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EUROPEAN PATENT APPLICATION

21 Application number: 79300429.2

51 Int. Cl.²: **C 25 D 15/00, B 24 D 3/06**

22 Date of filing: 19.03.79

30 Priority: 20.03.78 US 888081

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43 Date of publication of application: 03.10.79
Bulletin 79/20

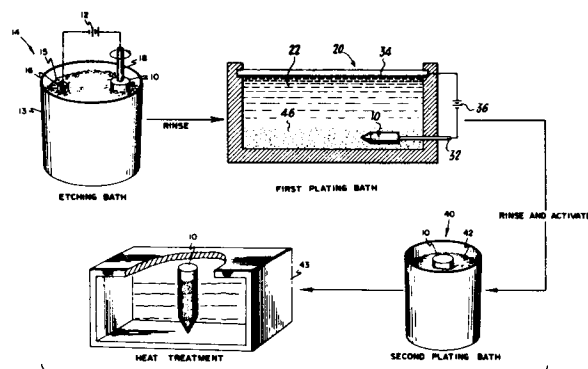
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84 Designated Contracting States: **BE CH DE FR GB IT LU NL SE**

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54 **Bonding process for grinding tools.**

57 A bonding process for grinding tools in which a metallic workpiece (10) is pre-etched (14) to form cavities in the surface of the workpiece for individually receiving abrasive particles to be bonded thereto. The etched workpiece is at least partially embedded in a layer (46) of the abrasive particles in a first plating bath (20) comprising an aqueous solution of metal ions (22) and an electromotive force is imposed across the workpiece and an anode (34) so that the abrasive particles become partially embedded in the cavities in the workpiece surface as metal is plated on to the surface and around the abrasive particles adjacent to the surface. A second plating of metal in a second plating bath (40) securely bonds the particles to the workpiece and can provide the workpiece with a predetermined hardness for a particular application. The dual bonding process can be repeated for each layer to make multi-layered tools.



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TITLE

Bonding process for grinding tools.

TECHNICAL FIELD

5 This invention relates to a process for bonding
abrasive particles to the surface of a metal workpiece.

BACKGROUND ART

10 The hardness and abrasive qualities of diamonds are
well known, particularly those of synthetically produced
virgin polycrystalline diamond particles. Virgin poly-
crystalline diamond particles are of particular interest
because of their greatly increased number of sharp points
or cutting edges and lack of fracture planes.

15 Tools such as for sharpening and grinding have been
prepared from natural and synthetic diamond particles by
bonding these particles together in the form of a sharp-
ening stone using a ceramic or polymeric matrix to bond
the diamonds into a unitary structure. However, this
20 process consumes an excessive amount of diamond particles,
and the ceramic structure is also easily susceptible to
fracture. For these reasons, such tools have increas-
ingly been prepared by bonding diamond particles to the
surface of a metal workpiece, while immersed in an

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electrolytic plating bath, by electrodeposition of a metallic bonding matrix on to the workpiece and around the diamond particles.

Although tools produced according to this latter
5 process have generally been more durable and less expensive to make than the ceramically bonded tools, they have nevertheless evidenced an inherent weakness in that the diamond particles tend to be pulled from the metal work-
10 piece by abrasive action during use of the tool. It has been found that pulling out of the diamond particles can be minimised by controlling the hardness of the metallic bonding matrix or by increasing the thickness and controlling the hardness of the metallic bonding matrix. The hardness of a metallic bonding matrix can be changed
15 by changing the type of metal used and/or by heat treatment, for various kinds of metals.

However, controlling the thickness and/or hardness of a metallic bonding matrix to prevent pulling out of the diamond particles results in other disadvantages. For example, if the metal bonding matrix is too thick and/or too hard for a given material to be cut or ground,
20 the diamond particles will wear down faster than the bonding matrix, and the diamond particles will thus become co-planar with the bonding matrix. The tool cutting edge
25 thus becomes glazed and thereafter ceases to work efficiently for purposes of grinding or cutting. When this happens, the tool must be re-dressed by abrading or otherwise treating its grinding surface. This of course results in increased cost and inconvenience to those
30 using the tool.

