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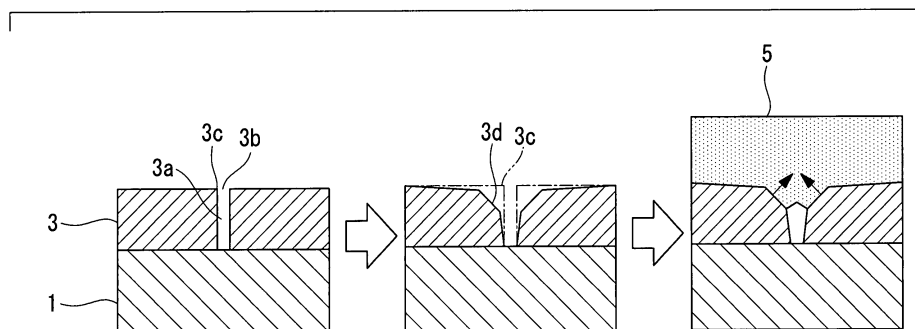
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(54) **METHOD FOR FORMING CORROSION RESISTANT PLATING LAYER AND ROTATING MACHINE**

(57) An object is to provide a method for forming a superior corrosion-resistant plating layer by sealing penetrating pinholes formed in an electroless plating layer. There are provided a first plating step of performing electroless Ni-P plating on a base material (1); an etching

step of etching a surface of a first plating layer (3) formed by the first plating step; and a second plating step of performing electroless Ni-P plating to form a second plating layer (5) on the first plating layer (3) processed by the etching step.

FIG. 2



Description

Technical Field

5 **[0001]** The present invention relates to a method for forming a corrosion-resistant plating layer by electroless nickel-based plating and a rotary machine processed by the method for forming a corrosion-resistant plating layer.

Background Art

10 **[0002]** Compressors (rotary machines) used in power-generating plants and chemical plants compress gases containing corrosive gases such as CO₂, H₂S, and H₂O. When carbon steel (cast iron, cast steel, or forged steel) is used as the base material for a compressor, since the anti-corrosion properties of the carbon steel are not sufficient, electroless nickel-based plating, such as Ni-P plating, is generally performed on a diaphragm and an impeller, which are exposed to corrosive gases.

15 However, as shown in Fig. 11, defects, such as cavities, are liable to be formed, particularly, in carbon steel during casting, and pores 100a having openings are formed in a surface of a base material 100. When the pores 100a as described above are present, even if electroless plating is performed on the base material 100, penetrating pinholes 101a are formed in an electroless plating layer 101 to penetrate the surface thereof.

20 When the penetrating pinholes 101a as described above are present, as shown in Fig. 12, a corrosive liquid infiltrates the base material 100. As a result, corrosion products 100b are formed on the base material 100. In addition, as the corrosion products 100b gradually grow, the electroless plating layer 101 is eventually peeled away.

The penetrating pinholes as described above may originate at a complex-shaped portion, such as a diaphragm or an impeller.

25 **[0003]** In order to seal the penetrating pinholes as described above, as disclosed in Patent Document 1, a technique in which a plating layer is further formed on an electroless plating layer has been known.

[0004]

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-147548

30 Disclosure of Invention

[0005] However, even when a plating layer is overlapped on the electroless plating layer as disclosed in the Patent Document 1, the penetrating pinholes formed in the lower electroless plating layer are liable to continuously grow also in the upper plating layer in many cases. As a result, the penetrating pinholes are essentially not sealed.

35 **[0006]** The present invention has been conceived in consideration of the above situation, and an object of the present invention is to provide a method for forming a superior corrosion-resistant plating layer by sealing penetrating pinholes formed in an electroless plating layer and to provide a rotary machine.

[0007] In order to solve the problem described above, a method for forming a corrosion-resistant plating layer and a rotary machine according to the present invention use the following solutions.

40 That is, a method for forming a corrosion-resistant plating layer according to the present invention is a method for forming a corrosion-resistant plating layer in which the corrosion-resistant plating layer is formed by performing electroless nickel-based plating on a base material, and the above method comprises: a first plating step of performing electroless nickel-based plating on the base material; an etching step of etching a surface of a first plating layer formed by the first plating step; and a second plating step of performing electroless nickel-based plating on the first plating layer processed by the etching step.

45 **[0008]** In the first plating step, the first plating layer is formed by performing electroless nickel-based plating on the base material. In the first plating layer, penetrating pinholes having openings at a surface side are formed due to the shapes of pores or the like formed in the surface of the base material.

In the etching step, corners forming opening portions of the penetrating pinholes are removed to form tapered shapes.

50 As a result, the opening portions of the penetrating pinholes each have a mortar shape.

In the second plating step, a second plating layer is formed on the first plating layer. In this step, since the opening portions of the penetrating pinholes are each formed to have a mortar shape by the etching step, the second plating layer is formed so as to be laminated on the tapered surfaces each having a mortar shape, that is, is formed so as to be grown in an oblique direction with respect to an extending direction of the penetrating pinholes. Since the second plating layer is grown obliquely at the opening portions of the penetrating pinholes, the opening portions of the penetrating pinholes are sealed.

55 The present invention is particularly effective when carbon steel (cast iron, cast steel, or forged steel) is used as the base material. The reason for this is that since many pores having openings are formed in the surface of carbon steel,

pin holes are liable to be formed in a plating layer.

As the electroless nickel-based plating, Ni-P plating or Ni-B plating is preferably performed.

The present invention is not limited to the first plating step, the etching step, and the second plating step; for example, after the second plating step, another surface treatment may also be performed.

[0009] Furthermore, in the method for forming a corrosion-resistant plating layer according to the present invention, the etching step is preferably performed using sulfuric acid.

[0010] The etching step is preferably performed by an acid treatment using sulfuric acid, hydrochloric acid, nitric acid, or the like, and in particular, an acid treatment using sulfuric acid is preferable. For the concentration of sulfuric acid, approximately 5 percent by weight is preferable.

[0011] Furthermore, in the method for forming a corrosion-resistant plating layer according to the present invention, the thickness of the first plating layer is preferably set to 5 μm or more.

[0012] When the thickness of the first plating layer is less than 5 μm , the base material may be corroded in the etching step through pinholes formed in the first plating layer. Hence, as the first plating layer, a thickness of 5 μm or more is necessary.

[0013] Furthermore, in the method for forming a corrosion-resistant plating layer according to the present invention, the thickness of the second plating layer is preferably set to 10 μm or more.

[0014] When the thickness of the second plating layer is less than 10 μm , penetrating pinholes formed in the first plating layer cannot be sufficiently sealed. Hence, as the second plating layer, a thickness of 10 μm or more is necessary.

[0015] Furthermore, in the method for forming a corrosion-resistant plating layer according to the present invention, the first plating step and the second plating step are preferably performed by electroless Ni-P plating, and a P concentration of an electroless Ni-P plating layer is preferably set in the range of 7 to 10 percent by weight.

[0016] Through intensive research carried out by the inventors of the present invention, it was found that when the P concentration of the electroless Ni-P plating layer is set in the range of 7 to 10 percent by weight, superior corrosion resistance can be obtained.

[0017] A rotary machine according to the present invention has a surface provided with a corrosion-resistant plating layer formed by one of the methods for forming a corrosion-resistant plating layer described above.

[0018] Since the rotary machine has a surface provided with a corrosion-resistant plating layer formed by one of the methods for forming a corrosion-resistant plating layer described above, even when this surface is exposed to a corrosive gas, such as CO_2 , H_2S , and H_2O , a rotary machine having sufficient durability can be provided.

As the rotary machine, for example, a compressor may be mentioned. In the case of the compressor, an anti-corrosion treatment is performed on surfaces of an impeller (rotor blade) and a diaphragm, which is a stationary member.

