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(54) METHOD FOR TREATING PLASMA UNDER CONTINUOUS ATMOSPHERIC PRESSURE OF WORK PIECES, IN PARTICULAR, MATERIAL PLATES OR STRIPS

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(57) ABSTRACT

The invention relates to a method for treating plasma under continuous atmospheric pressure of, in particular, electrically insulating workpieces, in particular material plates or strips. According to said method, the workpiece which is to be machined, is arranged at a distance below at least one electrode which is made of two barrier electrodes, which are arranged in a successive manner in the direction of displacement with a gap, and which extends in a manner which is transversal to the direction of displacement at least over the width of the surface of the workpiece which is to be machined. The electrode and the workpiece are mutually offset in the direction of displacement. High voltage, which is in the form of an alternating voltage, is applied to the barrier electrodes, in order to provoke at least plasma discharge in the gap. The plasma discharge is driven by the gas flow from the gap in the direction of the surface of the workpiece which is to be machined. The invention is characterised in that the surfaces of the barrier electrodes which are oriented towards the surface of the workpiece which is to be machined are impinged upon with high pressure.

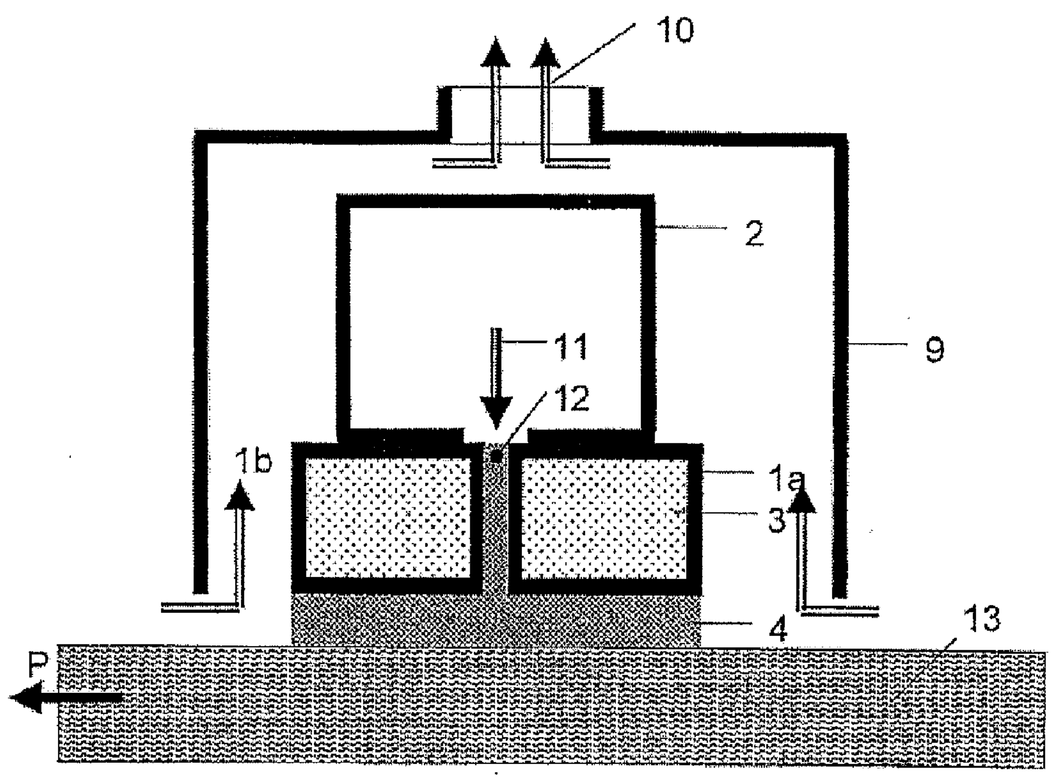
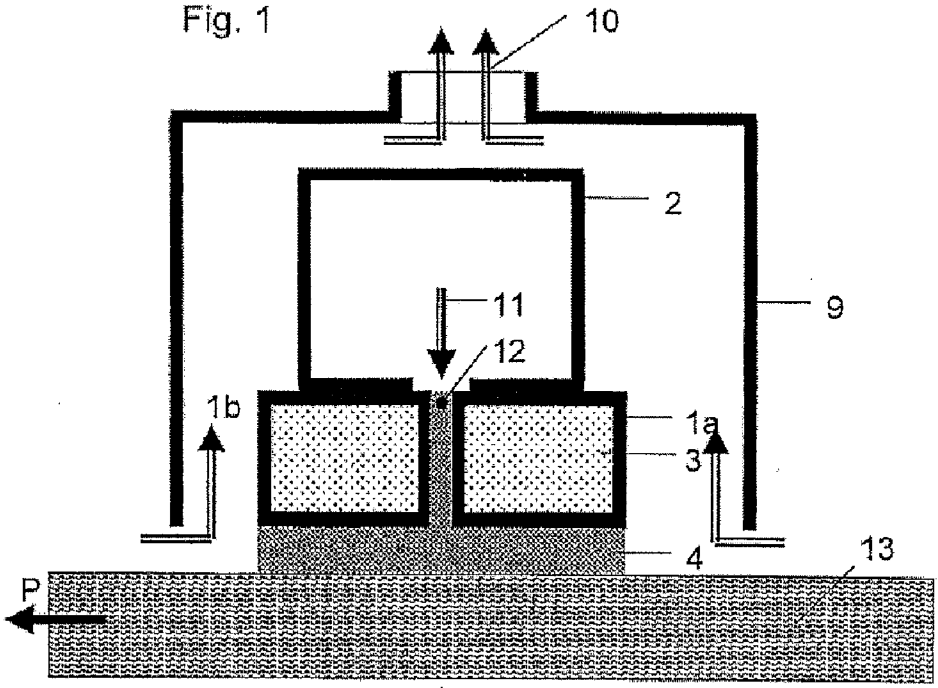