Typically, glazing is caused by one of two conditions. If a given material is cut or ground, minute particles (called "swarf") tend to fill in the crevices between the diamond particles. Thus, one reason the cutting edge

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may become glazed is because the swarf is not abrasive enough to erode away the bonding matrix at the same rate as the diamond particles are being worn down. The other reason the cutting edge may become glazed is because the
5 metal bonding matrix is not slick enough, and thus swarf will adhere to the bonding matrix and will fill in the crevices as described above.

It would, therefore, be an improvement in the art to provide a process whereby diamond or other abrasive
10 particles could be securely bonded to the surface of the workpiece so as to prevent pulling out of the abrasive particles, while at the same time forming a bonding matrix which would not be too hard or too thick, and which would be slick enough to minimise the adherence of swarf
15 to the matrix, thus minimising glazing of the cutting edge of the workpiece as it wears.

STATEMENT OF INVENTION AND ADVANTAGES

The present invention provides a process for bonding
20 abrasive particles to the surface of a metal workpiece by immersing the workpiece and the abrasive particles in an electrolytic plating bath comprising an aqueous solution of metal ions and electrodepositing a metallic bonding matrix on to the workpiece surface and around the
25 abrasive particles adjacent the surface, the process being characterised in that prior to such electrodeposition the surface of the workpiece is etched to form cavities therein of dimensions such that each cavity is capable of receiving a portion of one abrasive particle
30 and, subsequently to said etching step, the workpiece is at least partially embedded in a layer of the abrasive particles in the plating bath and an electromotive force is imposed across a metal anode in the plating bath and the workpiece whereby the abrasive particles become

individually partially embedded in the cavities of the etched workpiece surface as the metal is plated on to the workpiece and around the embedded particles, and in that subsequent to said electrodeposition step the workpiece
5 is at least partially immersed in a second plating bath comprising an aqueous solution of metal ions and a second coat of metal is plated around the partially embedded abrasive particles. Etching is believed to create small cavities in the workpiece surface, each cavity being
10 adapted to individually receive a portion of an abrasive particle, thereby providing for a stronger mechanical bond between the particle/metal plated surface of the workpiece by recessing at least a part of the abrasive particle below the shear plane.

15 By properly choosing the type and thickness of the second metal coating, as the abrasive particles wear, the swarf will not significantly adhere to the matrix and the swarf will evenly wear down the second coat of metal veneer, thus maintaining a cutting edge so as to prevent
20 glazing. The choice of type and thickness of the second metal coating will therefore depend on the ultimate use of the tool. Heat treatment after the second plating step can serve to control stresses in the plated surfaces and thereby provide a stronger bonded surface on the
25 workpiece to prevent pulling out of the abrasive particles.

Partial or complete embedding of the etched work-
piece in the layer of abrasive particles ensures the even distribution of the particles during plating in the first-
mentioned plating bath. Such even distribution may also
30 be enhanced by gentle rotation of the workpiece, care being taken not to dislodge particles already bonded to the workpiece.

FIGURES IN THE DRAWINGS

Two embodiments of apparatus for use in the process of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic flow diagram demonstrating a first embodiment of apparatus for carrying out the process of the present invention;

FIGURE 2 is a schematic cross-section of a workpiece that has been diamond plated by the process of the present invention, and

FIGURE 3 is a schematic cross-section of an alternative plating bath to replace the first plating bath shown in the apparatus of FIGURE 1.

DETAILED DESCRIPTION OF THE DRAWINGS

The invention is best understood by reference to the drawings wherein like parts are designated with like numerals throughout. The process of this invention is applicable to bonding any of a wide variety of abrasive particles, for example, diamond, boron nitride, silicon carbide and the like. For convenience, the process of this application will be described using diamond particles.

A workpiece that is plated with diamond particles in accordance with the present invention advantageously incorporates the durability of diamond with the versatility of a metal substrate. While natural diamond or static synthesis diamond grit can be used, synthetically produced virgin polycrystalline diamond grit or particles are particularly useful due to their increased surface irregularities as compared to natural or static synthesis diamond particles.

Plating these diamond particles on to the surface of

a metal workpiece provides a tool with an abrasive surface useful for many grinding and lapping applications, for example, those found in grinding wheels, lapping wheels, hones, tool sharpeners, etc..

