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(54) **METHOD AND APPARATUS FOR TREATMENT OF TEXTILE MATERIALS**

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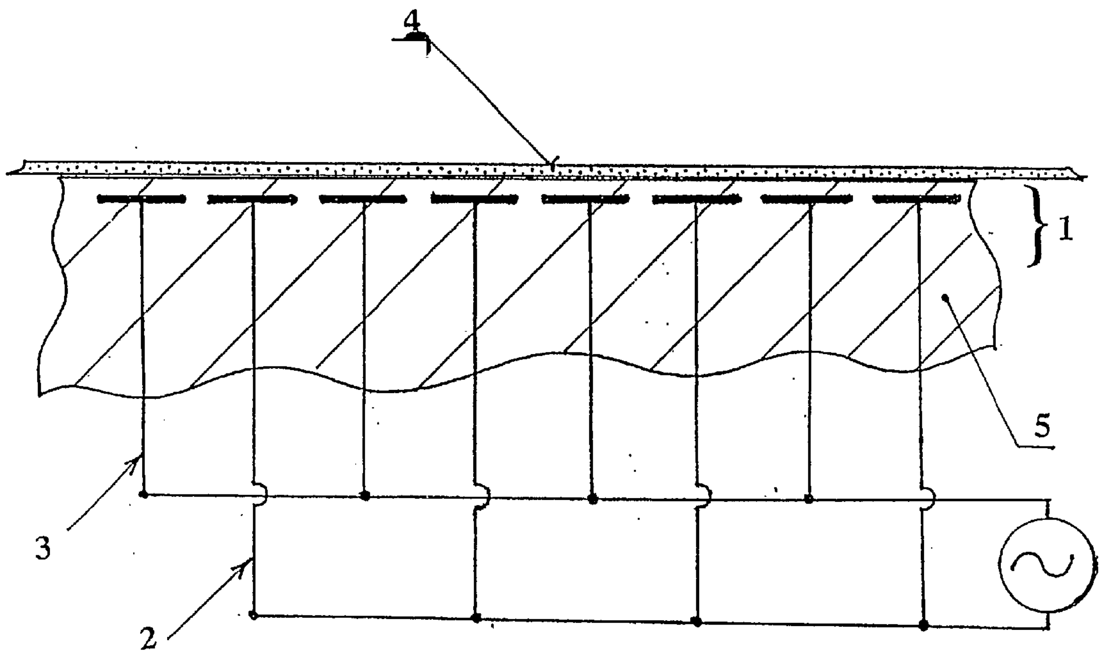
(57) **ABSTRACT**

A method and apparatus perform surface treatment of fibers of woven and non-woven textile materials to be affected by electrical plasma generated by electrical discharges from two electrically conductive electrodes situated inside a dielectric body. A voltage of a frequency from 50 Hz to 1 MHz and magnitude from 100 V to 100 kV is applied between the electrodes of the electrode system which is situated in a gas at a pressure from 1 kPa to 1,000 kPa. The electrical plasma is generated on a portion of the dielectric body surface without contacting the electrically conductive electrodes. The apparatus treats textile materials using electrically conductive electrodes situated inside of the dielectric body and are situated on the same side of the textile material affected by the plasma. The electrically conductive electrodes are parallel with the portion of the surface of the dielectric body on which the electrical plasma is generated.



