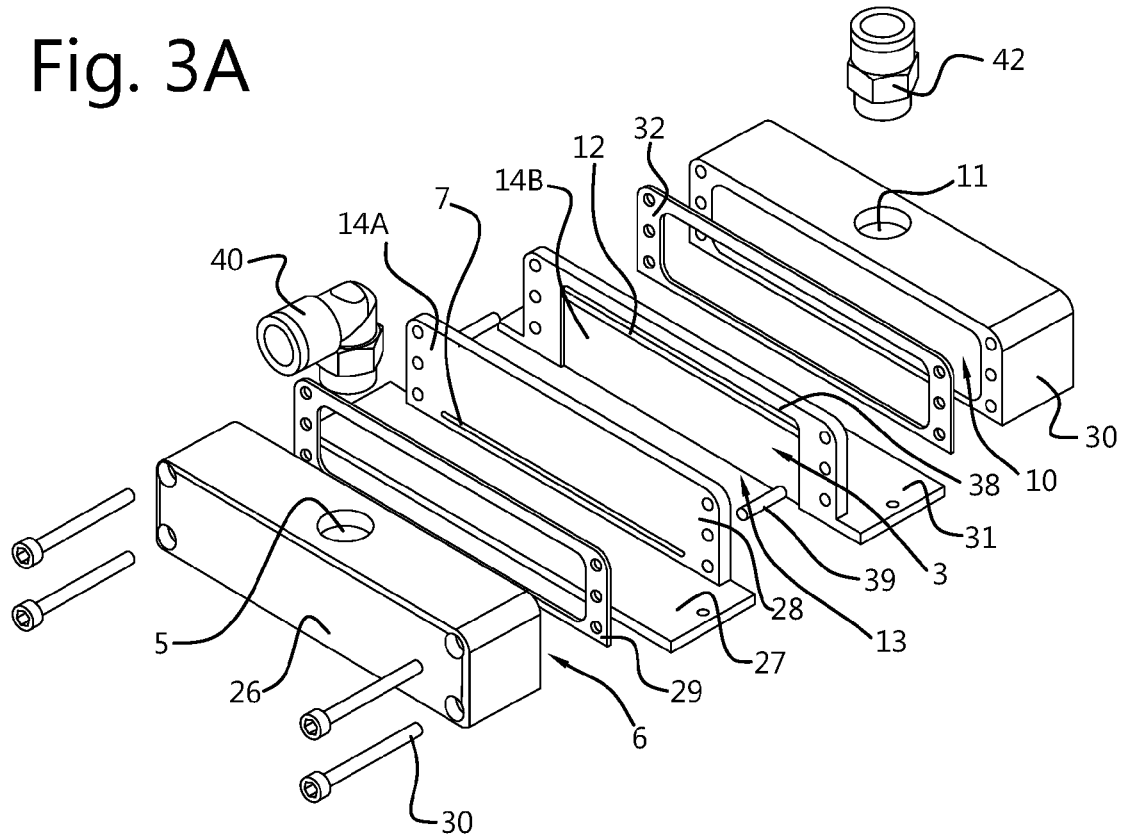


Fig. 3B

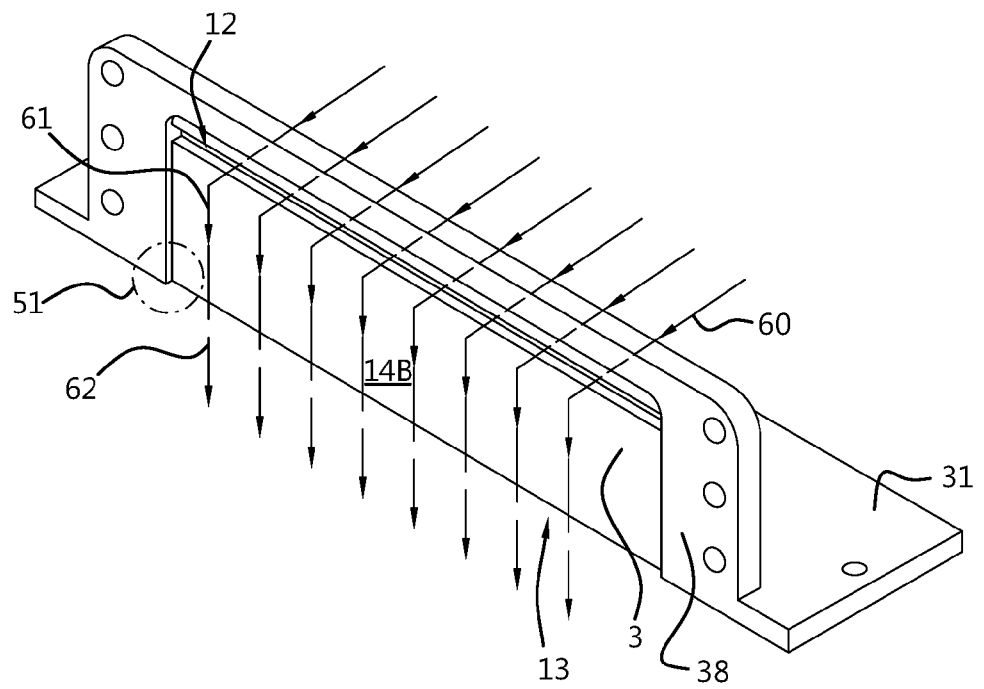


Fig. 4A

