Patent claims - AMENDED UNDER ART 19 PCT (CLEAN COPY)

1. A device for strengthening the surface of a workpiece (10) by introducing compressive stress, **wherein**

the device comprises a polymer strip (32) which is provided with a metal foil (71) on the surface of the side diverted from the surface of the workpiece (10) in which foil bridges (34) are formed to form projectiles (100),

and it further comprises two electrodes (33) and (66) adhering to the metal foil (71) located on the polymer strip (32), where the bridges (34) are formed between the contact surface areas (27) of the metal foil (71),

wherein the electrodes (33) and (66), between which a plasma is formed, are mounted in a support body (41), via which they are connected by means of flat conductors (44) and (46) to a switch (84) for switching large currents and voltages with a high voltage source (83),

wherein the polymer strip (32) provided with the metal foil (71) tightly adheres to the support body (41) with the electrodes (33) and (66), and the electrodes (33) and (66) protrude above the upper surface of the support body (41) to provide electrical contact with the contact surface areas (27) of the metal foil (71),

characterized in that for guiding and accelerating the projectiles (100), it further contains a nozzle (31) provided with a sharp edge (93) located on the lower side of its inlet opening, where the nozzle (31) opening is orientated towards the surface of the workpiece (10) being strengthened.

2. The device of claim 1, wherein the nozzle (31) and/or the support body (41) have the shape of a circular disc.

3. The device of any one of claims 1 to 2, wherein the metal foil (71) has the shape of a flat strip and contains a local narrowing between the two electrodes (33) and (66).

4. The device of any one of claims 1 to 3, **wherein** the foil (71) is locally narrowed to form the bridges (34) at periodically recurring longitudinal distances.

5. The device of any one of claims 1 to 4, **wherein** the polymer strip (32) passes through a displacement mechanism (35) shifting the strip (32) between the electrodes (33) and (66).

6. The device of any one of claims 1 to 5, **wherein** the polymer strip (32) is made of an electrically non-conductive material such as bi-axially oriented polyethylene terephthalate or polyimide Kapton.

7. The device of any one of claims 1 to 6, wherein, for the accumulation of energy necessary for the generation of plasma, it comprises a capacitor (50) to be charged from a high voltage source (83), where the capacitor (50) on its external surface comprises plates (53) surrounding a dielectric (52) with constant thickness, where the plates (53) are connected to conductors (44) and (46).

8. The device of any one of claims 1 to 7, wherein the conductors (44) and (46) are provided with electric insulation (85) with dielectric strength resistant to high voltage of at least 2 to 5 KV.

9. The device of any one of claims 1 to 8, wherein a switch (84) has the form of a spark gap, where the spark gap input (80) and the spark gap output (81) are separated from each other by air or other suitable dielectric gas, and it preferably comprises an auxiliary electrode for switching by a high voltage pulse to control the switch (84), or the switch (84) is in the form of a cascade of IGBT transistors.

10. The device of claim 9, wherein the spark gap input (80) and the spark gap output (81) are created on the conductor (46).

11. The device of any one of claims 1 to 10, **wherein** the bridge (34) is made of copper, aluminium, or gold.

12. The device of any one of claims 1 to 11, **wherein** the foil bridge (34) has a thickness of units to tens of micrometres.

13. The device of any one of claims 1 to 12, **wherein** the value of surface density of the bridge (34) corresponds to the value of surface density of the polymer strip (32).

14. The device of any one of claims 1 to 13, **wherein** the nozzle (31) is made of material based on zirconium dioxide.

15. The device of any one of claims 1 to 14, **wherein** it comprises a traverser (61) to displace the workpiece (10) between individual cycles of the treatment of its surface.

16. The device of any one of claims 1 to 15, **wherein** it comprises the cooling means for cooling of the nozzle (31) and/or of the support body (41) and/or the switch (84).

17. The device of any one of claims 1 to 16, **wherein** the capacitor (50) is made as a part of the generator of the projectiles (100) so that it is at least partially positioned between the support body (41) and the polymer strip (32) provided with the metal foil (71),

wherein at the location of the electrodes (33) and (66), the polymer strip (32) is mounted perpendicularly to the axis connecting the electrodes (33) and (66) and the polymer strip (32) extends above the dielectric (52) on both sides above the two electrodes (33, 66),

wherein the conductor (44) passing under the dielectric plate (52) is connected to the electrode (33) located above the dielectric plate (52).