Fig. 1



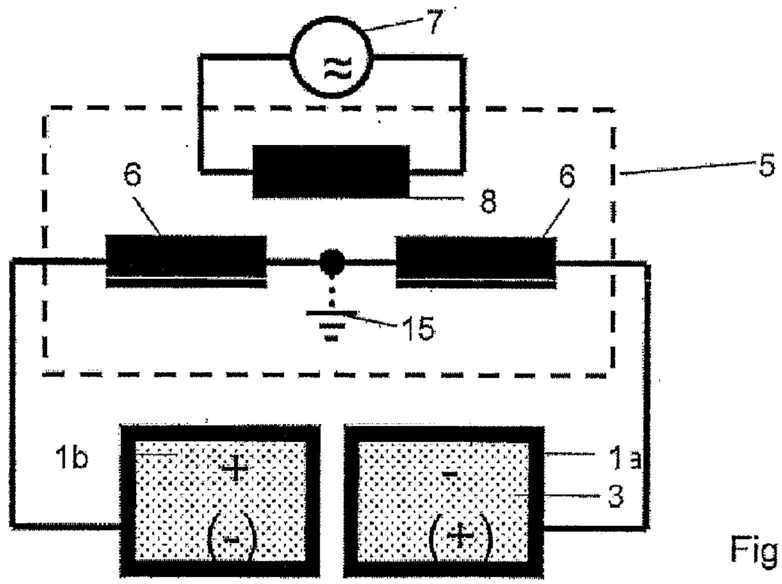


Fig. 2

Fig. 3

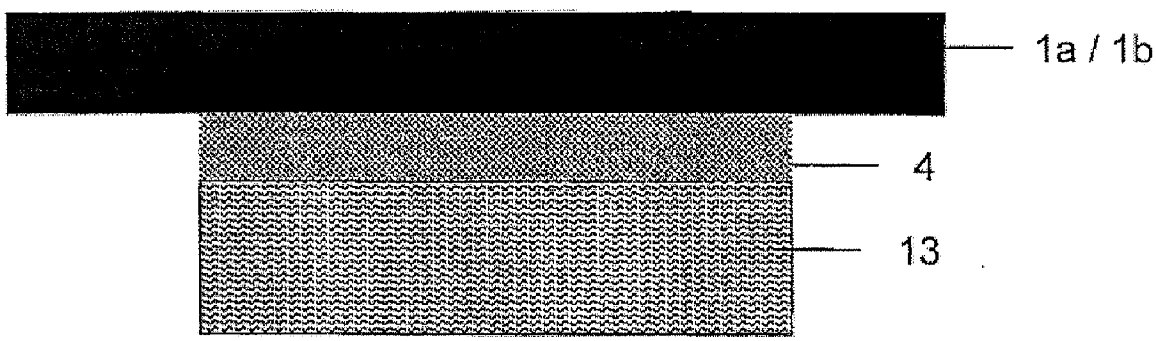


Fig. 4 a)

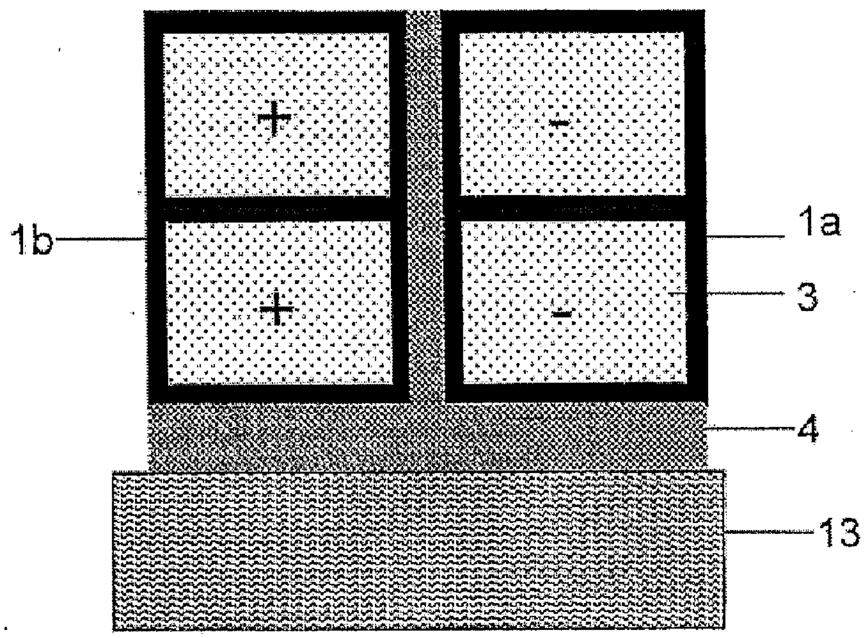


Fig. 4 b)