5 In the foregoing applications, it is readily apparent that considerable stress is placed on each diamond particle during use of the workpiece. This stress tends to loosen and eventually break the diamond particles from the surface of the workpiece. These stresses also tend
10 to break apart and tear loose the metal with which the diamond particles have been bonded to the surface of the workpiece. It has been found that this latter problem may be alleviated to some degree by etching the work-
15 piece surface prior to plating with diamonds and metal so as to create cavities therein. The cavities form a pocket to receive a portion of a diamond particle so that part of the diamond particle is recessed out of the shear plane formed along the surface of the workpiece. The cavities also assist in forming a stronger mechanical
20 bond between the workpiece and the plated surface.

 According to the illustrated embodiment of the present invention, a layer of diamond particles is bonded to the surface of a metal workpiece through electro-
25 deposition of nickel or other suitable metal to the workpiece. Diamond particles do not, in themselves, electroplate on the metal workpiece but are entrapped by the metal as it is electroplated thereon.

 Uniform dispersion of diamond particles is assured by partially or totally embedding the workpiece in a
30 layer of the diamond particles in an electroplating bath while an electromotive force imposed upon the bath assists in attracting the diamond particles to the workpiece, thereby enhancing the predetermined population and uniform packing of diamond particles on the workpiece surface.

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In this manner, the workpiece is surrounded by diamond particles which may be uniformly plated on to the workpiece in a substantially quiescent bath.

After a predetermined layer of diamond particles
5 has been bonded to the surface of the workpiece by the plating action of the metal, the workpiece is immersed in a second plating bath. There, a second coat of only metal is deposited over the diamond/metal surface. When the
10 type and thickness of this second coating of metal is properly selected for the intended application of the workpiece, the second coating of metal has the surprising advantage of wearing down evenly as the abrasive particles wear. This helps to prevent glazing of the cutting edge due to filling of the crevices between abrasive particles.
15 Furthermore, as this second coat of metal wears, the abrasive particles will not loosen and pull out since they will remain firmly bonded to the cavities of the workpiece surface by the remainder of the second coat and by the first coat of metal.

20 The second plating step is then followed by heat treatment of the workpiece so as to harden and toughen the metal and relax any stresses that may have developed during any of the previous processing steps. Importantly, the temperature during heat treatment is held below the
25 decomposition temperature of the diamond particles to preclude thermal decomposition.

Referring to FIGURE 1, a workpiece 10 is shown in an etching bath 14 comprising a solution 15 of aqueous sulphuric acid. One suitable etching solution has a
30 60% sulphuric acid concentration. To assist in the etching of workpiece 10, an electromotive force indicated at 12 is imposed between workpiece 10 and a cathode 16 or even a metal vessel 13 containing the acid solution 15. A reverse DC current of about

four amps at five to six volts for six or seven minutes has been found adequate. To improve uniformity in the etching process, workpiece 10 may be rotated either continuously or intermittently in the bath with a rotatable shaft 18. Rotation of shaft 18 and workpiece 10 also agitates the solution and minimises undesirable concentration of electrolytic action of any one portion of the surface of the workpiece thereby assuring more uniform etching. After etching, any remaining sulphuric acid is removed by rinsing workpiece 10 with water.

For some types of workpieces, as for example those made from stainless steel or aluminium, an oxide coating may readily form on the surface of the workpiece after it is removed from the vessel 13 and rinsed. To prevent the formation of such oxide, it has been found to be desirable for some types of material to plate a very thin metal veneer coating on to the workpiece after it has been etched. This may be done by placing the workpiece 10 in a bath similar to bath 40 described below for 6 to 10 seconds. This will result in a very thin metal coating (approximately 2.5×10^{-8} m) on the workpiece surface. This metal coating is sufficient to prevent oxide formation but is still thin enough to permit portions of the abrasive particles to be partially embedded in the cavities etched into the workpiece surface, as further described below. The workpiece 10 is then placed in a first plating bath generally designated 20.

Plating bath 20 may contain any suitable metal plating solution. In the illustrated embodiment, plating bath 20 contains a nickel plating solution 22 which may be a standard aqueous solution of nickel sulphate and nickel chloride heated to about 50°C . This plating solution is well known in the art and is commonly referred to as a standard Watts bath. Conventionally, the plating

solution includes about 110 to 380 g/l nickel sulphate and about 60 to 302 g/l nickel chloride in a boric acid buffer. Diamond particles 25 (see FIGURE 2) are provided as a layer 46 in the aqueous solution 22 at the bottom of the bath 20 so as to facilitate uniform distribution of diamond particles 25 about the workpiece 10 which is embedded in the layer 46. Diamond particles 25 may be of any suitable size although the very fine particles (24 to 41 microns) are preferred for sharpening tools and the like. Grinding wheels and related tools may require particle sizes upwards of 24 mesh.