[0019] After the corners of the opening portions of the penetrating pinholes are removed by the etching step to form tapered shapes, that is, mortar shaped portions, the second plating layer is formed on the first plating layer by the second plating step, and hence the opening portions of the penetrating pinholes can be sealed. Accordingly, a plating layer having superior corrosion resistance can be formed, and as a result, a rotary machine having superior corrosion resistance can be provided.

Brief Description of Drawings

[0020]

[FIG. 1] Fig. 1 is a flowchart showing steps of a treatment for forming a corrosion-resistant plating layer according to one embodiment of the present invention.

[FIG. 2] Fig. 2 is a cross-sectional view time-sequentially showing a first plating layer and a second plating layer which are formed by following the flowchart shown in Fig. 1.

[FIG. 3] Fig. 3 is a graph used in order to obtain a corrosion current density which is an evaluation index of the P concentration of an electroless Ni-P plating layer.

[FIG. 4] Fig. 4 is a schematic view showing an electrolytic corrosion test apparatus used for investigation of the P concentration of an electroless Ni-P plating layer.

[FIG. 5] Fig. 5 is a graph showing a corrosion-resistance evaluation result obtained by an electrolytic corrosion test.

[FIG. 6] Fig. 6 is a perspective view showing a plating base material which is a test specimen used for investigation of lamination of plating layers.

[FIG. 7] Fig. 7 is a flowchart showing a process used to determine experimental conditions.

[FIG. 8] Fig. 8 is a graph showing a factor effect figure (smaller-the-better characteristic) related to a penetrating defect density.

[FIG. 9] Fig. 9 is a flowchart showing a process used for a confirmation test and the conditions thereof.

[FIG. 10] Fig. 10 is a graph showing the relationship between the number density of penetrating defects and the thickness of an upper Ni-P plating layer.

[FIG. 11] Fig. 11 is a perspective cross-sectional view showing penetrating pinholes formed in a plating layer.

[FIG. 12] Fig. 12 is a view showing a process in which a plating layer is peeled away by penetrating pinholes formed in the plating layer.

5 Explanation of Reference Signs:

[0021]

- 1: base material
- 10 3: first plating layer
- 3a: penetrating pinhole
- 3b: opening portion
- 5: second plating layer

15 Best Mode for Carrying Out the Invention

[0022] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

In this embodiment, a corrosion prevention treatment is performed on a diaphragm and an impeller of a compressor which is exposed to a corrosive gas, such as CO₂, H₂S and H₂O, by electroless Ni-P plating. Carbon steel (cast iron, cast steel, or forged steel) is used as a base material to be processed by the anti-corrosion treatment.

Fig. 1 shows steps of performing the anti-corrosion treatment on the base material by electroless Ni-P plating.

As shown in the above figure, after cleaning, degreasing, and water washing are performed for the base material, pickling is performed, followed by water washing. Subsequently, after pickling is performed with diluted sulfuric acid, water washing is performed, and the electroless Ni-P plating is then performed. Accordingly, a first plating step is completed.

25 With this process, as shown in Fig. 2, a first plating layer 3 is formed on a base material 1. In this figure, a penetrating pinhole 3a formed in the first plating layer 3 is shown.

[0023] Next, the surface of the first plating layer 3 is etched by an acid treatment using diluted sulfuric acid or the like. By this etching step, a corner 3c forming an opening portion 3b of the penetrating pinhole (or penetrating defect) 3a is removed to form a tapered shape. Hence, as shown in Fig. 2, at the opening portion 3b of the penetrating pinhole 3a, a mortar shape 3d is formed.

[0024] Next, after water washing is performed, electroless Ni-P plating is performed (second plating step). By this second plating step, a second plating layer 5 is formed on the first plating layer 3. In this step, since the mortar shape portion 3d is formed at the opening portion 3b of the penetrating pinhole 3a by the etching step, the second plating layer 5 is formed so as to be laminated on a tapered surface forming this mortar shape portion 3b, that is, is formed so as to grow in an oblique direction with respect to an extending direction of the penetrating pinhole 3a. Since the second plating layer 5 is obliquely grown at the opening portion 3b of the penetrating pinhole 3a, the opening portion 3b of the penetrating pinhole 3a is sealed.

Subsequently, after water washing is performed, drying is performed, followed by baking, so that the anti-corrosion treatment is completed.

40 [0025] The etching step is preferably performed by an acid treatment using sulfuric acid, hydrochloric acid, nitric acid, or the like. In particular, as described later, an acid treatment using diluted sulfuric acid is preferable. For the concentration of sulfuric acid, approximately 5 percent by weight is preferable.

[0026] The thickness of the first plating layer is preferably 5 μm or more. The reason for this is that, in some cases, when the thickness of the first plating layer 3 is less than 5 μm, an acid treatment using diluted sulfuric acid or the like may corrode the base material 1 in the etching step through the penetrating pinhole 3a formed in the first plating layer 3.

45 [0027] The thickness of the second plating layer 5 is preferably 10 μm or more. The reason for this is that when the thickness of the second plating layer 5 is less than 10 μm, the penetrating pinhole 3a formed in the first plating layer cannot be sufficiently sealed.

50 (Examples)

[0028] Next, Examples will be described.

[Investigation of P concentration of electroless Ni-P plating layer]

55 [0029] First, in order to optimize the P concentration of an electroless Ni-P plating layer, the corrosion rate was evaluated by measuring polarization properties performed while the P concentration was varied.

(1) Test specimen

[0030] JIS SPCC (cold-rolled carbon steel) was used as a base material, and electroless Ni-P plating layer was formed on a surface of the base material by varying the P concentration from 2.5 to 12.5 percent by weight under the conditions shown in Table 1.

Table 1 Electroless Ni-P plating test

Types of prepared solutions

[Table 1]

No.	P concentration [wt%]/ (average)	Plating solution [Trade name]	Plating thickness [mm]	Producer
1	2~3 (2.5)	Nimuden LPX	20	C. Uyemura & Co., Ltd.
2	7~8 (7.5)	Nimuden 5X	20	C. Uyemura & Co., Ltd.
3	9~10 (9.5)	Nimuden SX	20	C. Uyemura & Co., Ltd.
4	12~13 (12.5)	Nimuden HDX	20	C. Uyemura & Co., Ltd.

(2) Test method

[0031] After anode/cathode polarization curves were measured by an electrolytic corrosion test, a corrosion current density (I_{corr}) was obtained by the Tafel method (see Fig. 3) to evaluate the anti-corrosion properties.

In Fig. 4, an electrolytic corrosion test apparatus used in this test is shown. A sample 12 is immersed in a test solution 10 and is disposed to face a counter electrode 14 made of Pt.

The test solution 10 is temperature-controlled by a heater 18 disposed around the periphery. The temperature of the test solution 10 is measured by a thermometer 16. In the test solution 10, CO_2 and H_2S gases are introduced as simulated corrosive gases. The test solution 10 is agitated by a stirrer 20.

The sample 12 and the counter electrode 14 are each connected to a potentiostat-galvanostat 21. A salt bridge 22 is connected to the sample 12. The other end of the salt bridge 22 is immersed in a bath 24 together with a reference electrode (Ag/AgCl electrode) 23 connected to the potentiostat-galvanostat 21.

The measurement conditions of this test are shown in Table 2.

Table 2 Measurement conditions for polarization properties

[Table 2]

Items	Conditions
Solution	Bubbling aqueous solution containing CO_2 + 10 vol% of H_2S (gas composition including maximum H_2S concentration estimated in compressor)
Solution temperature	80°C
Sweeping rate	20 mV/min

(3) Test procedure

[0032] The test procedure is as shown below.

(a) A test solution in a volume of 350 ml is received in an electrolytic bath made of glass (jacket type having a volume of 400 ml).