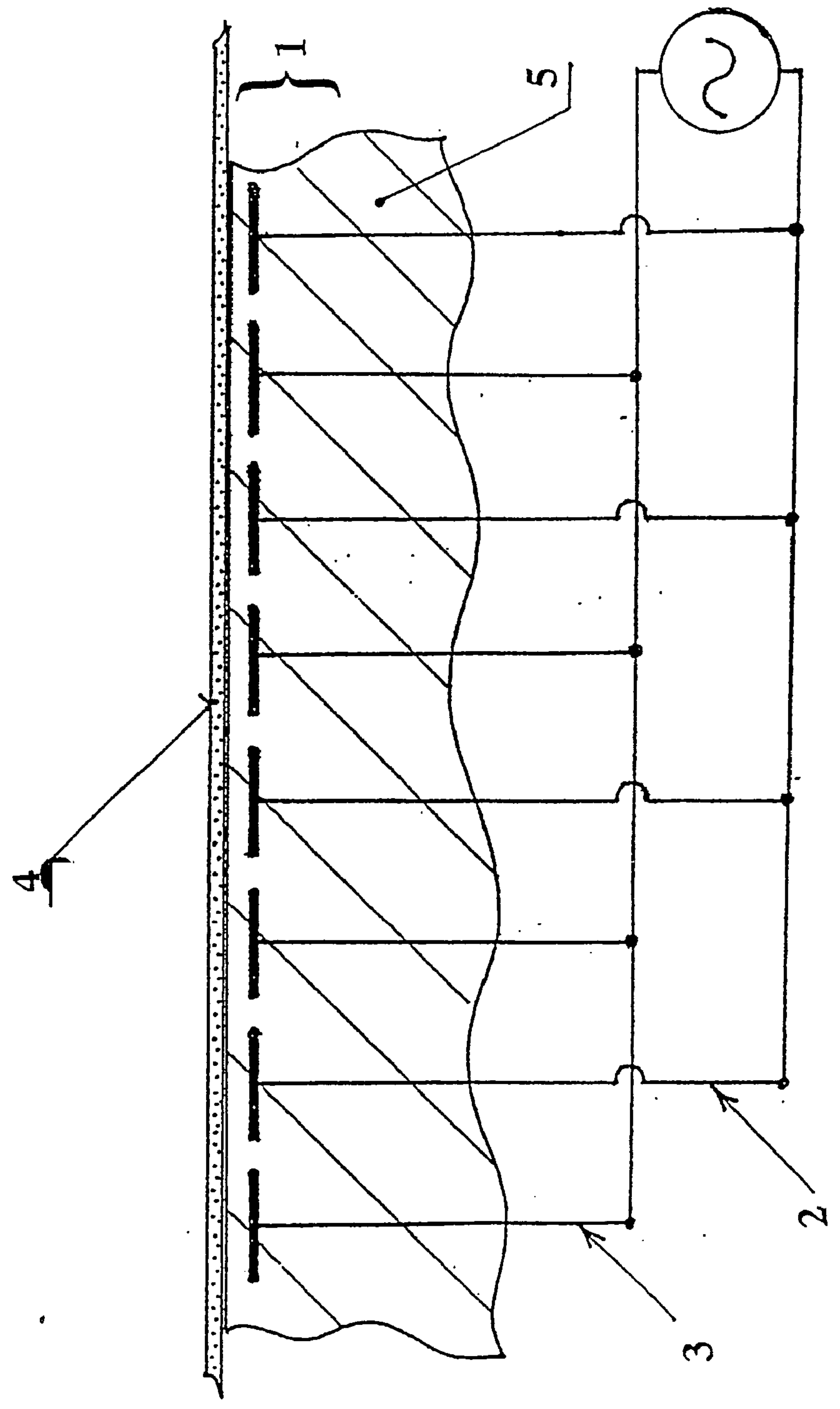


FIG. 1

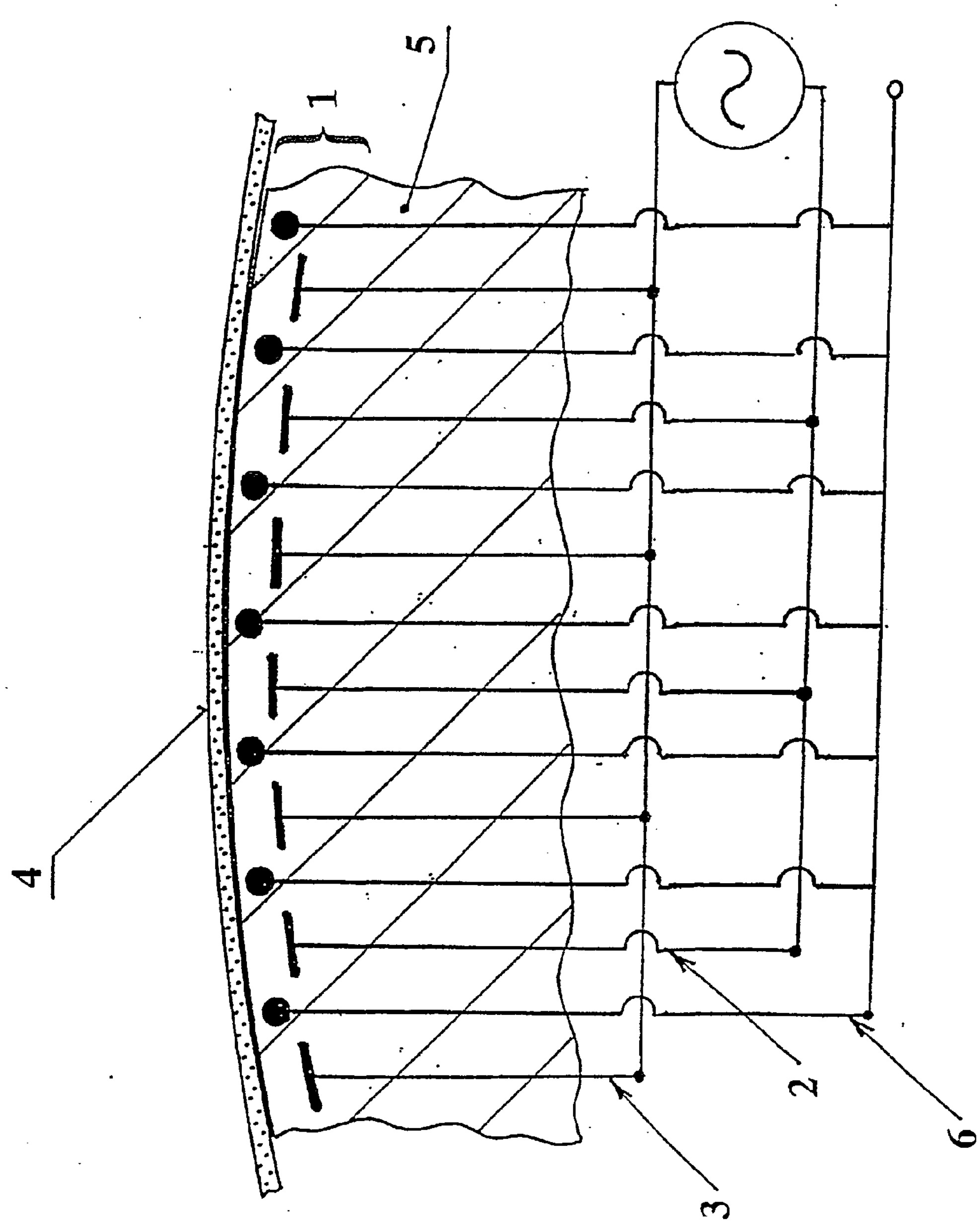


FIG. 2

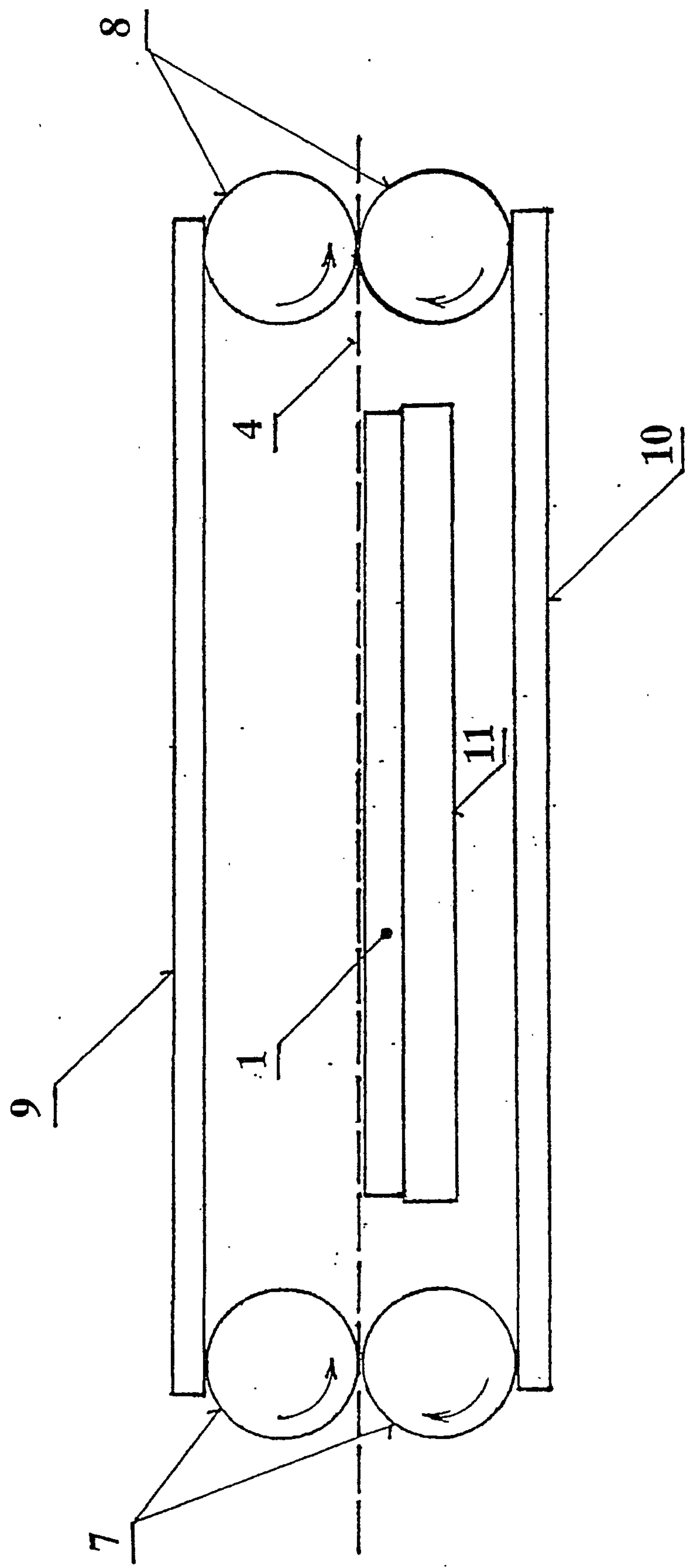


FIG. 3

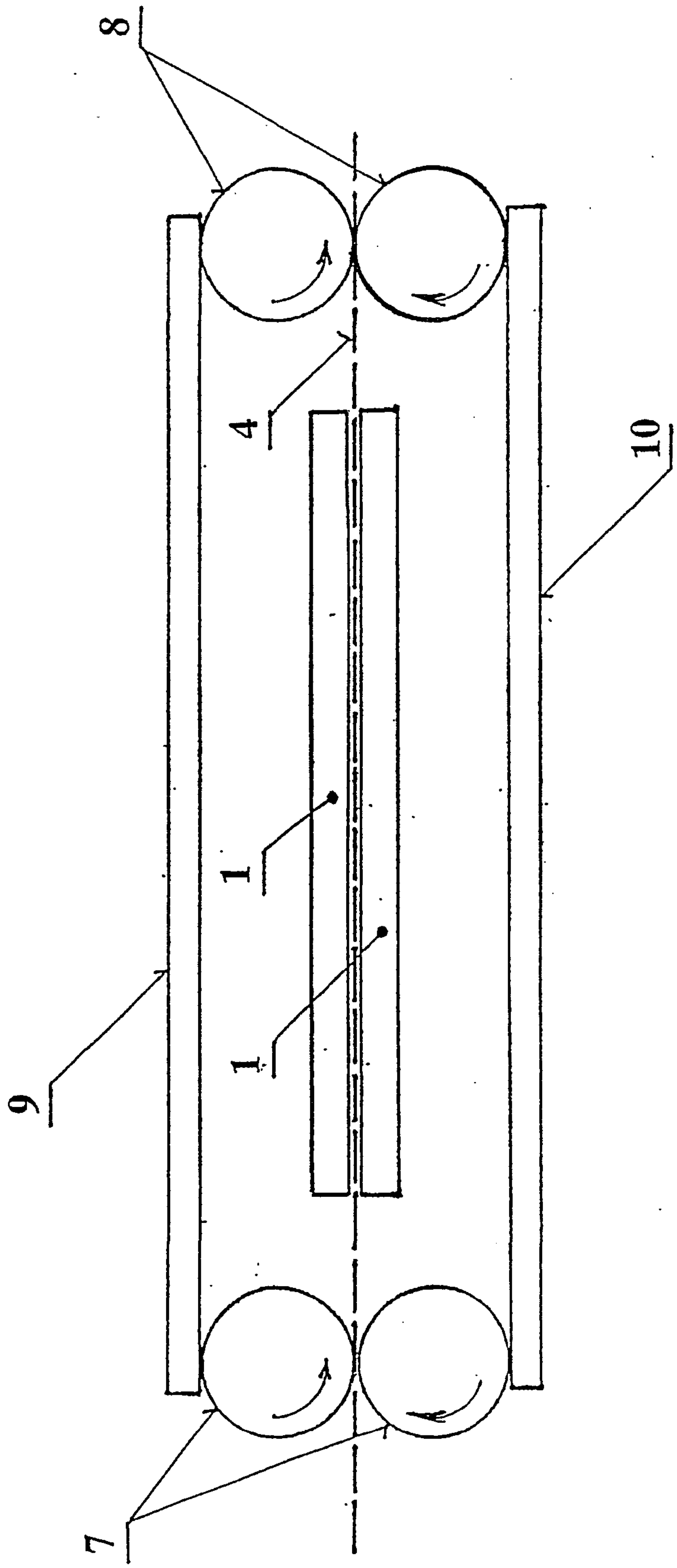


FIG. 4

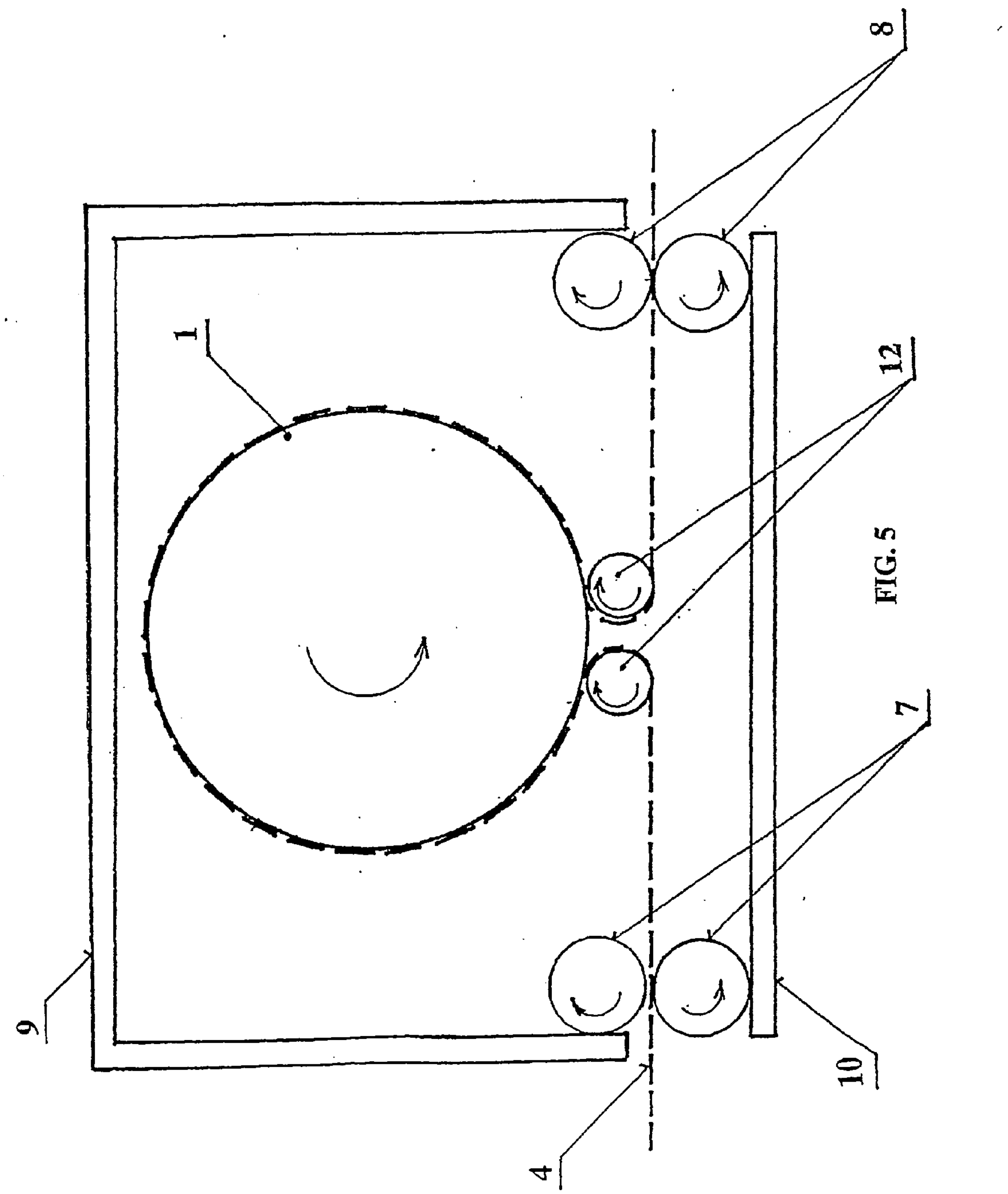


FIG. 5

METHOD AND APPARATUS FOR TREATMENT OF TEXTILE MATERIALS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a method and apparatus for treatment of inner and outer surfaces of woven and non-woven textiles and cords from organic and inorganic fibers with the aim to change surface properties of the fibers such as, first of all, hydrophilicity, hydrophobicity, surface energy, adhesion to other materials, colorability, surface electrical conductivity, and biocompactibility.

[0003] 2. Description of the Related Art

[0004] Textiles are made from organic or inorganic fibers that often do not possess the surface properties needed for given applications such as, for example, hydrophilicity, hydrophobicity, surface energy, adhesion to other materials, dyeability, surface electrical conductivity, and