Workpiece 10 is mounted upon a shaft 32, which may be rotatable, and suspended in plating bath 20. The workpiece may, if necessary, be rotated during plating to ensure an even dispersion of the particles on the workpiece surface, but care should be taken not to dislodge particles already bonded to the surface.

A nickel anode 34 is also suspended in plating bath 20 so as to be at least partly immersed in the solution 22. An electromotive force 36 is applied between workpiece 10 and anode 34 with workpiece 10 connected so as to act as a cathode. In this manner, workpiece 10 is plated with nickel metal ions. The plating action simultaneously entraps diamond particles 25 on the surface of workpiece 10 and the plated nickel metal 23 (see FIGURE 2) serves to mechanically bond diamond particles 25 to the etched surface of workpiece 10 as the particles 25 are individually embedded in the cavities 21 of the etched surface. It has been discovered that the imposition of an electromotive force 36 appears to cause an attraction between diamond particles 25 and workpiece 10 so as to more densely pack diamond particles 25 on the surface of workpiece 10. For example, approximately six minutes has been found satisfactory to form a single layer of 24 to

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41 micron diamond.

The cavities 21 (FIGURE 2) created in workpiece 10 during the etching step greatly assist in forming a strong bond between workpiece 10 and the first diamond/nickel matrix 23. Many of the diamond particles 25 are partially recessed into the cavities 21 so as to limit their exposure to the shear plane formed along the diamond/metal surface. The diamonds 25 thus secured have surprising resistance to shear and breakage away from the workpiece 10.

It may be advantageous to gently circulate the plating solution 22 through the layer 46 of abrasive particles, and this may be done, for example, by mechanical means (not shown) such as a pump, by convection currents, or by gravity flow.

After suitably electroplating the diamond particles 25 to the surface of workpiece 10, workpiece 10 is removed from the plating bath and rinsed with water to remove any unplated residue from bath 20. While not essential, it has been found desirable to follow the rinsing step with an activation step wherein the diamond plated workpiece is treated by dipping or rinsing in a 50% hydrochloric acid solution prior to immersing the workpiece in a second plating bath 40. Surface activation is primarily used where the workpiece surface has been oxidised. If care is taken to avoid drying of the workpiece 10 during the etching and electroplating process, activation can usually be avoided. Prior to treatment in the second plating bath 40, the diamond adheres to the workpiece 10 as a soft pack.

With continued reference to FIGURE 1, the second plating bath 40 comprises an electroless plating solution 42 of metal ions. The metal used may be nickel or any other suitable metal selected in accordance with the

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hardness and thickness characteristics desired in an intended application for workpiece 10. Any suitable electroless plating solution could be used such as solutions marketed by the Allied Kelite Division of Richardson Chemical Co. (Product No. 794 A, B and HZ). The workpiece is held in this electroless plating bath for sufficient time to achieve a suitable second coating of metal 27 (see FIGURE 2). For example, approximately 70 to 80 minutes has been found adequate for many intended applications. The temperature in the electroless plating bath 40 is elevated to about 90°C or such other elevated temperature as may be recommended by the manufacturer of the solution. It is pointed out that while electroless plating is preferred, electrolytic plating may be used. Nickel plating has been found to deposit about 2×10^{-5} m nickel per hour in this bath and it is presently preferred to substantially interfill the surface area around the diamonds 25 and/or cover the diamonds 25 adhering to the workpiece.

After removal from the second or electroless plating bath 40, workpiece 10 is cleaned with water, dried and then subjected to heat treatment, in a furnace 43 wherein workpiece 10 is heated to approximately 315°C for approximately one hour. Heat treatment between 340°C and 400°C for one hour yields a workpiece having a Rockwell C-Scale hardness of 72. Hardness of 46 to 72 has been found desirable. The actual hardness achieved is a function of the type of metal plated on to workpiece 10 in the second plating bath 40 (which may be different to the metal plated in the first bath 20) and the temperature and firing time of the heat treatment step.