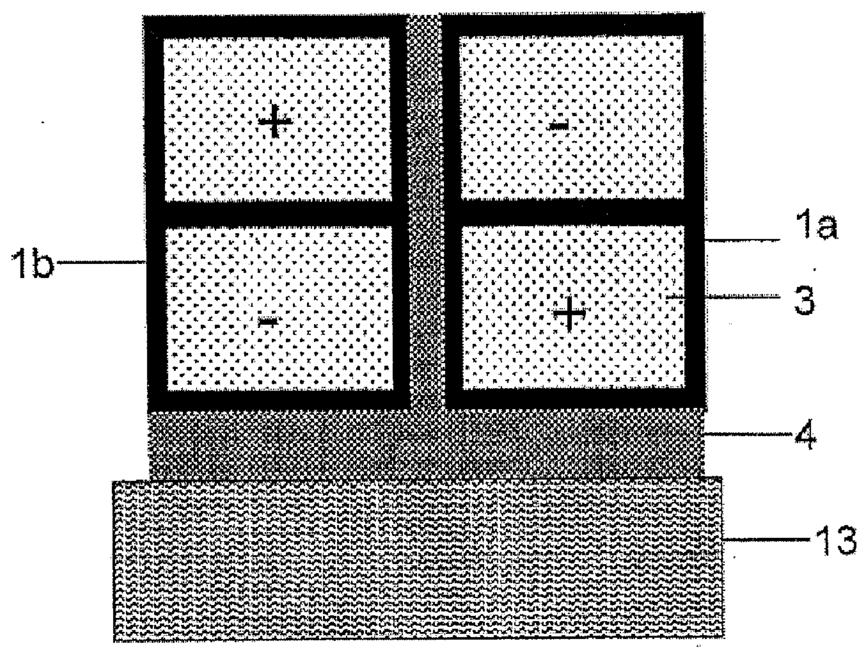


Fig. 5

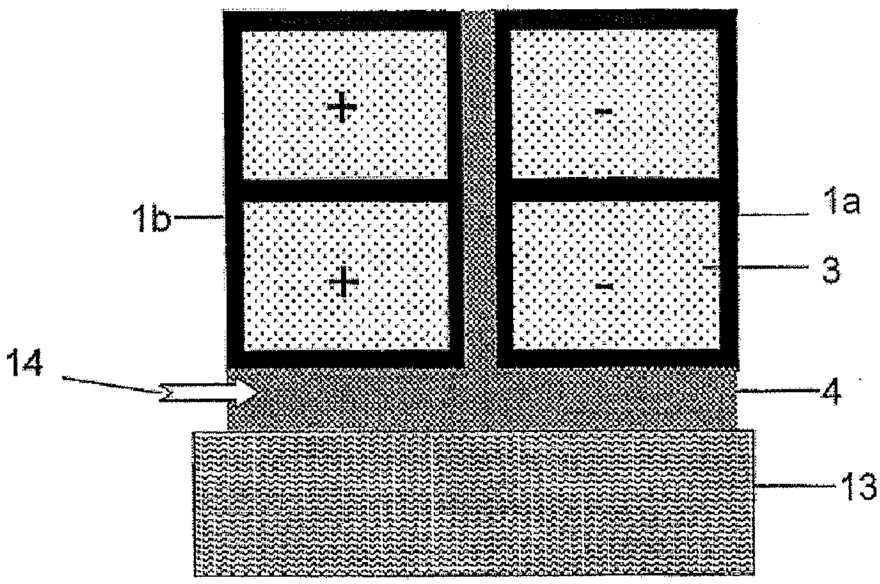
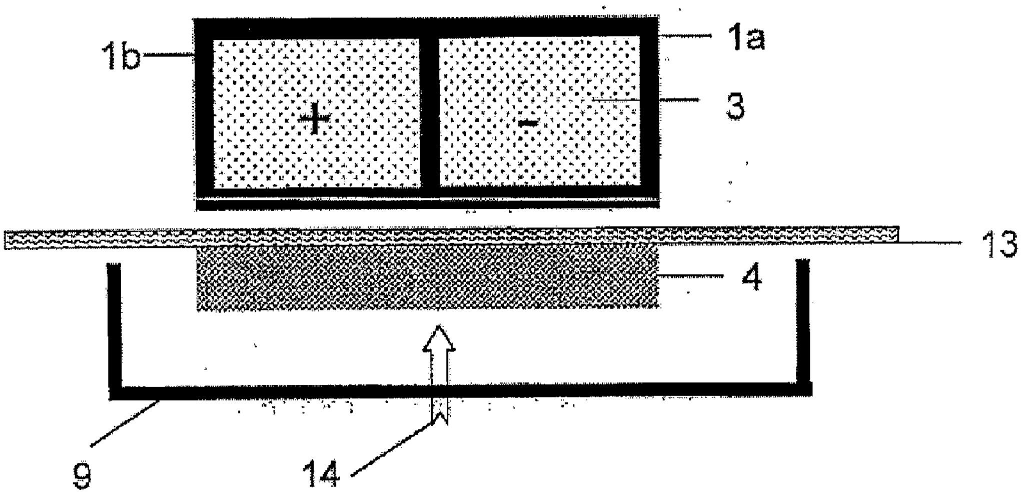


Fig. 6



METHOD FOR TREATING PLASMA UNDER CONTINUOUS ATMOSPHERIC PRESSURE OF WORK PIECES, IN PARTICULAR, MATERIAL PLATES OR STRIPS

[0001] The invention relates to a method for continuous atmospheric-pressure plasma treatment of workpieces, in particular boards or sheets of material according to the preamble of claim **1** and/or the preamble of claim **6**.

