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(54) METHODS OF PLATING OR COATING ULTRASOUND TRANSDUCERS

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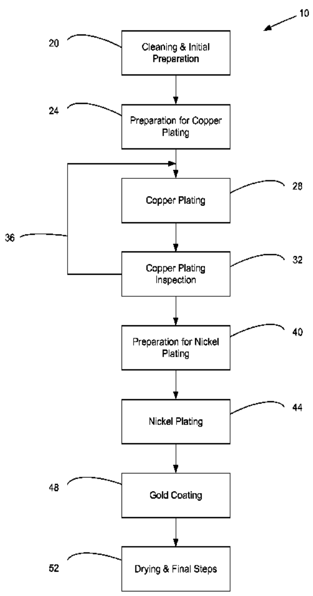
(57) ABSTRACT

According to some embodiments, a method of depositing at least one electrode on a base member of an ultrasound transducer comprises at least partially etching a surface of the base member using a first etching agent, catalyzing the surface of the base member using a first catalyst, plating copper on the surface of the base member using an electroless plating process, inspecting the copper plated on the surface of the base member, at least partially etching a surface of the copper-plated surface using a second etching agent, catalyzing the copper-plated surface using a second catalyst, plating nickel on the copper-plated surface using an electroless plating process and depositing at least one layer of gold on the nickel-plated surface.

19 Claims, 1 Drawing Sheet



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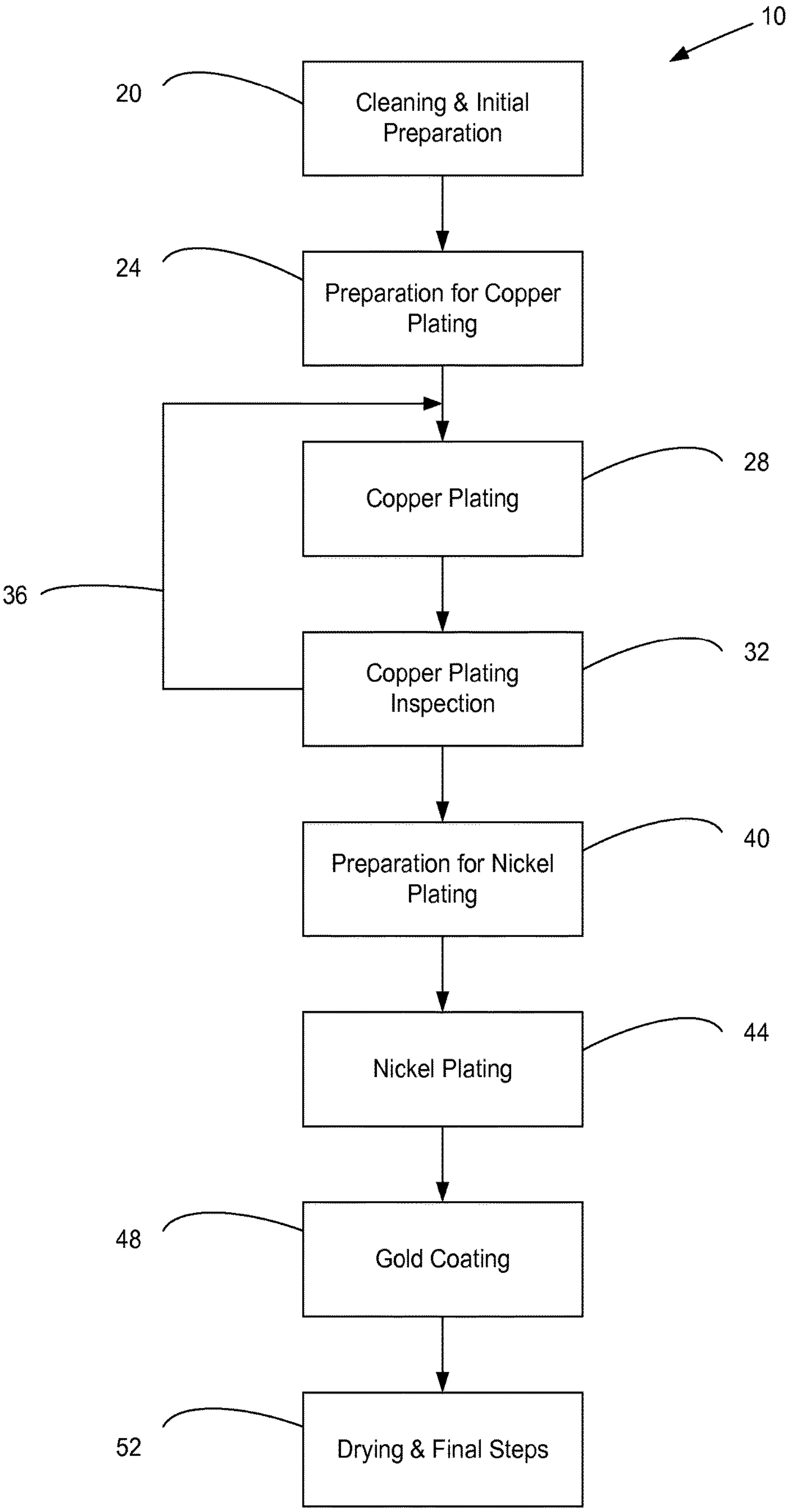
10
20
Cleaning & Initial Preparation
24
Preparation for Copper Plating
28
Copper Plating
36
32
Copper Plating Inspection
40
Preparation for Nickel Plating
44
Nickel Plating
48
Gold Coating
52
Drying & Final Steps