The embodiment of first plating bath shown in FIGURE 3 for electroplating diamond particles on to the etched surface of the workpiece 10 is similar to that

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described in connection with FIGURE 1 in that the or each workpiece 10 is at least partly embedded in a layer 46 of abrasive particles. In the embodiment shown in FIGURE 3 an enclosed box generally designated 41 is provided in
5 the first plating bath 20. The box 41 has sides 44 and a base 45. Nickel anode 34 is placed in the bottom of box 41 and connected to an electromotive force 36 as described previously. A port 48 permits plating solution 22 to enter the box 41. Alternatively, port 48 may be used
10 as an exit for plating solution 22 as hereinafter more fully described. A porous platform 50 is supported by sides 44 of box 41. A fine mesh net 52 is laid on top of porous platform 50 so as to prevent the diamond particles 46 from falling through the holes 54 of plat-
15 form 50.

A second platform 56 covers the diamond particles 46. Platform 56 has a plurality of openings 58 through which workpieces 10 may extend so as to permit the etched portion of each workpiece 10 to be embedded into the layer 46
20 of diamond particles. Importantly, openings 58 are only large enough to permit a very small tolerance between each workpiece 10 and opening 58. This prevents diamond particles 46 from being carried out of the openings 58 during the plating process. Each workpiece 10 is connected
25 through a wire 60 of cable 62 to electromotive force 36.

In order to plate the workpiece 10, plating solution 22 is drawn through port 48 into box 41. Alternatively, plating solution 22 may be drawn through openings 58 and may exit through port 48. Plating solution 22 may be circulated through box 41 by a pump (not
30 shown), by convection currents, or by gravity flow. The solution 22 and metal ions formed from anode 34 then are passed through porous platform 50 and net 52, and through the layer of diamond particles 46. Nickel or other metal

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is plated on to the workpiece 10 as the solution 22 circulates through box 41, and in this manner, diamond particles 25 may be uniformly plated into the cavities 21 (see FIGURE 2) etched into the surface of the workpiece 10 through the electrodeposition of metal on to the workpiece and around the particles 25.

The treatments of the workpiece 10 in accordance with the invention, before and after plating in the bath shown in FIGURE 3, may be identical to those discussed with reference to FIGURE 1.

INDUSTRIAL EXPLOITATION

From the foregoing description of the preferred embodiments, it will be appreciated that the process of the present invention advantageously provides a stronger bond of diamond particles to the surface of a workpiece. Additionally, the second coating of metal plated on to the workpiece may be advantageously selected so as to provide a surface which will surprisingly enhance the wear of the workpiece by helping to prevent glazing of the cutting edge.

The invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive and the scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

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CLAIMS

1. A process for bonding abrasive particles to the surface of a metal workpiece comprising immersing the workpiece and the abrasive particles in an electrolytic plating bath comprising an aqueous solution of metal ions and electrodepositing a metallic bonding matrix on to the workpiece surface and around the abrasive particles adjacent the surface, the process being characterised in that prior to such electrodeposition the surface of the workpiece (10) is etched to form cavities (21) therein of dimensions such that each cavity is capable of receiving a portion of one abrasive particle (25) and, subsequently to said etching step, the workpiece is at least partially embedded in a layer (46) of the abrasive particles in the plating bath (20) and an electromotive force is imposed across a metal anode (34) in the plating bath and the workpiece whereby the abrasive particles become individually partially embedded in the cavities of the etched workpiece surface as the metal (23) is plated on to the workpiece and around the embedded particles, and in that subsequent to said electrodeposition step the workpiece is at least partially immersed in a second plating bath (40) comprising an aqueous solution of metal ions and a second coat of metal (27) is

plated around the partially embedded abrasive particles.

2. A process according to claim 1 characterised in that the abrasive particles are supported on a porous platform (50) in the first-mentioned plating bath.

5 3. A process according to claim 1 or claim 2 characterised in that the aqueous solution in the first-mentioned plating bath is circulated around the portion of the workpiece embedded in the layer of abrasive particles.

10 4. A process according to any one of claims 1 to 3 characterised in that the second plating step is preceded by the removal of the workpiece from the first-mentioned plating bath and subjecting the workpiece to an aqueous rinse.

15 5. A process according to claim 4 characterised in that the rinsed workpiece is exposed to an acid wash prior to immersion or partial immersion in the second plating bath.