[0002] In the finishing industry or in the production of plastic films, the film is activated at the surface by a plasma treatment at atmospheric pressure, also known as a corona treatment. An industrial corona system usually comprises a high-voltage electrode and a counter-electrode designed as a roll which is guided over the plastic film in close proximity thereto. The electrode is arranged parallel to the roll, the electrode being connected to a high voltage of approx. 10 kilovolts at approx. 20-40 kilohertz and the roll being connected to ground potential. Due to the potential difference in the air gap between the high-voltage electrode and the roll with the plastic film, amounting to a few millimeters, a corona discharge develops with a conventional practical power output of 1 to 5 kilowatts per meter. The plastic film is activated by the corona discharge, i.e., oxidized at the surface.

[0003] Due to this activation, the surface tension is increased to thereby ensure adequate adhesion of printing inks and adhesives.

[0004] With the device described above, thin plastic films can be treated, but materials greater than 6 mm in thickness such as foam, plastic sheeting, plastic sections several centimeters thick or even wooden boards of similar thicknesses cannot be treated in this way. The reason for the restriction is the unequal development of the discharge channels with an increase in the electrode gap which thus results in an irregular activation of the surface of the material.

[0005] DE 102 28 506 A1 discloses a method for continuous atmospheric pressure plasma treatment of electrically insulated workpieces that operates by a different principle, but this method includes all of the features of the preamble of claim **1**. Thus two barrier electrodes arranged with a distance between them are used here, a plasma discharge is ignited in the gap formed between the barrier electrodes and is then expelled by a gas stream in the direction of the surface to be treated.

[0006] In the method disclosed in the aforementioned publication, the plasma acts only along a narrow strip, the width of which corresponds essentially to the width of the gap left between the barrier electrodes on the surface of the workpiece to be treated.

[0007] Against this background, the present invention describes a method with which a workpiece can be subjected to an atmospheric pressure plasma treatment continuously along a larger working width.

[0008] A first possibility for such a method is defined in claim **1**, this method being based on the method disclosed in DE 102 28 506 A1.

[0009] An alternative possibility for such a method is described in claim **6**.

[0010] Advantageous refinements of the method according to claim **2** are specified in greater detail in the dependent claims **2** through **5**.

[0011] The electrode consists of at least two barrier electrodes but more than two barrier electrodes may also be aligned in rows one after the other, leaving a gap after each.

[0012] The surfaces of the barrier electrodes facing the surface of the workpiece to be treated is acted upon by the high voltage. Therefore, due to the effect described above, a plasma discharge is ignited over the entire width of the surface of the workpiece to be treated, this plasma discharge being made possible by the ignition voltage which is reduced, due to the plasma species present in the space between the electrode and the workpiece because of the plasma gas expelled from the gap, thus allowing treatment of the surface of the workpiece over its entire width. This phenomenon is referred to here as "capacitive coupling discharge."

[0013] According to a simple variant, the electrode is composed of two single channel barrier electrodes. According to this invention, as the workpiece approaches the electrode, capacitive coupling occurs due to the dielectric mass of the workpiece as the workpiece is brought to an adjusted distance in proximity to the electrode with a suitable choice of the other parameters (high voltage, atmosphere). Due to the presence of the plasma species formed in the gap between the barrier electrodes and driven out of the gap in the direction of the workpiece surface, a uniform discharge therefore develops between the barrier electrodes and the workpiece resembling a glow discharge in a vacuum plasma. The electrode is operated mainly with air as the process gas, but it may also be operated in foreign gas atmosphere, e.g., in nitrogen or mixtures of nitrogen with other gases such as oxygen, carbon dioxide, hydrogen or noble gases. Due to the discharge, the workpiece surface is oxidized, depending on the type of gas, and/or other chemical groups, e.g., amines, amides or imides are incorporated. Therefore, the surface energy of the workpiece is increased and thus the adhesion of paints, enamels, adhesives or other coatings is improved or made possible. An advantage of this inventive method is in particular the fact that due to the capacitive coupling, the discharge is adapted to the dimensions of the workpiece, i.e., the discharge is ignited primarily on the workpiece surface but not beside it. This results in a location-specific discharge and also leads to savings of the energy required for igniting and maintaining the discharge.

[0014] The gap between the barrier electrodes is preferably between 0.5 millimeter and 5 millimeters wide. Gaps of these widths are especially suitable for ignition of the desired plasma with the voltage ranges preferred for performing this method.

[0015] The barrier electrodes are preferably made of aluminum oxide ceramic. This material is especially resistant.

[0016] The barrier electrodes are made of rectangular tubes each having one or more channels.