biocompactibility. The surface properties of fibers situated inside of the textile material or on the outer textile material surfaces can be modified by various chemical methods described in, for example, F. Baldwin: "The chemical finishing of nonwovens", INDA-TEC 97, pp. 6.0-6.42, as well as in patent applications DE 19,647,458; WO 97/11989; JP 09241980; and JP 09158020. These methods are based on the use of aggressive chemicals such as, for example, NaOH, SO_2, fluorine, chlorine, H_2O_2, and toxic chemicals such as, for example, blocked isocyanates and xylene. An environmentally more acceptable option is the use of surfactant-based finishes, such as described in WO 98/03717, which are applied mainly through topical treatments such as spraying, coating, padding, etc. A major problem encountered with these methods is that the coating is not usually well-bonded to the fiber and may be partially lost during storage or in subsequent operations.

[0005] It has been found that plasmachemical treatment methods can overcome these difficulties since they are more versatile and do not need the use of aggressive chemical, toxic and volatile organic solvents. The plasmachemical methods are based on the use of low temperature electrical plasmas. The low temperature plasmas as described herein are partially ionized and consist of activated species including gas molecules, ions, electrons, free radicals, metastables, and photons in the short wave ultraviolet range. While the gas temperature is low, the electrons have energies of several electron volts, corresponding to the temperatures on the order of 10^4 K. The electrons in collisions with gas molecules generate excited gas species, which can react with a variety of substrates to achieve modifications of surface properties. Such plasmas, plasmachemical methods, and apparatus for performing such methods to treat non-woven textiles are reviewed in W. Ralcowski: 2nd TANDEC Conf. (1992), D. Zhang et al.: Polym. Eng. Sci, 38 (1998) 965-70, and to treat woven textiles in M. Sotton, G. Nemoz: J. Coat. Fabrics 24 (1994) 138.