(b) An Ag/AgCl electrode is set as a reference electrode, Pt is as a counter electrode, and the sample 12 (measurement test specimen) is set as a test electrode.

(c) While agitation is performed at 0.3 m/s by bubbling CO_2 and H_2S gases, the temperature of the test solution is increased to 80°C.

(d) A spontaneous potential (E_{corr}) of the measurement test specimen (sample 12) is measured for 30 minutes.

(e) Polarization is performed to 400 mV on the cathode side of the spontaneous potential at a sweeping rate of 20 mV/min.

(f) Polarization is performed from the spontaneous potential to 1,000 mV on the anode side at a sweeping rate of 20 mV/min.

(g) Polarization curves shown in Fig. 3 are obtained from the above (e) and (f).

(4) Test results

[0033] Fig. 5 shows an anti-corrosion evaluation result obtained by the above electrolytic corrosion test. Under this corrosion environment, a composition region in which the P concentration in an electroless Ni-P plating layer is from 7 to 10 percent by weight is considered to have the most superior corrosion resistance. The reasons why a P concentration in an electroless Ni-P plating layer in the range of 7 to 10 percent by weight is considered to have superior corrosion resistance are as follows.

(i) Comparison with a plating material having a P concentration of 2 to 3 percent by weight.

In the case of a Ni-P plating layer having a P concentration of 2 to 3 percent by weight (approximately 5 percent by weight or less), the plating film is crystalline. When the P concentration is more than 7 percent by weight, the plating film is amorphous. It is believed that due to the presence of sources of corrosion at grain boundaries in a crystalline film, the corrosion resistance thereof was inferior to that of an amorphous film.

(ii) Comparison with a plating material having a high P concentration of 10 percent by weight or more.

[0034] Initially, it was estimated that a higher P concentration gave superior corrosion resistance; however, according to this test, at a P concentration of 10 percent by weight or more, the corrosion resistance was unexpectedly degraded. As the reason for this, it is believed that many pits caused by corrosion are generated in a high P material. Thereby the corrosion resistance is degraded. Although a passivation film, such as phosphorus oxide, can be formed on a plating surface, it is believed that as the P concentration is increased, microcrystalline are formed. Since a microcrystalline passivation film containing a high P concentration has many points that are liable to be broken, many pits caused by corrosion are generated. As a result, the corrosion current was increased in a Tafel method.

[0035] According to the results described above, a concentration in the range of 7 to 10 percent by weight is preferable as the P concentration of the electroless Ni-P plating layer.

Hence, in the investigation of the lamination of plating layers explained below, Nimuden SX manufactured by C. Uyemura & Co., Ltd. is used, which can form a plating film having a P concentration in the range of 9 to 10 percent by weight.

[Investigation of lamination of plating layers]

[0036] By using electroless Ni-P plating solution (Nimuden SX, P concentration: 9 to 10 percent by weight) from C. Uyemura & Co., Ltd. selected as described above, it was attempted to reduce defects (penetrating pinholes) by laminating plating layers.

[Test base material]

[0037] As a plating base material used as the base material, JIS SC480 cast steel was used, which was obtained by casting simultaneously performed during manufacture of a diaphragm of an actual compressor. A base material having a size of 30×30×L200 was cut into a size of $^{W}30 \times ^{L}100 \times ^{t}3$ mm by wire cutting as shown in Fig. 6, to form the plating base material.

[Experimental conditions set by the Taguchi Method]

[0038] A plating process for laminating layers (in this case, two-layer plating is considered) is performed as shown in Fig. 7. That is, by a lower layer electroless Ni-P plating process corresponding to the first plating step, an underlying Ni-P plating layer is formed to have a thickness of 20 μ m, followed by etching, and by an upper layer electroless Ni-P plating process corresponding to the second plating step, upper layer Ni-P plating is performed.

Table 3 shown factors affecting penetrating defects (penetrating pinholes) in the plating layer and the reasons for the determining standards.

Table 3 control factors of the test for reducing penetrating defects in electroless Ni-P plating layer

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[Table 3]

Control factors	Standards	Reasons for determining standards
Type of etching solution	Hydrochloric acid, sulfuric acid, nitric acid	Commonly used solutions are selected.
Concentration of etching solution	1, 5, and 10 percent by weight	Commonly used concentration range is selected.
Etching treatment time	1, 3, and 5 minutes	Times are determined in consideration of etching rate of Ni-P plating and thickness of lower plating layer of 20 μm .
Thickness of upper plating layer	10, 20, and 30 μm	Thicknesses are determined in order to obtain total thickness of 50 μm or less, which is current plating thickness.

[0039] (1) Experimental method

By the plating process shown in Fig. 7 and the conditions shown in the L9 orthogonal array of the following Table 4, electroless Ni-P plating was performed on the base material using SC480 to form two layers, and subsequently, the number of penetrating defects was investigated.

Table 4 Two-layer plating test conditions L9 orthogonal array

[Table 4]

No.	Control factors				Error factors	
	Type of etching solution	Concentration of etching solution [wt%]	Etching time [min]	Thickness of upper Ni-P plating layer [μm]	Temperature of etching solution [$^{\circ}\text{C}$]	
					50	60
1	Hydrochloric acid	1	1	10	Condition 1	Condition 10
2	Hydrochloric acid	5	3	20	Condition 2	Condition 11
3	Hydrochloric acid	10	5	30	Condition 3	Condition 12
4	Sulfuric acid	1	3	30	Condition 4	Condition 13
5	Sulfuric acid	5	5	10	Condition 5	Condition 14
6	Sulfuric acid	10	1	20	Condition 6	Condition 15
7	Nitric acid	1	5	20	Condition 7	Condition 16
8	Nitric acid	5	1	30	Condition 8	Condition 17
9	Nitric acid	10	3	10	Condition 9	Condition 18

The number of penetrating defects was measured by the ferroxyl test in accordance with JIS H8617 as described below.

<Procedure of ferroxyl test>

[0040]

- In 500 ml of pure water, 2 g of reagent-grade hexacyano iron (II) potassium trihydrate, 2g of reagent-grade hexacyano iron (III) potassium, and 12 g of reagent-grade sodium chloride were dissolved, affording a test solution.
- After a test piece was washed with ethyl alcohol, water washing was performed, and moisture was then wiped off.
- Two types of dense quantitative filter paper (manufactured by Toyo Advantec Co., Ltd.) used as test paper were cut into a size of 50 mm square, were immersed in the test solution, and were then placed on test surfaces while

the filters were wet.

(d) After 5 minutes elapsed, the test paper was peeled away and was dried, and the number of blue spots that appeared on the test paper was examined.

(2) Test results

[0041] A factor effect graph (smaller-the-better characteristic) of the penetrating defect density is shown in Fig. 8. A summary of the results is as follows.

(i) The factor having the most significant effect on plating defects is the thickness of the upper plating layer; as the thickness is increased, the number of defects is decreased, and the robustness is also improved.

(ii) The type of etching solution has a relatively small effect; however, in the case of nitric acid, it is believed that since the plating dissolving ability is high, and smut (impurities of oxides, carbides, and the like) is generated on the plating surface by long-term etching, the variation is increased when an actual machine with a large and complicated shape is processed.

(iii) An etching solution concentration in the range of 1 to 5 percent by weight showed a good result without any differences therebetween.

(iv) Although an etching time of 3 minutes did not show a good result, it is believed that this result is caused by the generation of smut due to 10 wt%-nitric acid (high concentration) etching and that the effect of an etching time of 1 to 5 minutes is essentially small.

(v) According to the results described above, the following conditions are selected: sulfuric acid is used as the type of etching solution, the etching solution concentration is 5 percent by weight, and the etching time is 5 minutes, and a confirmation test is performed by using the thickness of the upper plating layer, which has the most significant effect, as a parameter.