[0017] The barrier electrodes are preferably arranged on a holding body. However, the barrier electrodes may also be attached to a holding plate by means of electrode carriers via insulators. By sealing off the design space between the barrier electrodes and the holding plate, in this case a chamber is formed into which air or another gas can be fed, to then flow through the gap as a result of the excess pressure which then builds up and to drive the discharge out of the gap in the direction of the workpiece.

[0018] With a process management according to claim **2**, an additional coating of the workpiece surface with chemical compounds formed from the precursors in the plasma can be achieved.

[0019] According to a refinement of the present invention, a counter-electrode is arranged as described in claim **3**. The counter-electrode may be formed preferably as a supporting surface designed as an electrode. In the case of thick insulating materials such as sheets, sections, hollow chamber sections, web plates, etc., the counter-electrode may be omitted. Materials having a low dielectric mass such as plastic films, foams, air cushion film, paper, plastic fibers or natural fibers, granules or powders should be treated with a counter-electrode. The counter-electrode may serve as a dielectric mass (roller, conveyor belt) and/or as a ground metal roll or plate with a dielectric (silicone or ceramic) or may be designed without a dielectric. In the case of a dielectric roll, treatment of the back side is prevented or greatly suppressed in treatment of plastic films when there are indentations in the roll in the case of a dielectric roll with a capacitive coupling discharge. A counter-electrode can also be an electrode designed in mirror image to the electrode producing the discharge. Then the workpiece is passed between two electrodes. This also allows two-sided treatment of the substrate.

[0020] To create a high voltage as is necessary for ignition of the plasma discharge, preferably a symmetrical transformer with a primary coil connected to a generator and with two secondary coils each connected to one of the barrier electrodes is used (claim **4**). Instead of operation with one shared transformer, operation with two separate transformers is also possible. They may be operated in synchronized operation or in push-pull operation.

[0021] In the case of electrically conductive materials such as metallized plastic films, the high voltage is reduced to one-half by a symmetrical transformer. This prevents damage to the thin metal layer by the plasma discharge.

[0022] To be able to reliably divert the ozone and other byproducts formed in the plasma discharge from the processing site, the electrode is preferably arranged in a tunnel-like housing that is open on the side facing the top side of the workpiece and the housing is connected to a suction exhaust (see claim **5**).

[0023] An alternative method which solves the same problem as described above does not rely on a refinement of the state of the art according to DE 102 28 506 A1, but instead uses an alternative approach. This method is characterized in claim **6**.

[0024] The essential invention of the method here consists of controlling the ignition of plasma in a certain range through the type of atmosphere in this area and adjusting a suitable high-voltage accordingly. In this variant, a plasma should be ignited only on the side of the sheet or board of material that is opposite the electrode. To do so, in the area between the electrode and the first side of the workpiece, a first atmosphere is established in which a plasma does not yet ignite at a selected high voltage. On the opposite side of the sheet of material, a second atmosphere differing from the first atmosphere is established in which a plasma ignition can already take place, induced by the high voltage applied by the electrode. Thus in a targeted manner, a plasma is ignited only on the "back side" of the sheet or board of material so that a large area plasma treatment is performed there. Here again, this is a "capacitively coupling discharge" in the sense of the present invention, with the discharge also over the entire width and length of the electrodes in this example, but limited to the dimensions of the respective material to be treated.

[0025] Additional advantages and features of the invention are derived from the following description of the invention on the basis of exemplary embodiments depicted in the figures, in which

[0026] FIG. **1** shows a schematic side view of a device for performing the inventive method in a first variant, this view showing the direction of conveyance of a workpiece that is to be coated continuously;

[0027] FIG. **2** shows a basic diagram of the electric wiring of the electrode of the device shown in FIG. **1**;

[0028] FIG. **3** shows a schematic view in the direction of movement of the workpiece to be coated showing a detail of the device with the plasma ignited;

[0029] FIGS. **4***a* and **4***b* show two possible wiring variants of an alternative embodiment of an electrode with two double-channel barrier electrodes;

[0030] FIG. **5** shows another possible wiring of two double-channel barrier electrodes, a precursor additionally being fed into the ignited plasma discharge in this case and

[0031] FIG. **6** shows a schematic diagram of an inventive method according to the second variant.

[0032] In the figures, the same or similar elements are labeled with the same reference numerals.

[0033] FIG. **1** shows schematically a first cross section through a device for performing the inventive method according to the first alternative, this cross section being shown along a plane in which the direction of movement occurs. The inventive device consists of two barrier electrodes **1***a*, **1***b* arranged one after the other in the direction of movement (arrow P) of a workpiece **13**. A gap **12** is left between the barrier electrodes **1***a*, **1***b*. The barrier electrodes **1***a*, **1***b* are arranged on a holding body **2** which at the same time forms a chamber for introducing a gas **11**, preferably air or nitrogen and/or a gas mixture containing nitrogen to drive this gas and/or gas mixture through the gap **12** in the direction of the surface of the workpiece **13** to be treated. A plasma ignited in the gap **12** between the barrier electrodes **1***a*, **1***b* is conveyed through the gas and/or gas mixture constantly being resupplied into the gap and the plasma is conveyed into the area between electrodes **1***a*, **1***b* and the workpiece **13**, ultimately flowing out of this area in both directions, namely with and against the direction of movement (arrow P). A tunnel-shaped housing **9** which is open in the direction of the workpiece **13** is arranged above the arrangement of the holding body **2** and the electrode (barrier electrodes **1***a*, **1***b*) and this housing is connected via an upper opening to a suction device **10**, shown here schematically. The workpiece **13** is conveyed in the direction of movement (arrow P) by mechanisms that are not shown here. To this end the workpiece may rest on a supporting surface (e.g., a conveyor belt), for example, but it may also be conveyed away beneath the electrode without a supporting surface due to its own inherent rigidity. An electric conductor **3**, shown here schematically, runs in the barrier electrodes **1***a*, **1***b*, which in the present case are rectangular tubes made of aluminum oxide ceramic, to make it possible to apply an appropriate voltage to the respective barrier electrode **1***a*, **1***b*. The barrier electrodes **1***a*, **1***b* in this exemplary embodiment have a length of up to several meters. The electric conductor **3** may be comprised of, for example, a metal powder filling or a metal coating of the electrode from the inside.