18. The device of claim 17, **wherein** the polymer strip (32) has bridges (34) formed by a narrowing of the metal foil (71) that are perpendicular to the longitudinal axis of the strip (32), so that each bridge (34) conductively connects exactly one pair of contact surface areas (27) oriented transversely to the longitudinal axis of the strip (32).

19. The device of claim 17, **wherein** the electrodes (33) and (66) are positioned in a mutual configuration corresponding to the seating of the contact surface areas (27) interconnected by the bridge (34).

20. The device of claim 19, **wherein** the polymer strip (32) has bridges (34) formed by a narrowing of the metal foil (71) that are diagonal to the longitudinal axis of the strip (32), so that each bridge (34) conductively connects exactly one pair of contact surface areas (27) oriented diagonally to the longitudinal axis of the strip (32).

21. A device for strengthening the surface of the workpiece (10) by introducing a compressive stress, where the device comprises the polymer strip (32) which is provided with the metal foil (71) on the surface of the side diverted from the surface of the workpiece (10) in which foil bridges (34) are formed to create a plasma,

and it further comprises two electrodes (33) and (66) adhering to the metal foil (71) located on the polymer strip (32), where the bridges (34) from which the plasma is created are formed between the contact areas (27) of the metal foil (71),

where the electrodes (33) and (66), are mounted in a support body (41), via which they are connected by means of the flat conductors (44) and (46) to the switch (84) for switching large currents and voltages with the high voltage source (83),

where, for the accumulation of the energy necessary for the generation of plasma, it comprises the capacitor (50) to be charged from the high voltage source (83),

where the capacitor (50) on its external surface comprises plates (53) surrounding the dielectric (52) with constant thickness, where the plates (52) are connected to the conductors (44) and (46),

where the switch (84) has the form of a spark gap, where the spark gap inlet (80) and the spark gap outlet (81) are separated from each other by air or other suitable dielectric gas,

where both the spark gap input (80) and the spark gap output (81) are formed on the conductor (46), and the capacitor (50) is at least partially interposed between the support body (41) and the polymer strip (32) provided with the metal foil (71),

wherein the polymer strip (32) electrically insulating the workpiece (10) from the high-voltage circuit is placed in tight contact with the workpiece (10),

characterized in that the device comprises a second insulation layer (37) isolating the exploding bridge from the support plate (41) and protecting it from plasma ablation, where the electrodes (33) and (66) pass through holes in the second insulation layer (37).

22. The device of claim 21, **wherein the** polymer strip (32) is made of polyimide.

23. The device of claim 21 or 22, **wherein** the thickness of the polymer strip (32) does not exceed 25 micrometres.

24. The device of any one of claims 21 to 23, **wherein** the second insulation layer (37) is made of polyimide and / or Bi-PET.

25. The device of any one of claims 21 to 24, **wherein** the second insulation layer (37) is glued to the polymer strip (32) and the metal foil (71).

26. The device of any one of claims 21 to 25, **wherein** the support body and / or the electrodes (33) and (66) are made of molybdenum.

27. The device of any one of claims 21 to 26, **wherein** the spark gap formed by the leads (80) and (81) comprises a trigger electrode (86) for controlling the switching by the high-voltage pulse.

28. The device of any one of claims 21 to 27, **wherein** the electric conductors (44) and (46) leading from the capacitor (50) to the electrodes (33) and (66) are flat in shape, with a width greater than the thickness, one of these electrical conductors being in its part at the same time the capacitor plate (53) and the other conductor being interrupted by the switch (84).

29. The device of any one of claims 21 to 28, wherein the spark gap input (80) is connected to the support plate (41) and the electrode (66) thus forming one unit.

30. The device of any one of claims 21 to 29, wherein to protect the dielectric (52) at the location of the spark gap input (80) and output (81), the dielectric (52) is provided with a protective foil (54).