METHODS OF PLATING OR COATING ULTRASOUND TRANSDUCERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application No. 61/784,164, filed Mar. 14, 2013, the entirety of which is hereby incorporated by reference herein.

BACKGROUND

Field

This application relates generally to ultrasound transducers, and more specifically, to methods of plating or otherwise coating ceramic tubes to produce the electrodes of the transducer.

Description of the Related Art

Ultrasound transducers can comprise a ceramic base material having inner and/or outer electrodes that are electrically energized to produce acoustic energy. Therefore, methods of positioning the electrodes onto the surfaces of an ultrasound transducer are disclosed herein.

SUMMARY

According to some embodiments, a method of depositing at least one electrode on a base member of an ultrasound transducer comprises cleaning a base member with a cleaning agent, wherein the base member comprises a ceramic material. The method further comprises at least partially etching a surface of the base member using a first etching agent (e.g., an acid), catalyzing the surface of the base member using a first catalyst (e.g., a solution comprising palladium), plating copper on the surface of the base member using an electroless plating process, inspecting the copper plated on the surface of the base member, at least partially etching a surface of the copper-plated surface using a second etching agent (e.g., an acid), catalyzing the copper-plated surface using a second catalyst (e.g., a solution comprising palladium), plating nickel on the copper-plated surface using an electroless plating process and depositing at least one layer of gold on the nickel-plated surface.

According to some embodiments, the cleaning agent comprises a degreaser, an alcohol and/or the like. In some embodiments, the first etching agent and the second etching agent comprises an acid (e.g., Citranox, H2SO4, etc.). In some embodiments, plating copper on the surface of the base member comprises placing the base member in a copper bath. In some embodiments, inspecting the copper plated on the surface of the base member comprises verifying a thickness of copper plated on the base member, verifying a uniformity of plating along the base member and/or any other aspect of the quality and extent of the copper plating. According to some embodiments, if the base member does not meet at least one threshold requirement of the inspection, the method further comprises re-plating copper on the surface of the base member using an electroless plating process.

According to some embodiments, the second catalyst comprises a sulfate anion-based solution. In some embodiments, plating nickel on the copper-plated surface comprises placing the ultrasound transducer in a bath comprising high-phosphorus nickel. In some embodiments, depositing at least one layer of gold on the nickel-plated surface comprises immersing a monolayer of gold along the nickel-plated surface.

According to some embodiments, a thickness of copper along the surface of the base member is approximately 10-20 microinches (e.g., 15 microinches, 10-12, 12-14, 14-16, 16-18, 18-20 microinches, etc.). In some embodiments, a thickness of nickel along the copper-coated surface is approximately 100-200 microinches (e.g., 150 microinches, 100-120, 120-140, 140-160, 160-180, 180-200 microinches, etc.). In some embodiments, a thickness of gold along the nickel-coated surface is approximately 0.1-10 microinches (e.g., 5 microinches, 0-1, 1-2, 2-3, 4-5 microinches, etc.).

According to some embodiments, the base member comprises cylindrical shape. In some embodiments, the copper, nickel and gold are deposited along exterior and interior surface of the base member. In one embodiment, the base member comprises a piezoceramic material (e.g., PZT). In some embodiments, at least one electrode is deposited on a plurality of base members using a batch procedure (e.g., using a wire rack, a barrel system, etc.). In some embodiments, the base member is cut from a larger bulk member (e.g., a long ceramic cylinder).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates a flowchart of depositing an electrode on a base member of an ultrasound transducer according to one embodiment.