[0034] FIG. **2** shows schematically an electric wiring of the barrier electrodes **1***a*, **1***b*. To supply high voltage to the barrier electrodes **1***a*, **1***b*, the device has a transformer, which is indicated here by the border labeled as **5** and which in this case is a symmetrical transformer having a primary coil **8** and two secondary coils **6**. The secondary coils **6** are each connected to one of the barrier electrodes **1***a*, **1***b* and to ground **15**. The connection to the electric mass **15** may also be omitted. An alternating voltage generator **7** is connected to the primary coil **8** of the transformer **5**. The voltage may be wired in synchronized operation or in push-pull operation.

[0035] In this example, a sinusoidal voltage between 10 and 60 kilovolts with a frequency of 1 to 100 kilohertz, preferably 5 to 30 kilohertz is used. The voltage may also be pulsed. Due to the symmetrical transformer, the voltage is applied uniformly to the two barrier electrodes **1***a*, **1***b* so that a plasma can be ignited in the gap **12**. The gap **12** has a gap width of 0.5 to 5 millimeters, preferably 1 millimeter. Due to the flow of the gas **11** into the gap **12** and/or through the gap in the direction of the surface of the workpiece **13**, the ignited plasma **4** is conveyed in the direction of the surface of the workpiece **13** that is to be treated. In the plasma gas, the ignition voltage is reduced. Therefore, in approach of the workpiece **13** to a distance of 1 millimeter to 20 millimeters from the electrodes, there is a capacitive coupling due to the dielectric mass of the workpiece **13** and thus a uniform discharge **4** developments between the surface of the workpiece **13** that is to be treated and the facing surfaces of the barrier electrodes **1***a*, **1***b*. This discharge is like a glow discharge in a vacuum plasma. Due to the capacitive coupling, the discharge **4** is adapted in its dimensions to the dimensions of the workpiece, i.e., the discharge **4** ignites primarily on the workpiece surface and not beside it. This is indicated schematically in FIG. **3**, which is a schematic view of one of the barrier electrodes **1***a* and the workpiece **13** which is guided beneath a view as seen in the direction of movement (arrow P).

[0036] During operation of the device, the workpiece **13** has been moved beneath the electrodes formed by the two barrier electrodes **1***a*, **1***b* so that a continuous plasma treatment of the surface of the workpiece **13** facing the electrode can be achieved along its entire width.

[0037] Due to the gas **11** (e.g., air) which is supplied via the holding body **2**, not only is the discharge deflected out of the gap **12** in the direction of the surface of the workpiece **13** that is to be treated, but at the same barrier electrodes **1***a*, **1***b* are also cooled.

[0038] The thermal stress on the workpiece to be treated is low. After a treatment with the device depicted in FIG. **1**, an increase in temperature of only approx. 5° C. is found.

[0039] In addition to an electric wiring for a so-called capacitively coupling discharge, like that shown in FIG. **2**, in which the discharge is deflected onto the side facing the workpiece and takes place between the surface of the workpiece **13** to be treated and the entire surface of the electrode facing the surface of the workpiece **13** to be treated, other possible operating modes of an inventive device may also be considered.

[0040] With a modified device that has a double-channel tube instead of each of two simple rectangular tubes as barrier electrodes **1***a*, **1***b*, capacitively coupling discharges can be achieved (see FIGS. **4***a* and **4***b*).

[0041] In these cases, the barrier electrodes **1** are implemented by two double-channel tubes, each being equipped with conductors **3**. The barrier electrodes are either connected to the symmetrical transformer in parallel, as illustrated in FIG. **4***a*, or in an antiparallel (FIG. **4***b*). In the case of an antiparallel connection, there is a higher energy input due to the higher field line density of the electric field in the gap between the barrier electrodes **1***a*, **1***b*. Due to preionization of the discharge carriers in the gap **12**, the remote effect of the charge carriers leaving the electrode in the direction of the workpiece **13** may be expanded in comparison with the arrangement having two single channel barrier electrodes (FIG. **1**). Thus a linear plasma free jet develops, in particular when there is a great distance from the workpiece, which depends on the size of the dielectric mass. In an approach of the workpiece **13** to the electrode, the discharge **4** according to this invention is pulled toward the workpiece **13** by capacitive coupling.