[0006] The disadvantage of the plasmachemical methods disclosed in patents WO 00/16914, WO 96/27044, GB 2098636, U.S. Pat. No. 6,118,218, U.S. Pat. No. 6,103,068, U.S. Pat. No. 6,096,156, U.S. Pat. No. 5,501,880, U.S. Pat. No. 5,376,413, U.S. Pat. No. 5,328,576, U.S. Pat. No. 5,053,246, U.S. Pat. No. 4,479,369, JP 11256476, JP 10325078, JP 09330672, JP 06310117, JP 05287676 is that the low-temperature electrical plasmas are generated at low gas pressures thereby making the plasma equipment expensive and continuous operation difficult. Moreover, to generate a low-pressure plasma inside of a textile to treat the inner textile surfaces, an average fabric pore size must be larger than is the distance over which a charge imbalance (Debye length) can exist. This, however, is for the pore size on the order of 10 μm.-100 μm. fulfilled only at near-atmospheric pressures.

[0007] For almost two decades, examples of atmospheric pressure non-equilibrium plasmas have been entering the literature, including the examples where atmospheric pressure plasmas are used to treat textile materials. The atmospheric pressure level operation is employed for high throughput and reduced capital cost since batch processing of textiles and vacuum pumping equipment are not necessary. Such atmospheric-pressure plasmachemical methods and corresponding apparatus, where the low-temperature plasmas are generated in so-called volume barrier electrical discharges, are disclosed in patents JP 11329669, JP 11253484, JP 11217766, JP 10273874, JP 08337675, JP 07119021, JP 06119994, U.S. Pat. No. 5,830,810, U.S. Pat. No. 5,766,425, U.S. Pat. No. 5,688,465 and U.S. patent application 20010008733. The volume barrier discharge was generated by applying a high frequency, high voltage signal to an electrode separated from an earthen plane or cylinder by a discharge gap and a dielectric barrier. The fabric treated is localized on the dielectric barrier surface between both electrodes. The main drawback of such volume barrier discharge devices used for textile treatment is that the useful plasma conditions are achieved only in small volume plasma channels termed "streamers" developing perpendicularly to the textile fibers. As a consequence, the plasma is in a very limited contact with the textile fiber surfaces, which results in non-uniform treatment and long treatment times.

[0008] The technological developments have now made it possible to construct atmospheric-pressure plasma apparatus operating in a glow discharge mode, i.e., with a homogenous volumetric plasma structure without the streamers, which are similar to that of low pressure plasmas. Applications of such plasma apparatus for textile treatment, where the treated textile is localized between the discharge electrodes, are disclosed in patents JP 08311765, U.S. Pat. No. 5,118,218, U.S. Pat. No. 6,106,659, U.S. Pat. No. 5,895,558, U.S. Pat. No. 5,585,147, U.S. Pat. No. 5,529,631, and U.S. Pat. No. 5,456,972. Nevertheless, the discharge stability, in particular in air and other reactive gases, has continued to be a vexing problem preventing such apparatus from becoming commercial successes.

[0009] JP 10241827 and JP 10139947 disclose atmospheric-pressure plasma apparatus for the treatment of textiles and fibers energized by fast-rising high-voltage pulses, where the treated material is localized between the electrodes. Besides apparent safety and electromagnetic interference problems, such energization is technically and economically problematic.

[0010] In atmospheric-pressure plasmachemical methods and apparatus for the textile treatments described in patents JP 11354093, JP 11348036, JP 11335963, JP 11333225, JP 11102685, JP 11003694, JP 09007444, JP 08124578, WO 98/52240, WO 96/15306, U.S. Pat. No. 5,834,384, U.S. Pat.

No. 5,821,178, U.S. Pat. No. 4,466,258, EP 903794, EP 0483859, and EP 0730057 the low-temperature plasma is generated in corona discharges without a dielectric barrier between the discharge electrodes. The treated textile materials are situated between the electrodes. The use of such corona discharges for the textile treatment is, however, unsatisfactory because of their low power density and resulting long treatment times.

[0011] An atmospheric-pressure plasmachemical method for the treatment of skin surface of textile materials is disclosed in patent JP 100087857. The device described there differs from the volume barrier discharge devices chiefly in that the streamers are parallel with the fabric surface, and the discharge electrodes are situated on the same side of the treated textile material. In this way, using a surface barrier discharge, the plasma is in a better contact with the surface, which reduces the treatment time significantly. The patent discloses the treatment of a thin skin layer of the textile only, and the described method does not effect the properties of the surfaces of the textile materials. The use of an optimized apparatus with the same electrode arrangement as in patent JP 100087857 for the textile treatment including the inner textile surface treatment is described, for example, in M. Cernak et al.: Prof. 17th Symp. On Plasma Processing, Nagasaki 2000, pp. 535-8, M. Cernak et al.: Abstracts of 7th Int. Conf. on Plasma Surface Engineering, Garmisch-Partenkirchen 2000, p. 86, and J. Rahel, M. Cernak, I. Hudec, A. Brablec, D. Trunec: "Atmospheric-pressure plasma treatment of ultra-light-molecular-weight polypropylene fabric" Czech. J. Phys. 50 (2000), Suppl. S3, 445-48. An apparent disadvantage of such surface barrier discharges for potential industrial use is the limited lifetime of their electrode system due to a direct contact of the discharge plasma with metallic electrode surfaces and resulting electrode surface erosion. The electrode lifetime can be limited also by an abrasion at the metallic electrode-textile surface.