31. The device of claim 29, wherein the protective foil (54) is made of polyimide and/or polytetrafluoroethylene and/or a plate of mica.

32. The device of any one of claims 21 to 31, wherein the space between the input (80) and the output (81) of the spark gap is filled with nitrogen.

33. A method for strengthening the surface of workpieces (10) by means of the device of any one of claims 1 to 21, **wherein** one cycle of strengthening the surface of the workpieces (10) involves the action of an electric current pulse supplied from the high voltage source (83) after closing the switch (84) via the conductors (44, 46) to the electrodes (33, 66), between which a high voltage is introduced, thereby short-circuiting the circuit on the metal foil (71) at the location of the bridges (34) to form a plasma expanding and applying a compressive force to the polymer strip (32), part of which hits as the projectile (100) the surface of the workpiece (10), wherein the plasma generated by the electric current pulse, in addition to the expansion pressure, is also accelerated by the electromagnetic Lorentz force (20) caused by the passage of an electric current through this plasma in the generated magnetic field.

34. The method of claim 33, **wherein** after the expansion of the plasma, a part of the polymer strip is cut by the sharp edge (93) of the nozzle (31) and subsequently accelerated by a compressive force through the through hole of the nozzle (31) as the projectile (100) onto the workpiece surface (10).

35. The method of claim 33 or 34, wherein the surface of the workpiece (10) is treated in periodically repeating cycles, wherein at the beginning of each cycle the polymer strip is moved by means of the displacement mechanism (35) to a position in which the bridge (34) is located between the first electrode (33) and the second electrode (66),

both of them in electrically conductive contact with the metal foil (71) at opposite ends of the bridge (34).

36. The method of claim 34, wherein at the beginning of the cycle, the workpiece (10) is moved by the traverser (61).

37. The method of claim 33, wherein the switch (84) is closed by the voltage difference at the spark gap between the spark gap input (80) and the spark gap output (81) exceeding the value of the electrical strength of the air.

38. A method for strengthening the surface of workpieces (10) by means of the device of any one of claims 21 to 32 to produce an expanding plasma and a compressive force exerted by the polymer strip (32) on the workpiece surface (10), in which it induces a shock wave and subsequent plastic deformation in the surface layer,

characterized in that one cycle of strengthening the surface of the workpieces (10) involves the action of an electric current pulse supplied from the high voltage source to the capacitor after closing the switch (84) via the conductors (44, 46) to the electrodes (33, 66), between which a high voltage is applied, causing a current pulse to pass through the metal foil (71) and at the bridge (34) and making the bridge (34) to explode.

39. The method of claim 38, **wherein** the surface of the workpiece (10) is electrically insulated and protected by the polymer strip (32) from the products of ablation of the bridge (34), and the support body (41) is protected and insulated by the insulation layer (37).

40. The method of claim 38 or 39, **wherein** the surface of the workpiece (10) is treated in periodically repeating cycles, wherein at the beginning of each cycle the polymer strip is moved by means of the displacement mechanism (35) to a position in which the bridge (34) is located between the first electrode (33) and the second electrode (66), both of them in electrically conductive contact with the metal foil (71) at opposite ends of the bridge (34).

41. The method of claim 38 or 39, **wherein** the surface of the workpiece (10) is treated in periodically repeating cycles, wherein at the beginning of each cycle the assembly of elements comprising the polymer strip (32), bridges (34) formed in the metal foil (71) and the insulation layer (37) is displaced in the direction of its length by one spacing distance between the bridges (34), which were previously formed in the metal foil (71) on the polymer strip (32) formed by local narrowing of the metal foil, and then the movement of this assembly, i.e. the strip (32), the metal foil (71) with bridges (34) and the insulation layer (37) stops for the rest of the cycle, to effect the formation of a plasma by electric discharge by applying a charge from the capacitor via the electrodes (33) and (66) to the contact surface areas (27) of the metal foil (71).

42. The method of claim 40 or 41, wherein at the beginning of the cycle, the workpiece (10) is displaced by the traverser (61).

43. The use of the device of any one of claims 1 to 32 to strengthen the surface of workpieces, especially metal workpieces.