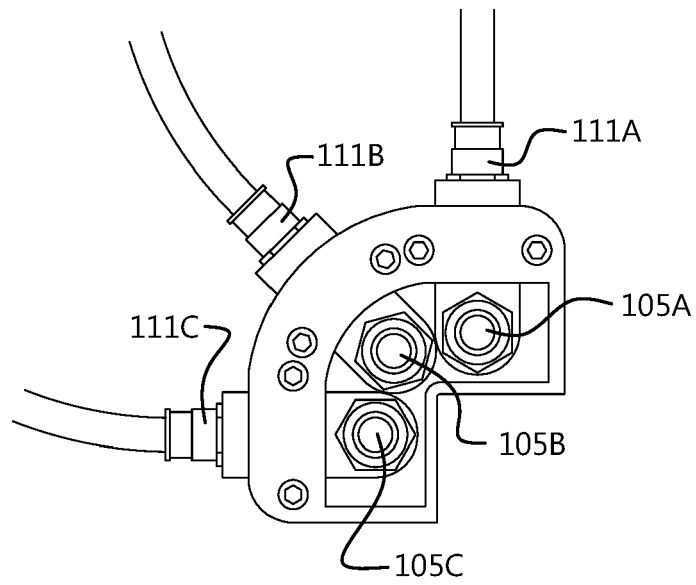


Fig. 4B

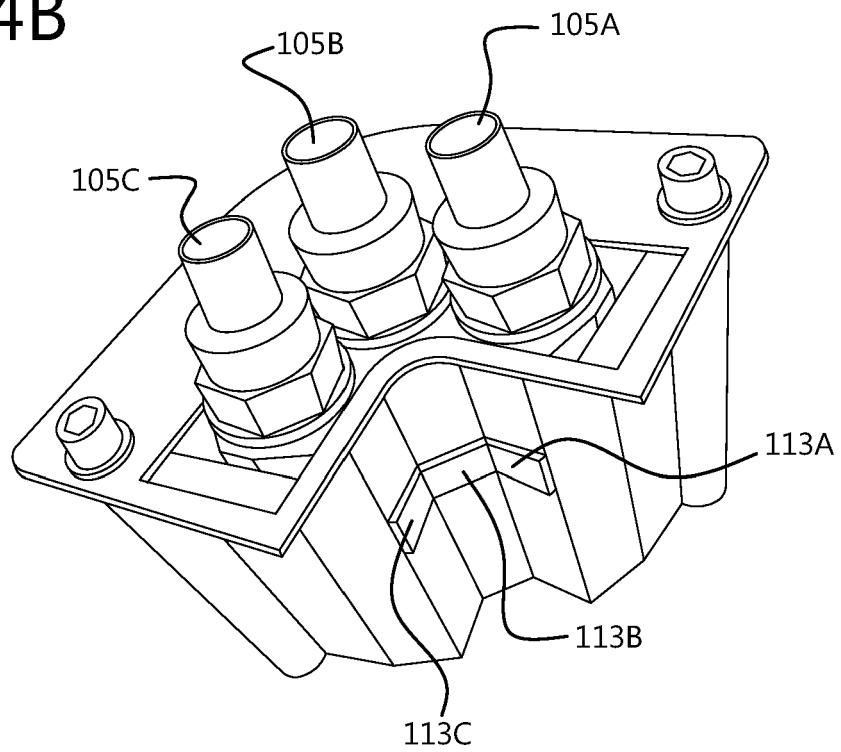


Fig. 4C