[0012] The electrode surface erosion and abrasion is eliminated in apparatus where the coplanar surface discharge is used. The coplanar surface discharge is described, for example, in A. Sato et al.: IEEE Trans. Electron Devices 23 (1976) 328, M. Haacke and G. J. Pietch: Proc. of XII Int. Conf. on Gas Discharges and their Appl., Glasgow, Sept. 2000, p. 267, V. I. Gibalov, G. J. Pietsch: J. Phys. D: Appl. Phys. 33 (2000) 2618, and E. H. Choi at al.: Jpn. J. Appl. Phys. 38 (1999) 6073. In the coplanar surface discharge defined in these references the electrodes are situated inside of a dielectric body and, consequently, the discharge plasma is not in contact with metallic electrodes. The coplanar discharges are widely used in AC plasma displays as described, for example, in U.S. Pat. No. 4,039,881 and U.S. 3,964,050. Patents JP 5810559 and U.S. Pat. No. 4,783,716 describe the coplanar surface discharges used as a source of ions for charging and discharging of dielectric surfaces. Patent JP 1246104 describes the coplanar surface discharge used for ozone production. Patent JP 3190077 describes the apparatus for ozone production where besides the main electrodes embedded in the dielectric body an auxiliary electrode situated on the dielectric body surface is used to generate a coplanar surface discharge. Such a surface auxiliary electrode has the disadvantage of its limited lifetime due to an interaction with the discharge plasma. U.S. Pat. No. 5,407,639 describes the auxiliary electrode of a coplanar surface discharge electrode system, which is embedded in the dielectric body. The aim of such a electrode is to initiate the discharge at reduced voltage values and increase its power for ozone production.

[0013] The present invention relates to the use of the known coplanar surface discharge for treatment of inner and outer surfaces of woven and non-woven textiles and cords from organic and inorganic fibers.

BRIEF SUMMARY OF THE INVENTION

[0014] It is the primary object of the present invention to provide a method and apparatus for treatment of internal and outer surfaces of woven and non-woven textiles and cords from organic and inorganic fibers with the aim to change surface properties of the fibers by the action of electrical plasma. The electrical plasma is produced by electrical discharges generated using a discharge electrode system that comprises at least two electrically conductive electrodes situated on the same side of the treated textile material inside of a dielectric body. The electrodes are energized by electrical voltage at a frequency from 50 Hz to 1 MHz and magnitude from 100 V to 100 kV, and the electrical discharges take place in a working gas at a pressure ranging from 1 kPa to 1,000 kPa above a part of the dielectric body surface, wherein the plasma is generated without a contact with the conductive electrodes.

[0015] According to the preferred embodiment of the invention, the conductive electrodes are situated in parallel with the part of the dielectric body surface above which the plasma is generated.

[0016] According to another preferred embodiment of the invention, the part of the dielectric body surface above which the plasma is generated has the shape of a given pattern.

[0017] According to another preferred embodiment of the invention, the apparatus comprises the electrode system consisting of at least two electrically conductive electrodes, which are situated inside of a dielectric body, and an auxiliary system of electrodes also situated inside of the dielectric body.

[0018] In a preferred embodiment of the invention the electrode systems are situated on both sides of the treated textile material.

[0019] According to another embodiment of the invention, the part of the dielectric body surface above which the plasma is generated has the shape of a plane surface, curved surface, or cylindrical surface.

[0020] According to another embodiment of the invention, a part of the dielectric body inside of which the electrodes are situated is made from a ferroelectric or liquid dielectric material.

[0021] According to a preferred embodiment of the invention the electrode edges are curved.

[0022] According to another embodiment of the invention a part of the dielectric body inside of which the electrodes are situated contains MgO.

[0023] According to the present invention, the electrical plasma is generated by electrical discharges in the vicinity of the dielectric body surface, wherein a part of the dielectric body insulating the electrodes from each other as well as from the electrical plasma is made preferably from a ferroelectric material. The treated textile material is situated on the part of the dielectric body surface above which the plasma is generated, or is in motion along the part of the dielectric body surface above which the plasma is generated, in a direct contact with this surface, or in close vicinity of this surface, in such a way that the discharge electrodes of the electrode system are embedded inside the dielectric body on the same side of the treated textile material. Such an electrode arrangement is characterized by the fact that all or the majority of electrical field lines enter and go out from the treated textile on the same side of the treated textile and by the fact that the discharge electrodes are not in a contact with the electrical plasma. As a consequence, the electric field lines and the electrical discharge channels have the direction mostly parallel with the textile fiber surfaces and the electrode lifetime is not reduced by oxidation or erosion due to a contact with the plasma, and due to the abrasion by the treated textile. An alternating or pulsed electrical voltage of a magnitude ranging from 100 V to 100 kV and a frequency ranging from 50 Hz to 1 MHz is applied between the discharge electrodes serving to generate the discharge. The apparatus can operate over a wide pressure range from on the order of 1 kPa to the order of 1,000 kPa, preferably at atmospheric gas pressure.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0024] **FIG. 1** is a schematic cross-sectional view illustrating a part of the planar electrode system for the surface discharge generation that can be an essential part of the apparatus schematically illustrated by **FIG. 3** and **FIG. 4**.

[0025] **FIG. 2** is a schematic cross-sectional view illustrating a part of the electrode system with a cylindrical surface shape, which is equipped with an auxiliary electrode structure and can be a substantial part of the apparatus illustrated in **FIG. 5**.

[0026] **FIG. 3** is a side sectional view schematically illustrating the apparatus aimed to treat textile materials from one side, where the treated textile material is moved along the planar electrode system shown schematically in **FIG. 1**.

[0027] **FIG. 4** is a side sectional view of the apparatus aimed to treat textile materials from both sides, where the treated textile material is moved between two electrode systems as that one illustrated schematically in **FIG. 1**.

[0028] **FIG. 5** is a side sectional view of the device, where the treated textile material is brought into close contact with the cylindrical surface of the electrode system that is illustrated schematically in **FIG. 2**.