DETAILED DESCRIPTION

In some embodiments, ultrasound transducers include a cylindrical shape comprising a base material. Such a base material can comprise a ceramic, such as for example, lead zirconate titanate (PZT), other piezoelectric ceramic materials and/or the like. In some embodiments, a long cylindrical tube of ceramic base material is cut and/or otherwise machined into smaller sections to make individual transducers having a desired length. After a base tube portion has been produced, one or more metal plating processes can be used to selectively deposit one or more electrodes thereon. As discussed herein, the electrodes can include one or more metals, alloys and/or other electrically conductive materials. One embodiment of a transducer plating method **10** is shown schematically in the flowchart of FIG. **1**. In any of the embodiments disclosed herein, a plurality of the cylindrical tubes can be prepared and coated at the same time, e.g., in a batch system. For example, in some embodiments, a plurality of transducer tubes is positioned in a rack system (e.g., wire rack), a barrel system and/or the like. Accordingly, the multiple tubes can be simultaneously submerged, at least partially, into one or more baths or solutions during the preparation, plating and/or other manufacturing steps.

Cleaning and Initial Preparation

In some embodiments, machining oil, other oils, grease, natural coatings or layers and/or other materials are used to produce the individual tube lengths. Thus, it may be desirable or required to clean and otherwise prepare **20** the tubes before beginning the coating process. For example, in some embodiments, the process includes degreasing the tube using an ultrasonic degreaser, alcohol-based cleaner and/or any other cleaning product or agent. As noted above, the tubes can be submerged or otherwise placed within a bath (e.g., degreasing solution). After a particular time period of exposure to the degreaser or other cleaner (e.g., ~1 minute), the tubes can be removed and placed in a deionized water solution or bath (e.g., for ~1 minute) to remove excess degreaser and/or other cleaning solution.

Next, in one embodiment, the surface of the tube can be further cleaned using an acid cleaner and/or other etching material. For example, the tube can be placed in a Citranox® solution or other relatively weak acid solution for about 1 minute. This can help remove additional unwanted layers, coatings and/or materials from the exposed, exterior surfaces (e.g., inner and outer) of the tube. In some embodiments, such a weak acid cleaning step at least partially etches the outer surfaces of the tube. A water rinse (e.g., using deionized water) can be used to remove excess acid cleaner from the tube.

Preparation for Copper Plating

In some embodiments, the tubes are initially plated with copper. Certain preparatory steps **24** can be taken, in some embodiments, in advance of the copper plating process. For example, the tube can be placed in a strong acid solution, such as, e.g., a 10% solution of HBF4 and Acetate. In one embodiment, the tube is exposed to this solution for about 90 seconds. As a result of such an exposure, the tube's outer surfaces can be at least partially etched. This can help remove lead and/or other undesirable substances that may interfere with the subsequent copper plating steps. In some embodiments, care must be taken to prevent damage to the geometry of the tube. In other words, if an excessive amount of etching is performed, the cylindrical shape of the tube can be changed, thereby negatively impacting the acoustic energy profile of the transducer. For example, if the tube is not cylindrical within a particular tolerance level, the acoustic energy emitted by the transducer may be unevenly delivered in the radial direction (e.g., creating hot spots, spots of lower energy intensity, etc.).

Once the tube has been adequately etched, it can be rinsed to remove any excess etching solution or material. For example, in one embodiment, the tube can be subjected to one, two or more deionized water rinses. For example, in some embodiments, the tubes are subjected to two separate deionized water rinse cycles, each of which can last about 30 seconds.

In some embodiments, the transducer tube is then subjected to a clean copper dummy load solution, e.g., a 10% solution of HBF4 for about 1 minute. Such a step can help make the outer and inner surfaces of the tube more reactive for the subsequent copper plating step. In some embodiments, one or more sheets or other members comprising copper are positioned within a bath or solution into which the tube is placed. For example, in some embodiments, about ½ square foot of surface area of one or more copper-containing components (e.g., plates) are placed in the bath about 1 to 5 minutes prior to starting the actual copper plating procedure.

Following its exposure to copper dummy load solution, the transducer tube can be rinsed during a water rinse stage. In some embodiments, the tube can be rinsed, for example, using deionized water for about 30 seconds.

Copper Plating

With continued reference to FIG. **1**, in some embodiments, following the copper plating preparation step, the transducer tube can proceed to a copper plating process **28**. In one embodiment, the surfaces of the tube can be treated for the subsequent application of one or more plating catalysts. For example, the tube can be exposed to Enthone 432 for about 1 minute. In some arrangements, the Enthone or other preparatory solution is exposed to one or more rinsing steps. For example, the tube can go through two rinsing steps using deionized water, each of which can last about 20 seconds.