Patent claims

1. A device for strengthening the surface of a workpiece (10) by introducing compressive stress, wherein

the device comprises a polymer strip (32) which is provided with a metal foil (71) on the surface of the side diverted from the surface of the workpiece (10) in which foil bridges (34) are formed to form projectiles (100),

and it further comprises two electrodes (33) and (66) adhering to the metal foil (71) located on the polymer strip (32), where the bridges (34) are formed between the contact surface areas (27) of the metal foil (71),

wherein the electrodes (33) and (66), between which a plasma is formed, are mounted in a support body (41), via which they are connected by means of flat conductors (44) and (46) to a switch (84) for switching large currents and voltages with a high voltage source (83),

wherein the polymer strip (32) provided with the metal foil (71) tightly adheres to the support body (41) with the electrodes (33) and (66), and the electrodes (33) and (66) protrude above the upper surface of the support body (41) to provide electrical contact with the contact surface areas (27) of the metal foil (71),

characterized in that for guiding and accelerating the projectiles (100), it further contains a nozzle (31) provided with a sharp edge (93) located on the lower side of its inlet opening, where the nozzle (31) opening is orientated towards the surface of the workpiece (10) being strengthened.

2. The device of claim 1, **wherein** the foil (71) is locally narrowed to form the bridges (34) at periodically recurring longitudinal distances between contact surface areas (27).

3. The device of claim 1 or 2, **wherein** the polymer strip (32) passes through a displacement mechanism (35) shifting the polymer strip (32) between the electrodes (33) and (66).

4. The device of any one of claims 1 to 3, **wherein** the polymer strip (32) is made of an electrically non-conductive material such as bi- axially oriented polyethylene terephthalate or polyimide.

5. The device of any one of claims 1 to 4, **wherein** for the accumulation of energy necessary for the generation of plasma, it comprises a capacitor (50) to be charged from a high voltage source (83), where the capacitor (50) on its external surface comprises plates (53) surrounding a dielectric (52) with constant thickness, where the plates (53) are connected to conductors (44) and (46).

6. The device of any one of claims 1 to 5, **wherein** the conductors (44) and (46) are provided with electric insulation (85) with dielectric strength resistant to high voltage of at least 2 to 5 KV.

7. The device of any one of claims 1 to 6, **wherein** a switch (84) has the form of a spark gap, where the spark gap input (80) and the spark gap output (81) are separated from each other by air or other suitable dielectric gas, and it preferably comprises an auxiliary electrode for switching by a high voltage pulse to control the switch (84), or the switch (84) is in the form of a cascade of IGBT transistors.

8. The device of any one of claims 1 to 7, **wherein** the foil bridge (34) has a thickness of units to tens of micrometres.

9. The device of any one of claims 1 to 8, **wherein** the value of surface density of the bridge (34) corresponds to the value of surface density of the polymer strip (32).

10. The device of any one of claims 1 to 9, **wherein** it comprises the cooling means for cooling of the nozzle (31) and/or of the support body (41) and/or the switch (84).

11. The device of any one of claims 1 to 10, **wherein** the capacitor (50) is made as a part of the generator of the projectiles (100) so that it is at least partially positioned between the support body (41) and the polymer strip (32) provided with the metal foil (71),

wherein at the location of the electrodes (33) and (66), the polymer strip (32) is mounted perpendicularly to the axis connecting the electrodes (33) and (66) and the polymer strip (32) extends above the dielectric (52) on both sides above the two electrodes (33, 66),

wherein the conductor (44) passing under the dielectric plate (52) is connected to the electrode (33) located above the dielectric plate (52).

12. The device of any one of claims 1 to 11, **wherein** the polymer strip (32) has bridges (34) formed by a narrowing of the metal foil (71) that are perpendicular or diagonal to the longitudinal axis of the polymer strip (32), so that each bridge (34) conductively connects exactly one pair of contact surface areas (27) oriented transversely or diagonally to the longitudinal axis of the strip (32).