[Confirmation test]

(1) Test base material

[0042] A cast iron material (SC 480) similar to that described above was used. The base material dimensions were set to $W30 \times L100 \times t3$ mm.

(2) Experimental Method

(i) Lower layer process

[0043] The process shown in Fig. 7 was carried out.

(ii) Upper layer plating conditions

[0044] An upper layer plating (etching and second plating layer) process and conditions thereof are shown in Fig. 9. The thickness of the upper plating layer was used as a parameter, and the target thickness was varied from 10 to 30 μm .

(3) Experimental results

[0045] The number density of penetrating defects was measured by a ferroxy test.

In Fig. 10, the relationship between the thickness of the upper Ni-P plating layer and the number density of penetrating defects, which is obtained by the confirmation test, is shown. A summary of the results is as described below.

By increasing the thickness of the upper plating layer, the number density of penetrating defects is decreased. In particular, when the upper plating layer had a thickness of more than 15 μm , the defect reduction effect was significant, and when the thickness of the upper plating layer was 23 μm (20 (thickness of the lower plating layer) + 3 (thickness of the upper plating layer) = 43 μm (total thickness)), the number density of penetrating defects was decreased to 1.7 per 50 mm square. When the two-layer plating material of this test and a current single-layer plating material are compared, the results are as shown in Table 5. It is understood that the effect of a two-layer lamination including the etching step and the second plating step is significant.

Table 5 Comparison of number of penetrating defects

[Table 5]

Name of test object	Number density of penetrating defects
Two-layer Ni-P plating of the invention	1.7/50 mm square
Current Ni-P plating material (single layer: 50 μm)	15 to 20/50 mm square

[0046] As described above, according to this embodiment, the corner 3c forming the opening portion 3b of the penetrating pinhole 3a is removed by the etching step to form a tapered shape, so that the mortar shaped portion 3d is formed. Subsequently, since the second plating layer 5 is formed on the first plating layer 3 by the second plating step, the opening portion of the penetrating pinhole 3a can be sealed. Accordingly, a plating layer having superior corrosion resistance can be formed. As a result, a compressor having superior corrosion resistance can be provided.

[0047] The present invention is not limited to the first plating step, the etching step, and the second plating step: for example, after the second plating step, another surface treatment may also be performed. Instead of the electroless Ni-P plating, electroless Ni-B plating may be used.

Claims

1. A method for forming a corrosion-resistant plating layer in which a corrosion-resistant plating layer is formed on a base material by performing electroless nickel-based plating, comprising:
 - a first plating step of performing electroless nickel-based plating on the base material;
 - an etching step of etching a surface of a first plating layer formed by the first plating step; and
 - a second plating step of performing electroless nickel-based plating on the first plating layer processed by the etching step.
2. The method for forming a corrosion-resistant plating layer according to Claim 1, wherein the etching step is performed using sulfuric acid.
3. The method for forming a corrosion-resistant plating layer according to Claim 1 or 2, wherein the thickness of the first plating layer is set to 5 μm or more.
4. The method for forming a corrosion-resistant plating layer according to one of Claims 1 to 3, wherein the thickness of the second plating layer is set to 10 μm or more.
5. The method for forming a corrosion-resistant plating layer according to one of Claims 1 to 4, wherein the first plating step and the second plating step are each performed by electroless Ni-P plating, and a P concentration of the electroless Ni-P plating is set in the range of 7 to 10 percent by weight.
6. A rotary machine having a surface provided with a corrosion-resistant plating layer formed by the method for forming a corrosion-resistant plating layer according to one of Claims 1 to 5.