[0042] FIG. **5** shows another variant where so-called precursors **14** are fed into the plasma discharge for deposition of layers on the workpiece **13**. Such precursors **14** may be, for example, tetramethylorthosilicate, hexamethylene disiloxane in the form of vapor or aerosols. With the aforementioned precursors **14**, a silicon dioxide layer, for example, in the range of a few nanometers to micrometers may be deposited on the surface of the workpiece. With the capacitively coupling discharge, a precursor current like that described here may be fed preferably into the capacitively coupled discharge zone between the surface of the workpiece **13** that is to be treated and the surfaces of the barrier electrodes **1***a*, **1***b* facing the surfaces of the workpiece **13** that is to be treated.

[0043] It is important for the precursors **14** not to be fed between the electrodes, which are connected to the high voltage, in order to prevent the latter from being coated.

[0044] Finally, FIG. **6** shows schematically how an inventive method is performed according to the claimed alternative.

[0045] This shows how an electrode, which in this case is made up of a double-channel barrier electrode **1***a*, **1***b*, is arranged on one side of a workpiece **13** (a sheet or panel of material) and a housing **9** is arranged on the opposite of the workpiece **13** with respect to the electrodes **1***a*, **1***b*. An atmosphere fed into the housing **9** is such that, when an ac high voltage is applied to the electrodes **1***a*, **1***b*, this atmosphere allows ignition of a plasma discharge **4** on this side of the workpiece **13**, with a different accordingly prevailing in the area between the electrodes **1***a*, **1***b* and the workpiece **13** to suppress a plasma discharge. In this way the workpiece **13** is coated over a large area of the "back side" which is opposite the electrodes **1***a*, **1***b*. The atmosphere in the housing **9** is also removed by suction in this method to prevent unwanted plasma products, especially ozone, from entering the environment. This figure additionally shows how precursors **14** are introduced into the area of the plasma discharge **4**. This is possible but not necessary for the inventive method. This method functions equally well without the introduction of precursors.

[0046] The electrodes **1***a*, **1***b* may also be, for example, an electrode formed by two individual barrier electrodes separated from one another by a gap (an electrode pair). As long as the gap is not too great, a continuous plasma discharge will still develop on the side of the workpiece **13** facing the housing **9**, producing a desired surface change on this side of the workpiece.

[0047] Other possible applications are conceivable, for example, for internal treatment and/or internal coating of planar three-dimensional components, where electrically insulated workpieces having multiple channels are treated and coated in the interior. This is done by passing a noble gas such as argon through the channels, thereby lowering the ignition voltage according to Paschen's law so that the discharge is ignited in the interior. As already described above, the capacitively coupling discharge is ignited mainly on the workpiece and not in the gas space beside it and therefore is ignited mainly in the channels of the workpiece. If the carrier gas stream is provided with the vapor and/or aerosol of a precursor, then layers are deposited in the channels. In the treatment, the workpiece lies on a counter-electrode. Instead of the pure noble gas, mixtures with air, nitrogen, oxygen and the like may also be used.

[0048] Furthermore, a capacitive coupling may be performed in a large volume reaction chamber. The plasma discharge is ignited throughout the entire chamber in the case of a large volume chamber through which a noble gas flows, by attaching the barrier electrodes through the capacitive coupling described above. Depending on the size of the chamber, several electrodes may be necessary. Instead of a pure noble gas, mixtures with air and nitrogen, oxygen and the like may again be used here. Here again, precursors may be added to the carrier gas in the case when coating is desired.

[0049] In this reaction, it is also conceivable to treat melts on an extruder. Polymer melts can also be treated with a capacitively coupling discharge shortly after discharge from an extruder nozzle to thereby ensure adhesion to a web to be coated.

[0050] It is also possible with the inventive device and/or with the inventive method to activate liquids in the mode of the capacitively coupling plasma discharge. Then chemical reactions may be induced at the plasma-liquid interface, their products then being able to diffuse into the liquid. It is also possible to crosslink thin liquid films by using a plasma discharge according to this invention.

[0051] Description of Treatment Example:

[0052] 1. Treatment not Including the Back Side by Capacitively Coupling Discharge

[0053] An LDPE film with a surface energy (before the plasma treatment) of 30 mN/m on both sides was plasma treated on the side facing the barrier electrodes. The LDPE film was freely clamped, i.e., no counter-electrode was used. The plasma treatment was performed with a pair of electrodes according to FIG. **4***a*, formed by a double-channel tube and arranged in parallel with one another from a distance of 0.5 mm leaving a gap. The film was moved at the rate of 60 m/min beneath the electrode using a linear table, where the distance from the barrier electrodes to the LDPE film was 1.5 mm.

[0054] An electric energy of 500 watts was applied to the double barrier electrode at a frequency of the ac high voltage of 8 kilohertz. Blowing air was fed into the gap between the two double-channel tubes of the double barrier electrodes at essentially atmospheric pressure. Under the aforementioned boundary conditions, the plasma between the barrier electrodes ignited and was expelled by the blowing air onto the LDPE film. The ignition voltage in this range was reduced due to the plasma species blown out into the interspace between the double barrier electrode and LDPE film to such an extent that a "secondary ignition" of a large area plasma was ignited in the entire area between the surfaces of the barrier electrodes facing the surface of the LDPE film and the surfaces facing the film (remote discharge). Ten treatments were performed in this way.