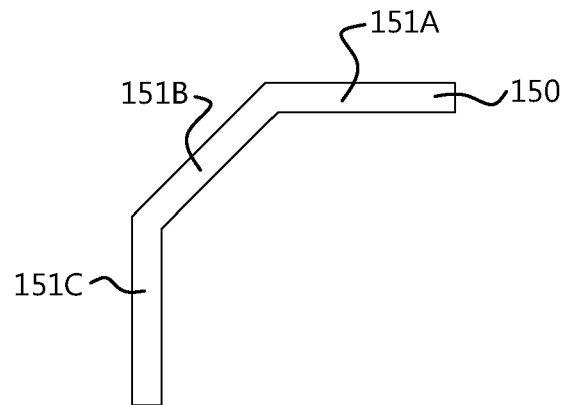


Fig. 5

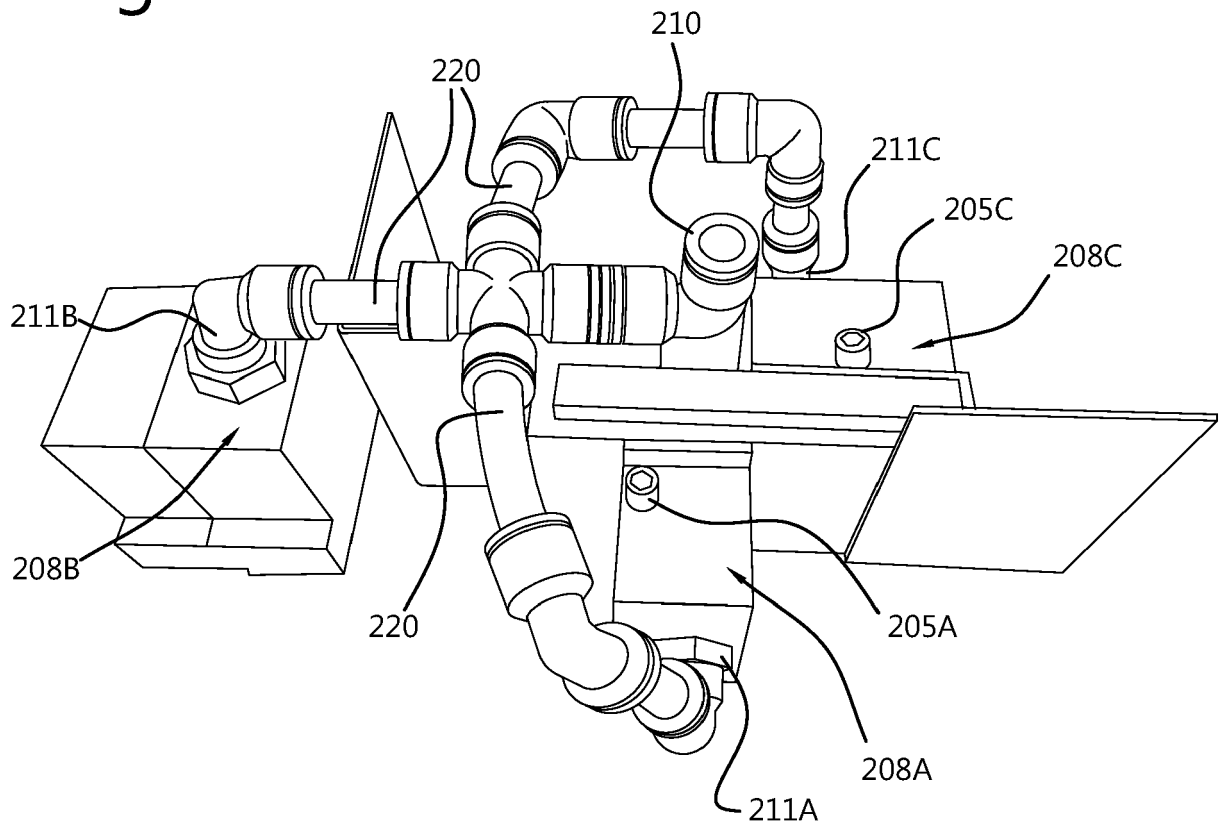