20 6. A process according to any one of the preceding claims characterised in that the workpiece is heat treated at a temperature below the decomposition temperature of the abrasive particles, so as to harden the metal plating, after the workpiece is removed from the second-mentioned plating bath.

25 7. A process according to any one of the preceding claims characterised in that the second-mentioned plating bath comprises an electroless plating bath.

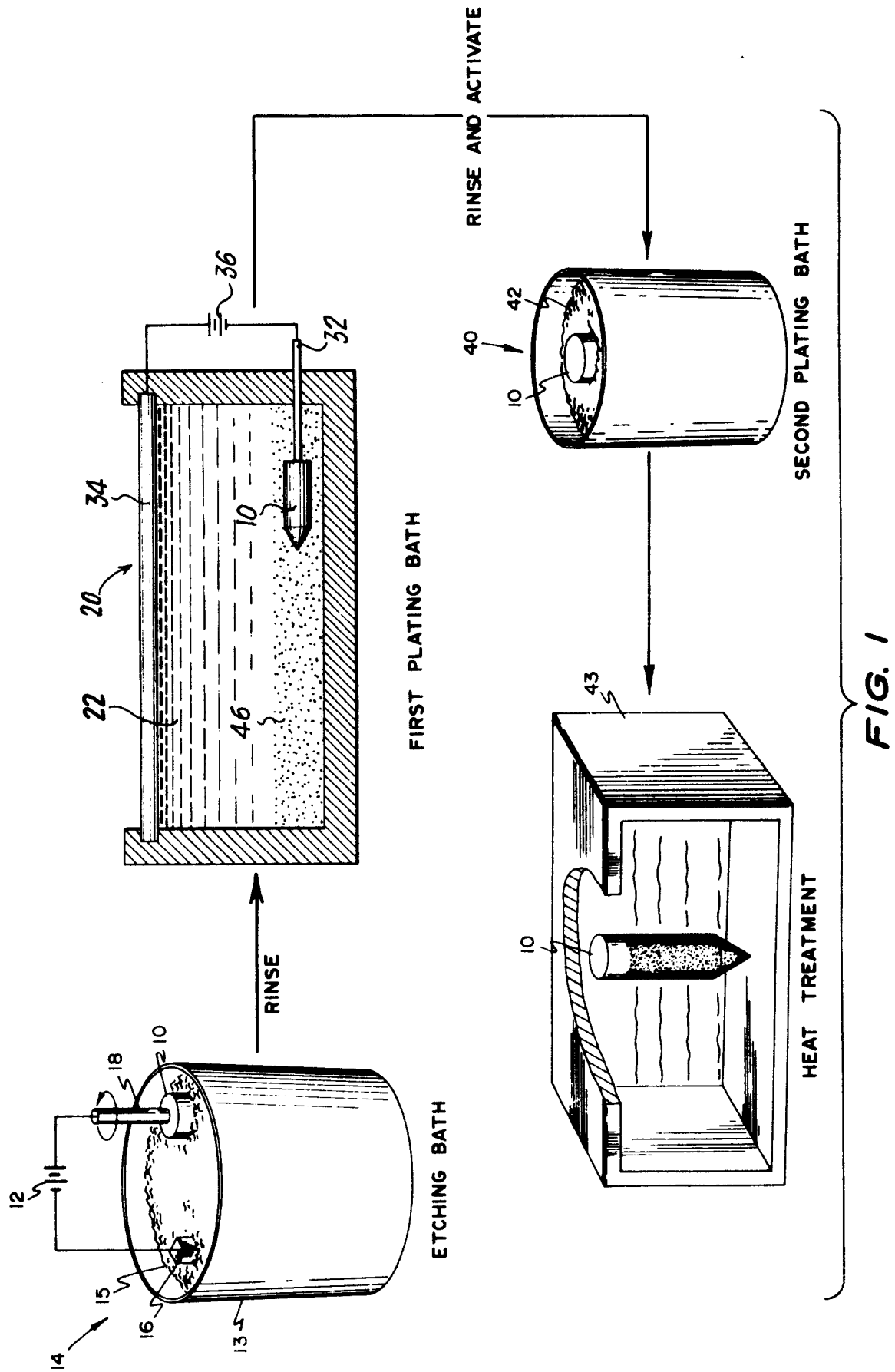
30 8. A process according to any one of the preceding claims characterised in that the workpiece is rotated in the first-mentioned plating bath as metal is plated on to the workpiece.