13. A device for strengthening the surface of the workpiece (10) by introducing a compressive stress, where the device comprises the polymer strip (32) which is provided with the metal foil (71) on the surface of the side diverted from the surface of the workpiece (10) in which foil bridges (34) are formed to create a plasma,

and it further comprises two electrodes (33) and (66) adhering to the metal foil (71) located on the polymer strip (32), where the bridges (34) from which the plasma is created are formed between the contact areas (27) of the metal foil (71),

where the electrodes (33) and (66), are mounted in a support body (41), via which they are connected by means of the flat conductors (44) and (46) to the switch (84) for switching large currents and voltages with the high voltage source (83),

where, for the accumulation of the energy necessary for the generation of plasma, it comprises the capacitor (50) to be charged from the high voltage source (83),

where the capacitor (50) on its external surface comprises plates (53) surrounding the dielectric (52) with constant thickness, where the plates (52) are connected to the conductors (44) and (46),

where the switch (84) has the form of a spark gap, where the spark gap inlet (80) and the spark gap outlet (81) are separated from each other by air or other suitable dielectric gas,

where both the spark gap input (80) and the spark gap output (81) are formed on the conductor (46), and the capacitor (50) is at least partially interposed between the support body (41) and the polymer strip (32) provided with the metal foil (71),

wherein the polymer strip (32) electrically insulating the workpiece (10) from the high-voltage circuit is placed in tight contact with the workpiece (10),

characterized in that the device comprises a second insulation layer (37) isolating the exploding bridge from the support plate (41) and protecting it from plasma ablation, where the electrodes (33) and (66) pass through holes in the second insulation layer (37).

14. The device of claim 13, **wherein** the polymer strip (32) is made of polyimide.

15. The device of claim 13 or 14, **wherein** the second insulation layer (37) is glued to the polymer strip (32) and the metal foil (71).

16. The device of any one of claims 13 to 15, **wherein** the spark gap formed by the leads (80) and (81) comprises a trigger electrode (86) for controlling the switching by the high-voltage pulse.

17. The device of any one of claims 13 to 16, **wherein** the electric conductors (44) and (46) leading from the capacitor (50) to the electrodes (33) and (66) are flat in shape, with a width greater than the thickness, one of these electrical conductors being in its part at the same time the capacitor plate (53) and the other conductor being interrupted by the switch (84).

18. The device of any one of claims 13 to 17, **wherein** to protect the dielectric (52) at the location of the spark gap input (80) and output (81), the dielectric (52) is provided with a protective foil (54).

19. The device of any one of claims 13 to 18, **wherein** the space between the input (80) and the output (81) of the spark gap is filled with nitrogen.

20. A method for strengthening the surface of workpieces (10) by means of the device of any one of claims 1 to 19, **wherein** one cycle of strengthening the surface of the workpieces (10) involves the action of an electric current pulse supplied from the high voltage source (83) after closing the switch (84) via the conductors (44, 46) to the electrodes (33, 66), between which a high voltage is introduced, thereby short-circuiting the circuit on the metal foil (71) at the location of the bridges (34) to form a plasma expanding and applying a compressive force to the polymer strip (32), part of which hits as the projectile (100) the surface of the workpiece (10), wherein the plasma generated by the electric current pulse, in addition to the expansion pressure, is also accelerated by the electromagnetic Lorentz force (20) caused by the passage of an electric current through this plasma in the generated magnetic field.

21. The method of claim 20, **wherein** after the expansion of the plasma, a part of the polymer strip is cut by the sharp edge (93) of the nozzle (31) and subsequently accelerated by a compressive force through the through hole of the nozzle (31) as the projectile (100) onto the workpiece surface (10).

22. The method of claim 20 or 21, **wherein** the surface of the workpiece (10) is treated in periodically repeating cycles, wherein at the beginning of each cycle the polymer strip is moved by means of the displacement mechanism (35) to a position in which the bridge (34) is located between the first electrode (33) and the second electrode (66), both of them in electrically conductive contact with the metal foil (71) at opposite ends of the bridge (34).

23. The method of any one of claims 20 to 22, **wherein** the switch (84) is closed by the voltage difference at the spark gap between the spark gap input (80) and the spark gap output (81) exceeding the value of the electrical strength of the air or other suitable dielectric gas.

24. The use of the device of any one of claims 1 to 19 to strengthen the surface of workpieces, especially metal workpieces.