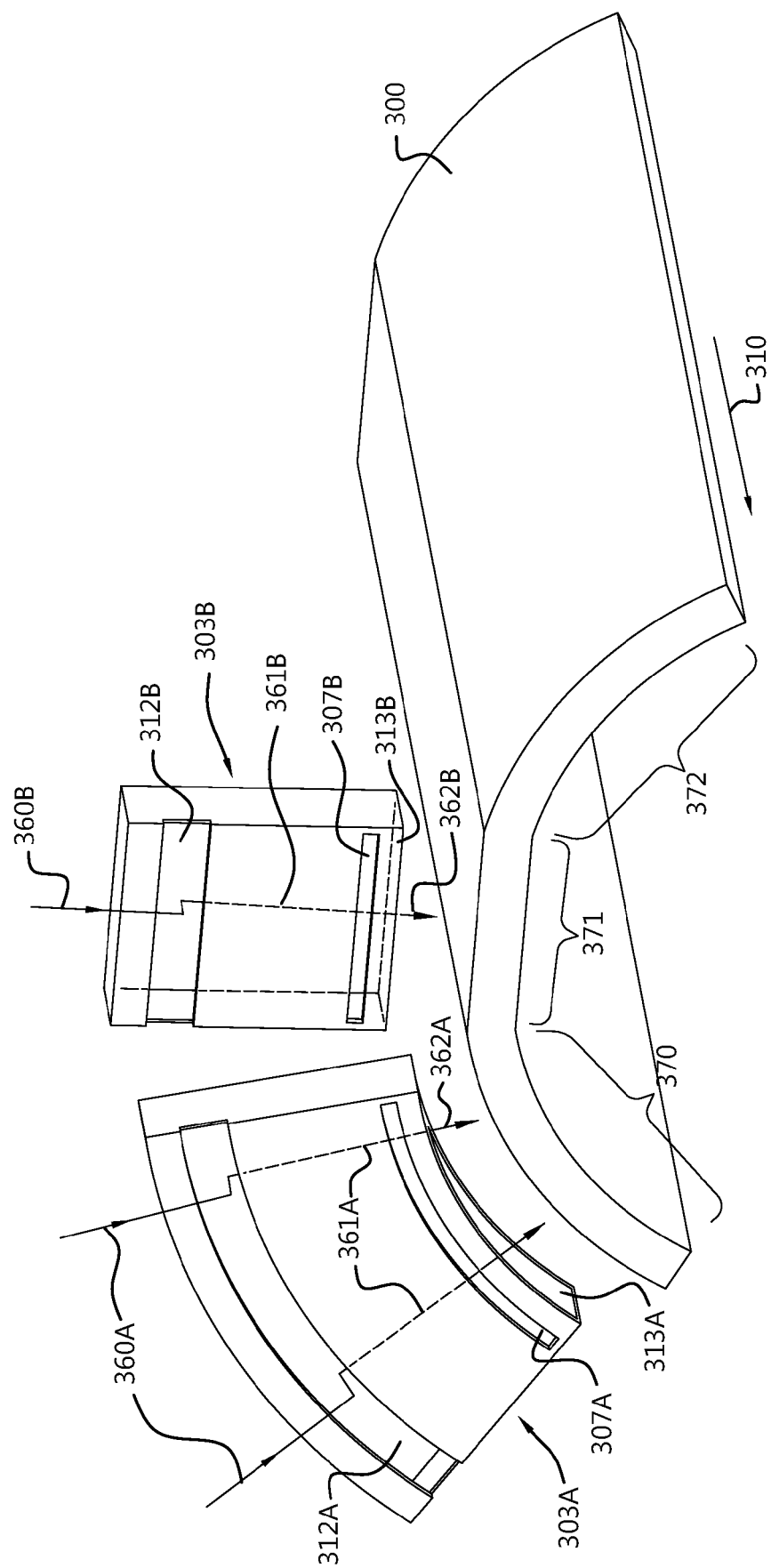


Fig. 6





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