FIG. 1

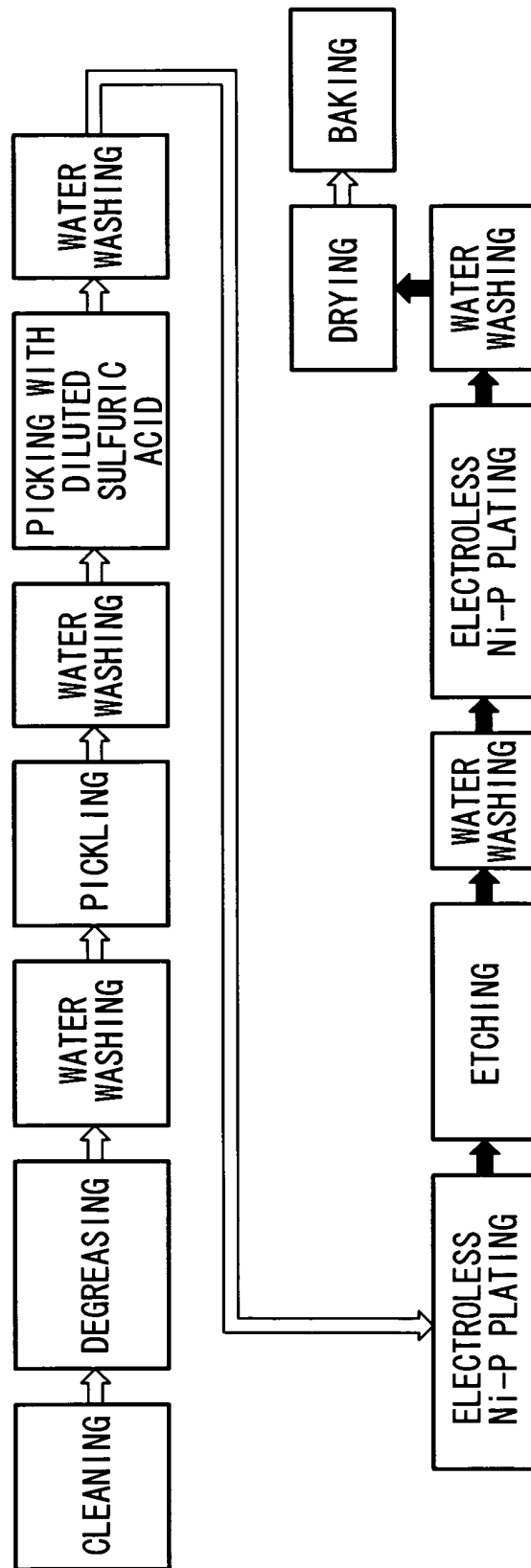


FIG. 2

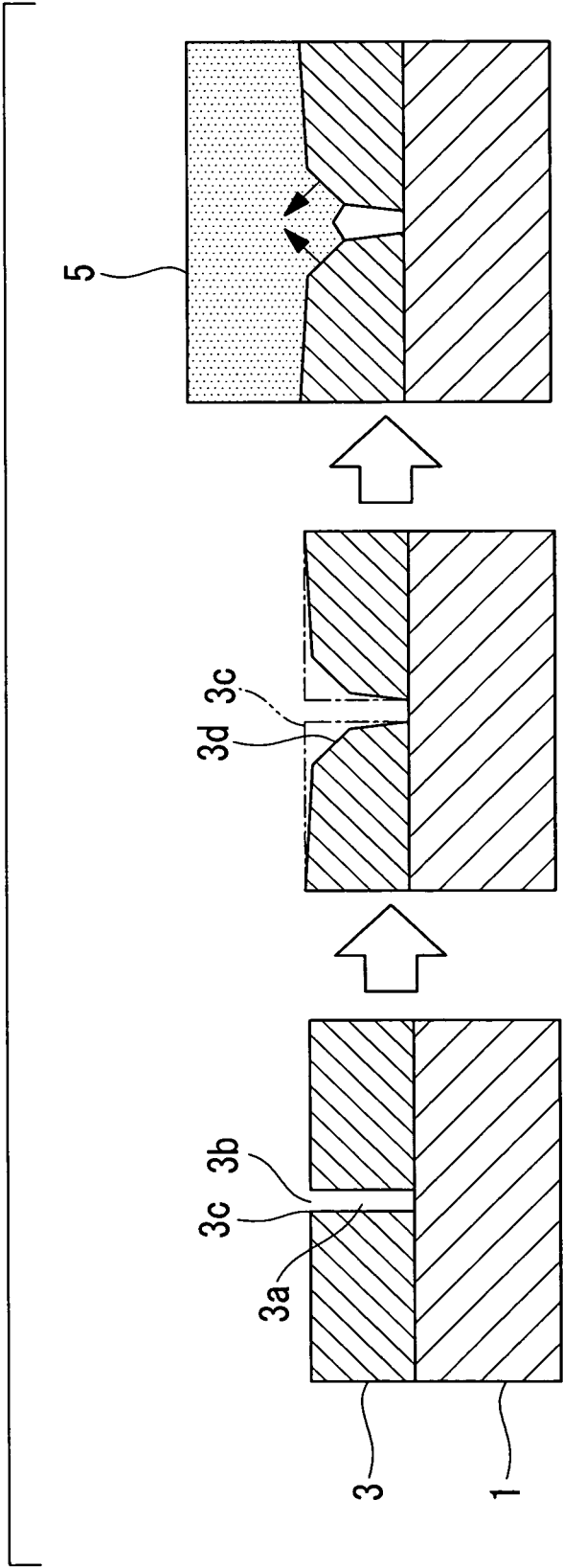


FIG. 3

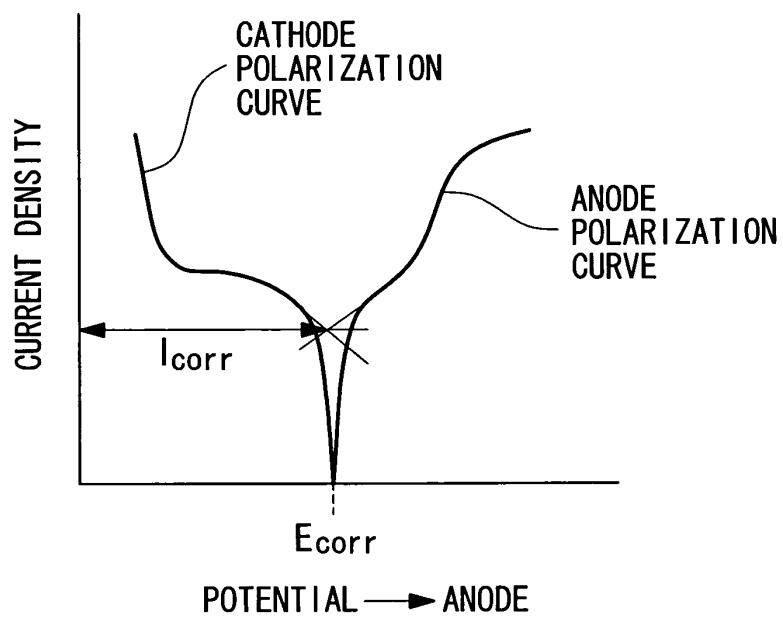


FIG. 4