[0055] The surface energy was measured with test inks according to the DIN ISO 8296.

[0056] On the basis of the plasma treatment described above, on the barrier electrode side of the LDPE film, an increase in the surface energy to 42 mN/m could be achieved through a capacitively coupling discharge; this is a typical value for a print pretreatment. The surface energy on the side of the LDPE film facing away from the barrier electrodes (back side of the film) still amounted to 30 mN/m. Thus, no treatment has taken place here.

[0057] 2. Treatment of Web Plates

[0058] A 7.5 mm thick polypropylene web plate with a surface energy (before the plasma treatment) of 30 mN/m on both sides was plasma treated on the side facing the barrier electrodes. This was done by freely clamping the polypropylene web plate, i.e., no counter-electrode was used.

[0059] The plasma treatment was performed with a pair of double-channel tubes according to FIG. **4***a* arranged at a distance of 0.5 mm in parallel with one another while leaving a gap.

[0060] The web plate was moved beneath the electrode system using a linear table at the rate of 10 m/min.

[0061] The electric energy applied to the double barrier electrode was 500 watts at a frequency of the ac high voltage of 8 kilohertz. The distance between the barrier electrodes and the web plate was 1.0 mm. Blowing air was fed into the gap between the two double-channel tubes of the double barrier electrodes.

[0062] Under the boundary conditions defined above, the plasma ignited between the barrier electrodes and was expelled onto the web plate by the blowing air. The ignition voltage was reduced in this area due to the plasma species blown out into the interspace between the double barrier electrodes and the web plate until a "secondary ignition" of a large area plasma was ignited in the entire area between the surfaces of the barrier electrodes facing the plate and the surface of the web plate (remote discharge). Two treatments were performed.

[0063] The surface energy is measured with test inks according to DIN ISO 8296.

[0064] This plasma treatment resulted in an increase in the surface energy to 50 mN/m owing to the capacitively coupling discharge on the barrier electrode side of the polypropylene web plate; this is a typical value for adhesive bondability. The back side of the web plate did not receive any treatment and the value of the surface energy remained at the original level of 30 mN/m.

LIST OF REFERENCE NOTATION

[0065] **1***a, b* Barrier electrode

[0066] **2** Holding body

[0067] **3** Electric conductor

[0068] **4** Plasma discharge

[0069] **5** Transformer

[0070] **6** Secondary coil

[0071] **7** Generator

[0072] **8** Primary coil

[0073] **9** Housing

[0074] **10** Suction

[0075] **11** Gas

[0076] **12** Gap

[0077] **13** Workpiece

[0078] **14** Precursor

[0079] **15** Electric mass

[0080] P Arrow

1. Method for continuous atmospheric pressure plasma treatment of electrically insulated workpieces in particular, especially plates or sheets of material, whereby a workpiece that is to be treated is arranged at a distance beneath an electrode consisting of at least two barrier electrodes arranged after the other in the direction of movement, leaving a gap between them, and extending across the direction of a movement and at least over the width of the surface of the workpiece to be treated, and the electrode and the workpiece are set in motion in a direction of motion in relation to one another, with a high voltage in the form of an ac voltage being applied to the barrier electrodes to ignite a plasma discharge at least in the gap, and whereby a stream of gas drives the plasma discharge out of the gap in the direction of the surface of the workpiece to be treated, characterized in that the high voltage acts upon the surfaces of the barrier electrodes facing the surface of the workpiece to be treated, thereby resulting in a reduced ignition voltage for ignition of a plasma discharge between the surfaces of the barrier electrodes facing the workpiece and the surface of the workpiece to be treated, said reduction in ignition voltage being achieved because of the plasma gas flowing out of the gap and into the area between the barrier electrodes and the surface of the workpiece to be treated, and thereby igniting a plasma that acts over the entire width of the workpiece.

2. The method according to claim **1**, wherein chemical reagents (precursors) are introduced into the plasma in the area between the barrier electrodes of the surface of the workpiece to be treated.

3. The method according to claim **1** wherein a counter-electrode is arranged on a side of the workpiece opposite the electrode.

4. The method according to claim **1** wherein the high voltage is generated with a symmetrical transformer with a primary coil connected to a generator and with two secondary coils each connected to one barrier electrode.

5. The method according to claim **1** wherein gases generated in the area of the plasma treatment are removed by suction.

6. Method for continuous atmospheric-pressure plasma treatment of electrically insulated workpieces in particular, especially plates or sheets of material, whereby a workpiece to be treated is arranged at a distance beneath a barrier electrode extending across the direction of movement at least over the width of the surface of the workpiece that is to be treated, and the electrode and the workpiece are set in motion in relation to one another in a direction of movement, whereby a high voltage in the form of an ac voltage is applied to the barrier electrodes, characterized in that a first space situated between the barrier electrodes and the workpiece is filled with a first atmosphere formed by a first gas or gas mixture, and a second space opposite the side of the workpiece which is opposite the barrier electrode and adjacent to the back side of the workpiece is filled with a second atmosphere formed by a second gas or gas mixture, whereby the choice of the high voltage and of the first and second atmospheres is made in such a way that a plasma discharge ignites in the second atmosphere but not in the first atmosphere.

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