9. A process according to any one of the preceding claims characterised in that a thin metal coating is plated on to the workpiece surface between etching and

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plating in the first-mentioned plating bath, to prevent formation of oxide on the workpiece surface.

10. A process according to any one of the preceding claims characterised in that the metal ions in the first-
5 and second-mentioned plating baths are different.



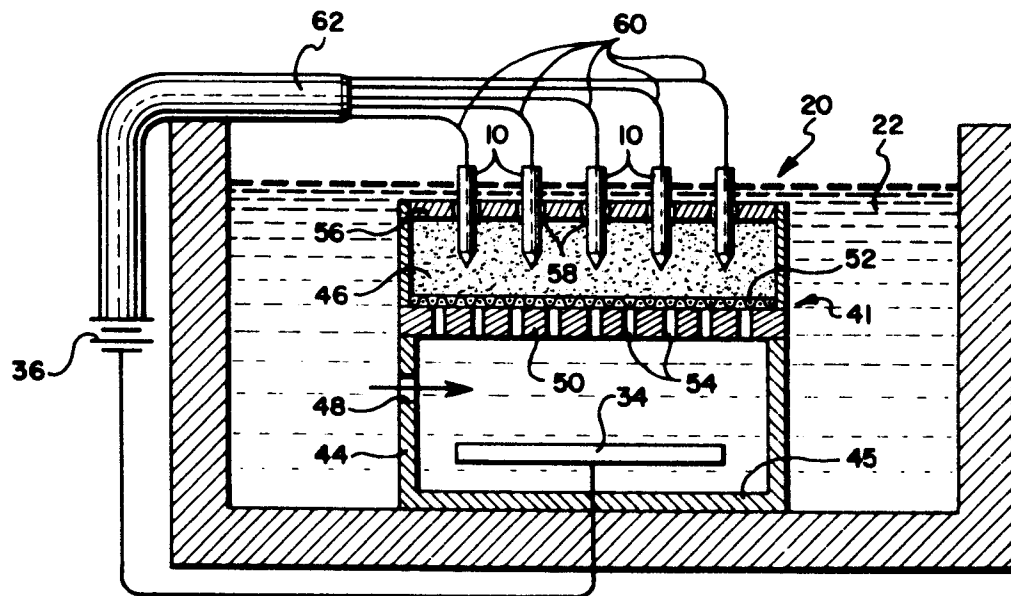
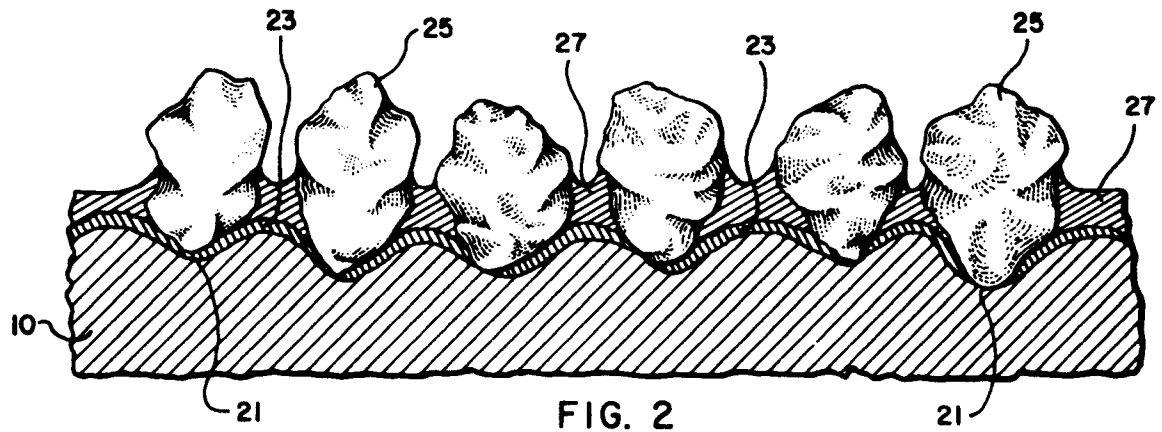


FIG.3