Next, in some embodiments, the surfaces of the transducer tube can be catalyzed, at least in part, with palladium. For example, the tube can be placed in a bath of Enthone 440 for about 3 minutes. In some embodiments, the palladium is a catalyst to assist in the subsequently plating of copper onto the tube surface. One or more other catalysts can be used, either in lieu of or in addition to palladium. Excess Enthone 432 and/or other palladium-containing solution can then be removed using a quick dip procedure.

Once the surfaces of a transducer tube have been prepared, it can be placed in a bath or other solution of Enthone 406 to allow the copper to plate onto the tube. For example, in some embodiments, the tubes are kept in such a bath for about 10 minutes. In some embodiments, such a plating process can result in a copper coating on the tube of about 10-20 microinches (e.g., 15 microinches).

Copper Plating Inspection

In some embodiments, if, after an inspection phase **32**, it is determined that the plating of the copper is inadequate (e.g., insufficient plating thickness, non-uniform plating, etc.), the tube can be exposed to another copper plating cycle **28**. Thus, as schematically illustrated by step **36** in FIG. **1**, the need to begin the plating process from the beginning (e.g., step **20** or **24** in FIG. **1**) can be eliminated. This type of short-circuiting step **36** in the process **10** can reduce manufacturing time, simplify the manufacturing protocol and provide one or more benefits and advantages. In some embodiments, the short-circuiting step **36** can be repeated up to about 4 times before a transduce tube is discarded.

Nickel Plating Preparation

If the copper plating is satisfactory, the tube can be subjected to subsequent nickel plating steps. In some embodiments, after the copper plating and inspection steps **28**, **32**, the tube can proceed to a nickel plating preparatory process **40**. For example, the tube can be rinsed using a deionized water rinse for about 20 seconds before being exposed to an etching step. In some embodiments, the copper-plated tube can be at least partially etched in a 10% H_2SO_4 solution for about 30 seconds. The use of H_2SO_4 can provide a better match for the sulfate anion used in the previous copper plating steps, thereby facilitating the nickel plating process.

In some embodiments, once the copper-plated tube has been etched, it can be subjected to a palladium catalyst solution (e.g., TechniCatalyst AT 4000). For example, the tube can be placed in a palladium catalyst solution for about 2 minutes. In some embodiments, the palladium catalyst solution comprises a sulfate ion activator. In some embodiments, the palladium catalyst solution does not comprise a chloride ion activator. After exposure to the palladium catalyst, the copper dummy load can be terminated and the tube can be rinsed to remove any excess palladium catalyst solution (e.g., using deionized using a quick dip procedure).

Nickel Plating

In some embodiments, the transducer tube can then proceed to the nickel plating process **44**. For example, the tube can be placed in a nickel solution for approximately 15 minutes. In some embodiments, the nickel solution comprises a high-phosphorus nickel solution (e.g., NICHEM 5100). As a result of the exposure to such a nickel solution, in some embodiments, about 100-200 microinches (e.g., 150 microinches) of nickel can be electroplated onto the outside surface of the transducer tube (e.g., over the electroplated copper layer). After the nickel has been adequately plated on the outside surfaces of the transducer tube, excess nickel solution can be removed by rinsing the tube with deionized water for about 20 seconds.

Gold Immersion

In some embodiments, a layer of gold can be positioned **48** along the outside of the copper and nickel layers that have been plated on the transducer tube. For example, the gold can be immersed as a monolayer onto the outside of the tube. In other embodiments, more than one layer (e.g., 2, 3, more than 3, etc.) layers of gold are used, as desired or required. In some embodiments, the tube is subjected to an immersion of gold (e.g., OMG Fidelity 9027+potassium gold) for about 2 minutes. The use of such an immersion layer can eliminate or reduce the likelihood of complications resulting from electrolytic plating of gold onto the surfaces of the cylinder, especially within the interior surfaces of relatively small cylinders. Therefore, in some embodiments, the gold is placed onto the transducer tube without using an electrolytic process. In some embodiments, the thickness of the gold monolayer deposited on the tube (e.g., along the outside of the copper and nickel layers) is about 2-10 microinches (e.g., 5 microinches). Following the gold immersion process, any excess gold can be removed from the outside of the tube using deionized water rinse (e.g., for about 20 seconds).