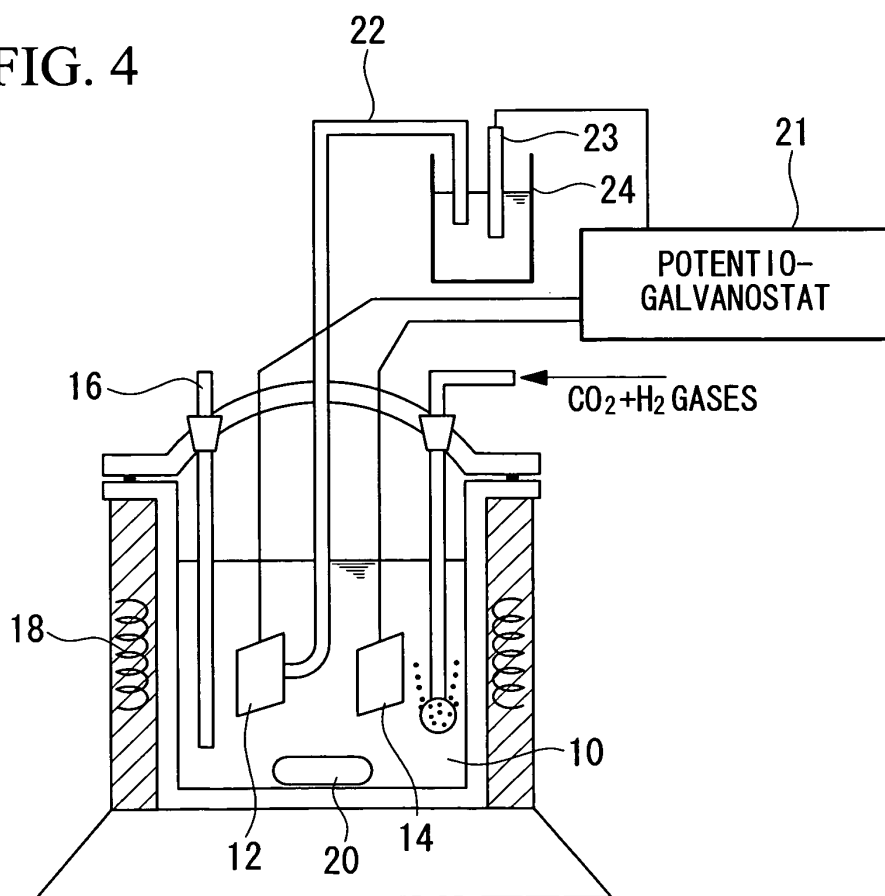


FIG. 5

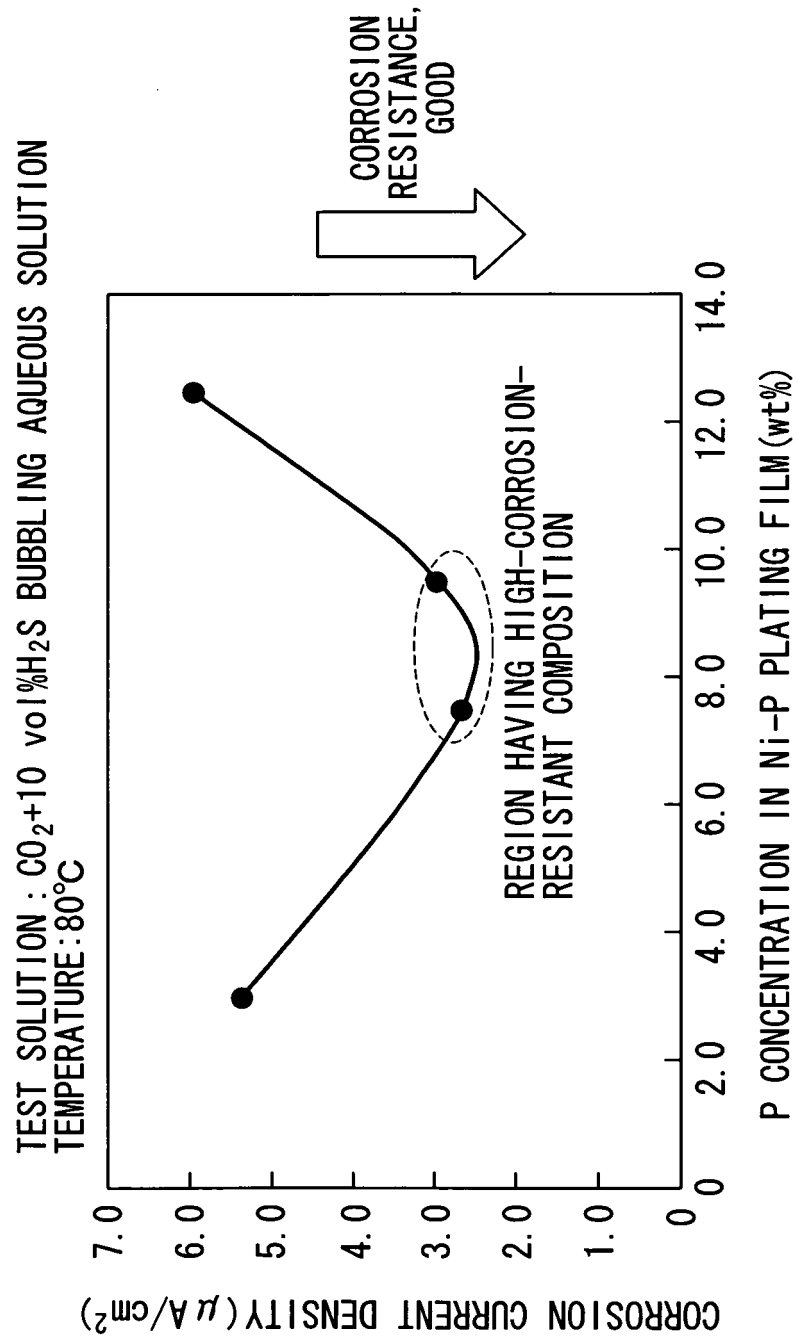


FIG. 6

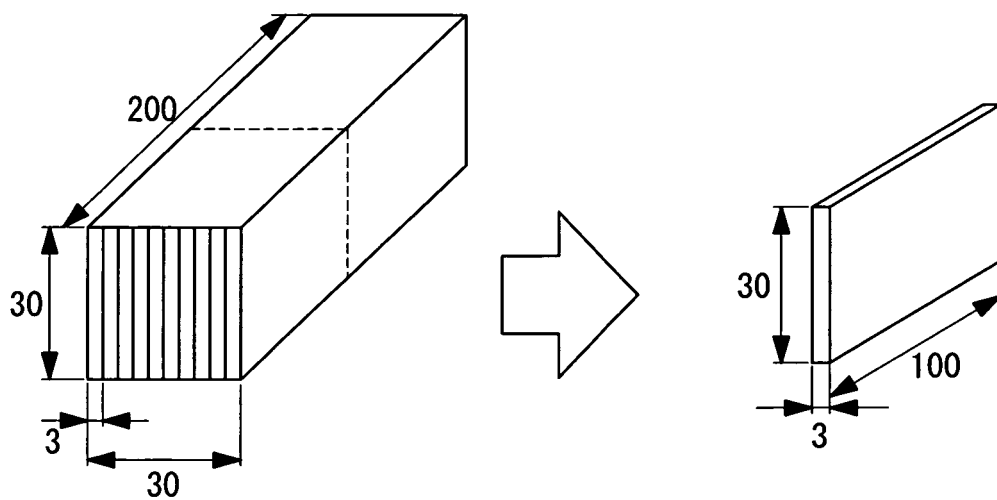
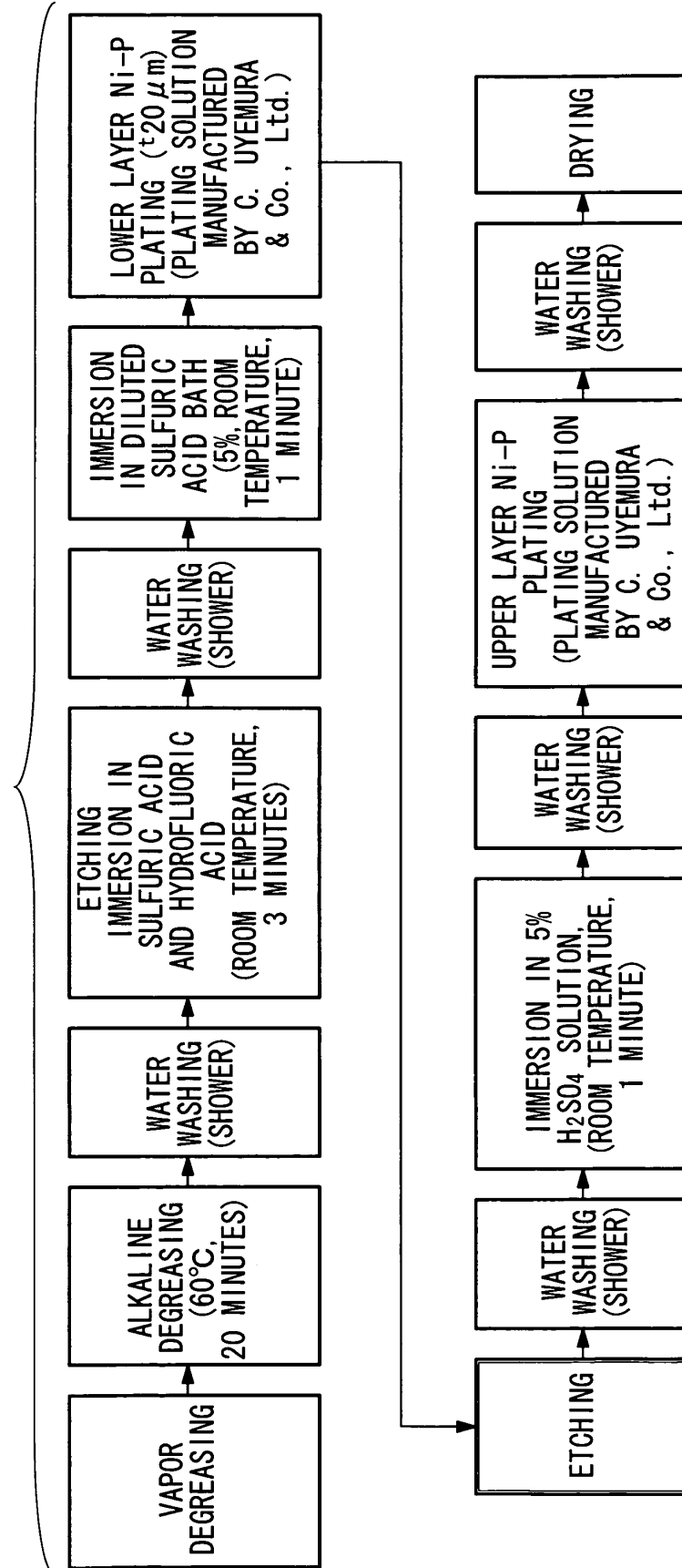