DETAILED DESCRIPTION OF THE INVENTION

EXAMPLE 1

[0029] In the device used for the surface treatment of textile materials from one side, which is illustrated by **FIG. 1**, the treated textile material **4** was moved continuously on the surface of the electrode system **1**. The electrode system **1** is in detail illustrated in **FIG. 1**. The textile material **4** was moved by means of two pairs of rolls **7** and **8**. The space between both pairs of rollers was sealed by an upper wall **9**, bottom wall **10**, and by side walls that are not shown. A working gas with a pressure a little above the atmospheric pressure was fed into the sealed space. An electrical plasma was generated in the working gas on the surface of the electrode system **1**. The electrode system **1** was situated on the surface of a cooler **11**.

[0030] The planar electrode system **1** illustrated by **FIG. 3** and shown in detail in **FIG. 1**, which was used to generate surface electrical discharges, comprised two coplanar electrodes **2** and **3** having the shape of a system of 2-mm-wide parallel strips. The distance between the strips of both electrodes **2** and **3** was 0.5 mm. The dielectric body **5** shown in **FIG. 1** comprised a 0.5-mm-thick Al_2O_3 layer with the coplanar metallic electrodes **2** and **3** deposited by vacuum sputtering and subsequent electroplating on its bottom surface and of a solid dielectric layer coating the Al_2O_3 layer and electrodes **2** and **3** from their bottom side. An alternating electrical voltage was applied between the electrodes **2** and **3**. The frequency of the voltage was 25 kHz and the voltage was 10 kV peak-to-peak.

EXAMPLE 2

[0031] A non-woven polypropylene textile (spunbond, 15 g/m^2, 2.8-3.2 dtex) was treated according to the invention. The aim was to impart hydrophilicity to fiber surfaces in the whole volume of the textile and, consequently, to improve perviousness of the textile for water, urine, and other liquids. The non-woven fabric was treated by the plasma generated in nitrogen using the device described in Example 1. The strike-through time of test liquid through the textile was measured using a standard ETR 150.3-96 method. The exposure time of 0.8 s resulted in a 30-fold reduction in the strike-through time.

EXAMPLE 3

[0032] The method according to the present invention was used for a hydrophilic treatment of biodegradable PLA textile of square weight of 15 g/m^2. The aim of the treatment was to impart hydrophilicity to fiber surfaces in the whole volume of the textile and, consequently, to improve perviousness of the textile for water, urine, and other liquids. The textile was treated using the apparatus described in Example 1 in a CO_2 plasma. The exposure time of 1.2 s resulted in the permanent strike-through time value of 3 s.

EXAMPLE 4

[0033] The method according to the present invention was used for hydrophilic treatment of a non-woven polypropylene textile (spunbond, 18 g/m^2, 2.8-3.2 dtex). The aim was to impart the hydrophilicity to a portion of the textile in the shape of a given pattern for the application in baby diapers manufacturing. Using the apparatus described in Example 1, the portion of the surface of the dielectric body **5** under which the electrodes **2** and **3** were situated had the shape of a given pattern, and the textile movement was interrupted for a treatment time of two seconds. The 2 s treatment resulted in a 30-fold reduction in the strike-through time on the treated textile portion, whereas the rest of the textile remained hydrophobic.

EXAMPLE 5

[0034] The method according to the present invention was used for surface activation of a woven textile material made from E-glass (210 g/m^2, 0.18 mm. thick) for the use as a reinforcement in composite materials. The textile was treated in a mixture of nitrogen and water vapor at 80° C. When compared with a conventional thermal activation method, a treatment time of five seconds resulted in a fivefold higher density of surface OH groups measured by the ESCA method.

EXAMPLE 6

[**0035**] The method according to the present invention was used for surface activation of a thin skin layer of a thick (200 g/m^2) PP meltblown non-woven textile with the aim to increase textile surface energy and its adhesive properties for the following lamination. A 2 s exposition of the textile to the plasma generated in nitrogen with 3%-admixture of hydrogen resulted in an increase of the surface energy from 30 N/m for the untreated textile to 72 N/m for the plasma-treated textile, and the adhesive properties were improved significantly.

EXAMPLE 7

[**0036**] In the apparatus illustrated in **FIG. 3**, which was used for a treatment of the textile in the shape of given surface pattern, the treated textile **4** was moved intermittently on the surface of the planar electrode system **1**. The textile was moved intermittently for the length of the electrode system **1** in a one movement cycle using two pairs of guide rolls **7** and **8**. The space between both pairs of rollers was sealed by an upper wall **9**, bottom wall **10**, and by side walls that are not shown. A working gas with a pressure a little above the atmospheric pressure was fed into the sealed space. An electrical plasma was generated in the working gas on the surface of the electrode system **1**. The planar electrode system **1** illustrated by **FIG. 3** and shown in detail in **FIG. 1**, which was used to generate surface electrical discharges, comprised two coplanar electrodes **2** and **3** having the shape of a system of 1-mm-wide parallel strips. The distance between the strips of both electrodes **2** and **3** was 0.5 mm. The dielectric body **5** shown in **FIG. 1** comprised a 0.25-mm-thick Al_2O_3 layer with the coplanar metallic electrodes **2** and **3** deposited by vacuum sputtering and subsequent electroplating on its bottom surface and a solid dielectric layer coating the Al_2O_3 layer and electrodes **2** and **3** from their bottom side. The electrode system **1** was situated on the surface of a cooler **11**. An alternating electrical voltage was applied between the electrodes **2** and **3**. The frequency of the voltage was 5 kHz and the voltage was 5 kV peak-to-peak. From a plan view in the direction perpendicular to the electrode system **1** surface, the electrodes **2** and **3** covered the electrode system surface portion corresponding to the shape of a given pattern, where a thin plasma layer was generated in the shape of the given pattern.

EXAMPLE 8

[**0037**] The device illustrated in **FIG. 7** was used for the textile treatment by plasma from both sides of the treated textile. The treated textile **4** was moved between two planar electrode systems **1**. The electrode system **1** is in detail illustrated by **FIG. 1**. The electrode systems **1** used were identical with the electrode system **1** described in Example 1. The treated textile **4** was moved by means of two pairs of rolls **7** and **8**. The space between both pairs of rollers was sealed by an upper wall **9**, bottom wall **10**, and by side walls that are not shown. A working gas with a pressure a little above the atmospheric pressure was fed into the sealed space. An electrical plasma was generated in the working gas on the surface of the electrode system **1**.

EXAMPLE 9

[**0038**] In the apparatus according to the present invention, which is illustrated in **FIG. 5**, the electrode system **1** has the shape of a cylinder envelope. The treaded textile **4** was fed into and out of the apparatus by means of two pairs of rolls **7** and **8**. Inside of the device, the treated textile **4** was brought on the surface of the electrode system **1** by means of a pair of internal guide rolls **12**. The space between the pairs of rolls **7** and **8** was sealed by an upper wall **9**, bottom wall **10**, and by side walls that are not shown. A working gas with a pressure a little above the atmospheric pressure was fed into the sealed space. An electrical plasma was generated in the working gas on the surface of the electrode system **1**.

[**0039**] The outer part of electrode system **1** having the shape of a cylinder envelope, which is shown in detail in **FIG. 2**, was made from a 1-mm-thick glaze layer. The glaze layer was deposited on the surface of a cooled ceramic cylinder and coplanar metallic electrodes **2** and **3**, having the shape of a system of 1-mm-wide parallel strips with the distance between the strips of 0.5 mm, were embedded in it. The auxiliary electrode structure **11** was situated symmetrically between the electrodes **2** and **3** in such a way that the distance between the auxiliary electrode structure **11** surface and the surface of the electrode system **1** was 0.25 mm. The auxiliary electrode structure **11** was made from 0.5-mm-diam. metallic wires. The cylinder with the electrode system **1** on its surface rotated and carried the treated textile **4** on its surface. The frequency of the voltage applied between the electrodes **2** and **3** was 5 kHz and the voltage was 12 kV peak-to-peak.

[**0040**] List of the Reference Symbols Used:

[**0041**] **1** electrode system

[**0042**] **2** first electrically conductive electrodes

[**0043**] **3** second electrically conductive electrodes

[**0044**] **4** treated textile material

[**0045**] **5** dielectric body

[**0046**] **6** auxiliary electrode structure

[**0047**] **7** pair of guide rolls

[**0048**] **8** pair of guide rolls

[**0049**] **9** upper wall

[**0050**] **10** bottom wall

[**0051**] **11** cooler

[**0052**] **12** pair of internal guide rolls

1-19. (canceled).

20. A method for treating textile materials for surface treatment of fibers of woven and non-woven textile materials that are situated inside of the textile materials or on the surface of the textile materials, comprising the step of:

affecting the textile materials with electrical plasma generated by electrical discharges initiated using an electrode system having at least two electrically conductive electrodes situated inside of a dielectric body on the same side of the textile material treated, wherein the step of affecting includes the steps of:

applying a voltage of a frequency from 50 Hz to 1 MHz and magnitude from 100 V to 100 kV between the electrodes of the electrode system; and

situating the electrode system in a gas at a pressure from 1 kPa to 1,000 kPa, wherein the electrical plasma is generated on a portion of the dielectric body surface without a contact with the electrically conductive electrodes.

21. The method of claim 20, wherein the treated material is in contact with the surface of the dielectric body in which the electrodes are situated.

22. The method of claim 20, wherein the electrical discharge initiation and the plasma generation is facilitated by an addition auxiliary electrode structure that is a part of the electrode system and is situated inside the dielectric body.

23. The method of claim 20, wherein the electric voltage applied to the auxiliary electrode structure is different from the voltage applied to the other electrically conductive electrodes of the electrode system.

24. The method of claim 22, wherein the textile material is treated in the shape of a given planar pattern in contact with the plasma generated on the dielectric body surface under which the electrodes are situated and that has the shape of the given pattern.

25. The method of claim 20, wherein the treated textile material is moved along the dielectric body in which the electrodes are situated.

26. The method of claim 21, wherein the treated textile material is moved along the dielectric body in which the electrodes are situated.

27. The method of claim 20, wherein the treated textile material is moved between two electrode systems.

28. The method of claim 20, wherein the treated textile material is guided by the electrode system surface having the shape of a cylindrical surface.

29. An apparatus for treating textile materials comprising:

electrically conductive electrodes (**2**) and (**3**) that are situated inside of the dielectric body and are situated on the same side of the textile material (**4**) affected by the plasma.

30. The apparatus of claim 29, wherein the electrically conductive electrodes (**2**) and (**3**) are parallel with the portion of the surface of the dielectric body (**5**) on which the electrical plasma is generated.

31. The apparatus of claim 29, wherein the portion of the dielectric body (**5**) surface under which the electrodes (**2**) and (**3**) are situated has the shape of a given pattern.

32. The apparatus of claim 29 wherein the apparatus contains the electrode system (**1**) having:

at least two electrically conductive electrodes (**2**) and (**3**), which are situated inside of the dielectric body (**5**); and

an auxiliary electrode structure (**6**) that also is situated inside the dielectric body (**5**).

33. The apparatus of claim 29, further comprising:

electrode systems (**1**) situated on both sides of the textile material (**4**) affected by the plasma.

34. The apparatus of claim 33, wherein a portion of the electrode system (**1**) has the shape of a plane surface, curved surface, or cylindrical surface.

35. The apparatus of claim 29, wherein a part of the dielectric body (**5**) is made from a ferroelectric material.

36. The apparatus of claim 29, wherein a part of the dielectric body (**5**) is made from a liquid dielectric material.

37. The apparatus of claim 29, wherein edges of electrically conductive electrodes (**2**) and (**3**) are curved.

38. The apparatus of claim 29, wherein a part of the dielectric body contains MgO.

39. The apparatus of claim 29, wherein edges of electrodes of the auxiliary electrode structure (**6**) are curved.

* * * * *