FIG. 7

LOWER LAYER ELECTROLESS Ni-P PLATING PROCESS



UPPER LAYER ELECTROLESS Ni-P PLATING PROCESS

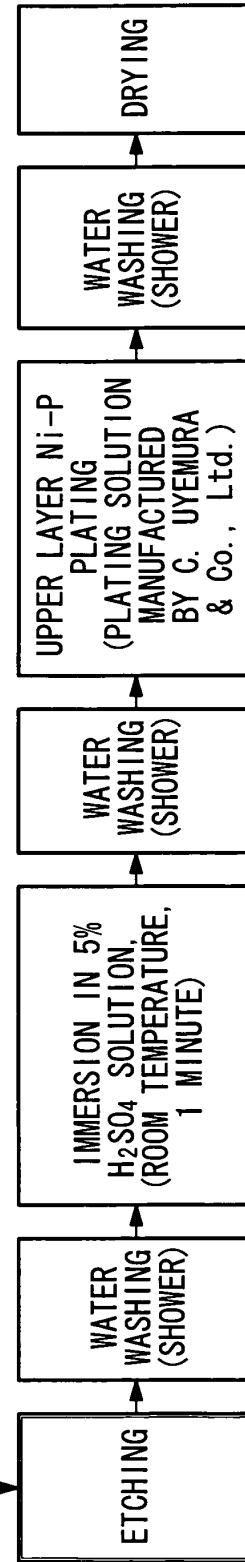


FIG. 8

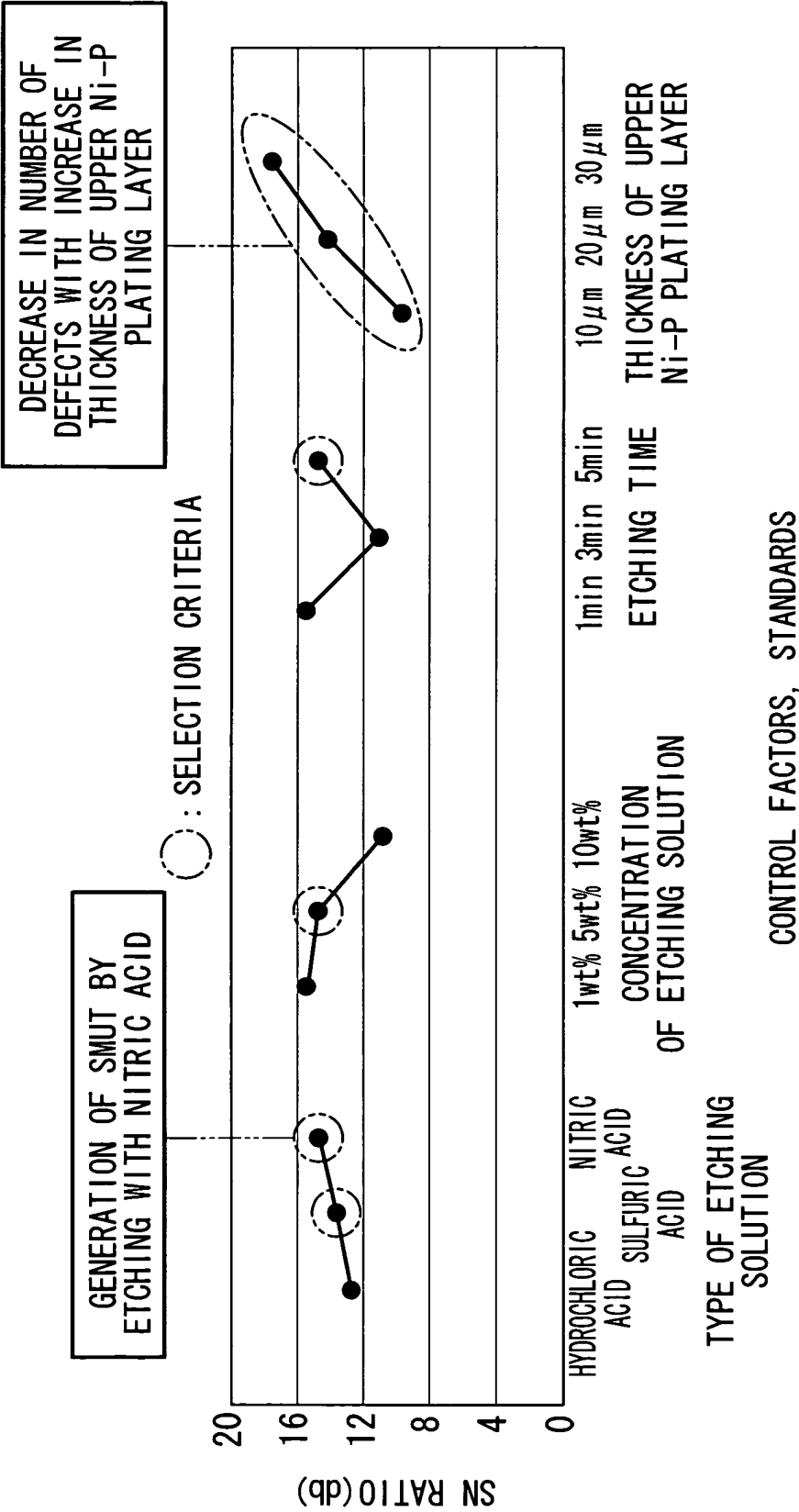


FIG. 9

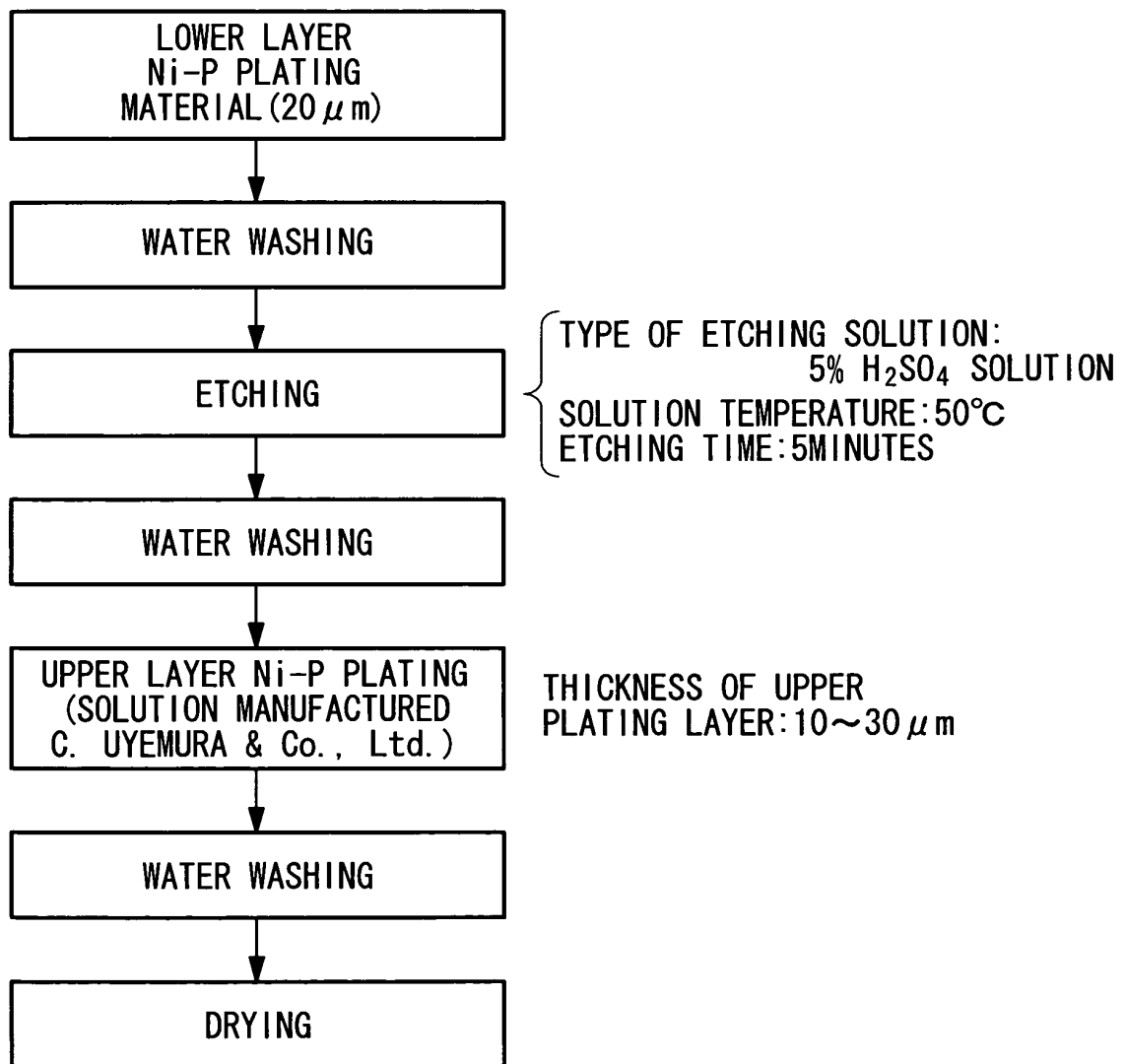


FIG. 10

TYPE OF ETCHING SOLUTION: SULFURIC ACID
 CONCENTRATION OF ETCHING SOLUTION: 5wt%
 ETCHING TIME: 5 MINUTES

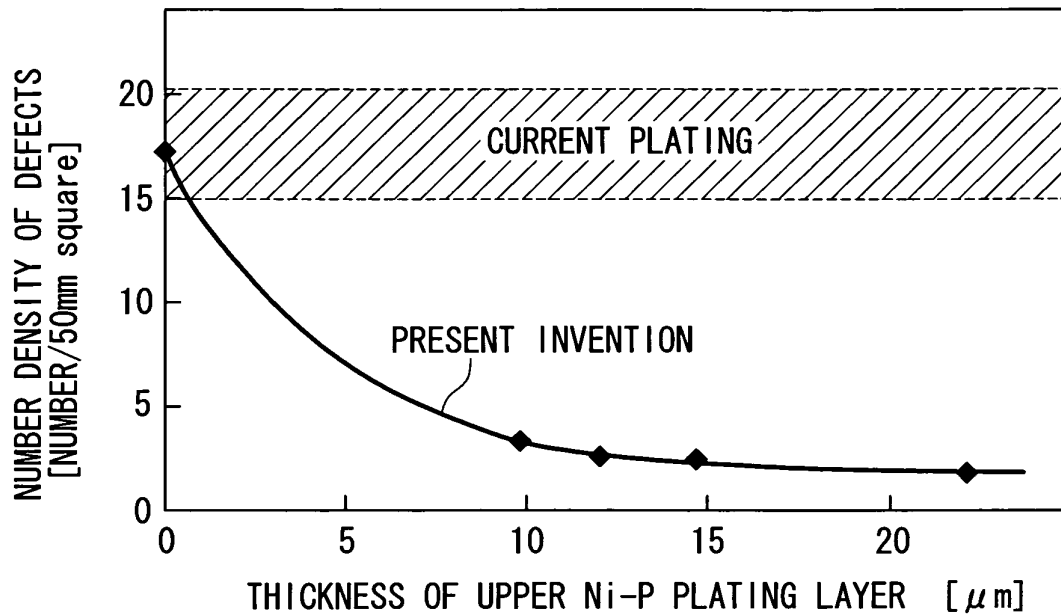


FIG. 11

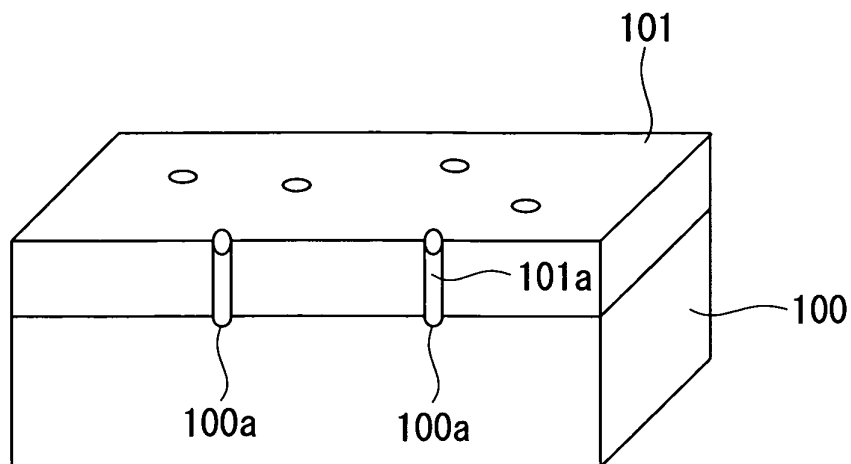
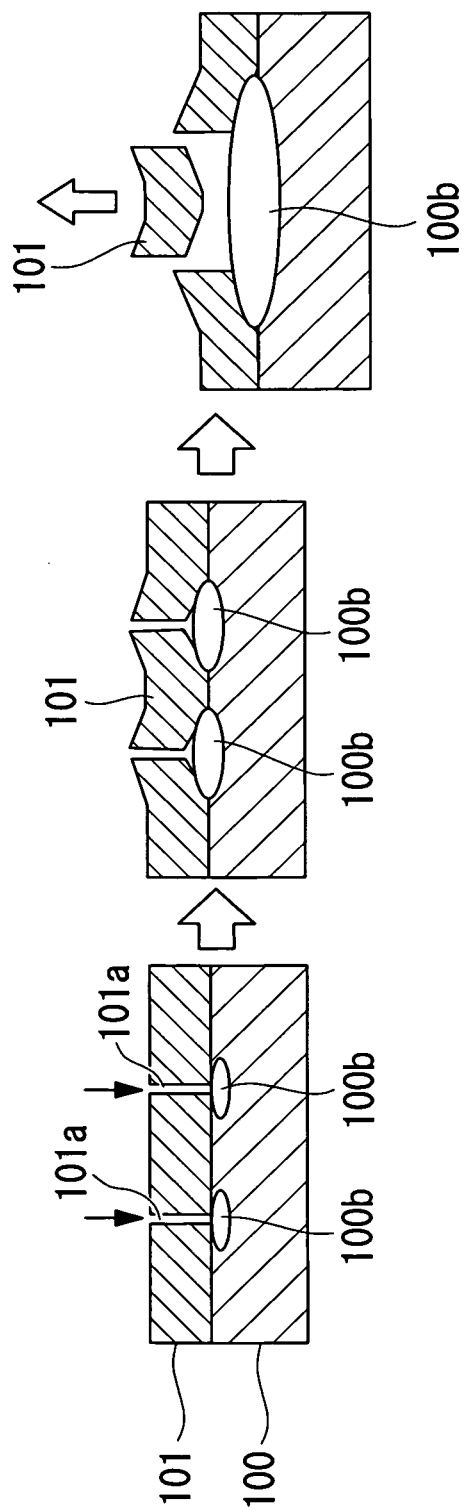


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/072151

A. CLASSIFICATION OF SUBJECT MATTER

C23C18/52(2006.01)i, C23C18/31(2006.01)i, C23C18/34(2006.01)i, C23F1/28
(2006.01)i, F04D29/02(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C18/00-20/08, C23F1/28, F04D29/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2008

Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

JSTPlus(JDream2, MUDENKAI Ni-P*ETCHINGU) (in Japanese)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 8-283955 A (Seiko Seiki Kabushiki Kaisha), 29 October, 1996 (29.10.96), Claim 1; Par. Nos. [0029] to [0039] (Family: none)	1-6
Y	JP 2005-206866 A (Fuji Electric Device Technology Co., Ltd.), 04 August, 2005 (04.08.05), Claim 1; Par. Nos. [0007] to [0010] (Family: none)	1-6
Y	JP 2006-28207 A (Polyplastics Co., Ltd.), 02 February, 2006 (02.02.06), Par. No. [0032] (Family: none)	2-6

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search
08 February, 2008 (08.02.08)

Date of mailing of the international search report
19 February, 2008 (19.02.08)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/072151

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2004-323913 A (Nihon Parkerizing Co., Ltd.), 18 November, 2004 (18.11.04), Claim 6; Par. No. [0022] (Family: none)	2-6
Y	JP 54-25225 A (Hitachi, Ltd.), 26 February, 1979 (26.02.79), Claims (Family: none)	2-6
Y	JP 5-86483 A (Hitachi, Ltd.), 06 April, 1993 (06.04.93), Claims & KR 9411251 B	6
Y	JP 7-27131 A (Ricoh Co., Ltd.), 27 January, 1995 (27.01.95), Par. Nos. [0032], [0033] & US 5769544 A	6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003147548 A [0004]