Drying and Completion

According to some embodiments, after the desired layers of copper, nickel, gold and/or any other material have been placed along the outside of the transducer tube, the tube can undergo one or more finishing steps **52**. For example, an alcohol rinse (comprising, e.g., isopropyl alcohol) can be used to remove any excess water and to facilitate drying of the outer surfaces of the tube. Finally, in some embodiments, the tube can be placed in an oven or other thermal environment to remove the alcohol and dry the tube.

A transducer tube plated and/or otherwise coated in accordance with the various embodiments disclosed herein can include three different metals, such as, for example, a copper base layer, a nickel intermediate layer and a gold outer layer. In some embodiments, the thickness of the various metals placed on the tube can be about 150-200 microinches. For example, in one embodiment, a transducer can include a base layer of copper, an intermediate layer of nickel and an outer layer of gold having thicknesses of about 15 microinches, 150 microinches and 5 microinches, respectively. IN other embodiments, the thickness of one or more layers can vary, as desired or required.

Additional details regarding possible ultrasonic transducer designs and embodiments (e.g., both structurally and operationally) are provided in U.S. patent application Ser. No. 11/267,123, filed on Jul. 13, 2001 and published as U.S. Publ. No. 2002/0068885 on Jun. 6, 2002 and issued as U.S. Pat. No. 7,540,846 on Jun. 2, 2009; U.S. patent application Ser. No. 09/905,227, filed Jul. 13, 2001 and issued as U.S. Pat. No. 6,635,054 on Oct. 21, 2003; U.S. patent application Ser. No. 09/904,620, filed on Jul. 13, 2001 and issued as U.S. Pat. No. 6,763,722 on Jul. 20, 2004; U.S. patent application Ser. No. 10/783,310, filed Feb. 20, 2004 and issued as U.S. Pat. No. 7,837,676 on Nov. 23, 2010; U.S. patent application Ser. No. 12/227,508, filed on Feb. 3, 2010 and published as U.S. Publ. No. 2010/0130892 on May 27, 2010; U.S. patent application Ser. No. 10/611,838, filed on Jun. 30, 2003 and published as U.S. Publ. No. 2004/0082859 on Apr. 29, 2004 Now abandoned; and PCT Appl. No. PCT/US2011/025543, filed on Feb. 18, 2011 and published as PCT Publ. No. WO 2012/112165 on Aug. 23, 2012. The entireties of all the foregoing applications is hereby incorporated by reference herein and made a part of the present application.

The features and attributes of the specific embodiments disclosed herein may be combined in different ways to form additional embodiments, all of which fall within the scope of the present disclosure. Although the concepts presented herein have been disclosed in the context of certain embodiments and examples, the present application extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the concepts disclosed herein and obvious modifications and equivalents thereof. The disclosure herein of any particular feature, aspect, method, property, characteristic, quality, attribute, element, or the like in connection with an embodiment can be used in all other embodiments set forth herein. The ranges disclosed herein also encompass any and all overlap, sub-ranges, and combinations thereof. Language such as "up to," "at least," "greater than," "less than," "between," and the like includes the number recited. Numbers preceded by a term such as "about" or "approximately" include the recited numbers. For example, "about 10 mm" includes "10 mm." For all of the embodiments described herein the steps of the methods need not be performed sequentially. Thus, it is intended that the scope of the concepts disclosed herein should not be limited by the particular disclosed embodiments described above.

What is claimed is:

1. A method of depositing at least one electrode on a base member of an ultrasound transducer, the method comprising:

cleaning a base member with a cleaning agent, wherein the base member comprises ceramic;

at least partially etching a surface of the base member using a first etching agent comprising a solution of tetrafluoroboric acid and acetate;

catalyzing the surface of the base member using a first catalyst;

plating copper on the surface of the base member using an electroless plating process such that the copper is adjacently deposited onto the base member;

inspecting the copper plated on the surface of the base member;

at least partially etching a surface of the copper-plated surface using a second etching agent;

catalyzing the copper-plated surface using a second catalyst;

plating nickel on the copper-plated surface using an electroless plating process; and

depositing at least one layer of gold on the nickel-plated surface.

2. The method of claim **1**, wherein the cleaning agent comprises at least one of a degreaser and an alcohol.

3. The method of claim **1**, wherein the second etching agent comprises an acid.

4. The method of claim **1**, wherein at least one of the first catalyst and the second catalyst comprises palladium.

5. The method of claim **1**, wherein plating copper on the surface of the base member comprises placing the base member in a copper bath.

6. The method of claim **1**, wherein the second catalyst comprises a sulfate anion-based solution.

7. The method of claim **1**, wherein plating nickel on the copper-plated surface comprises placing the ultrasound transducer in a bath comprising high-phosphorus nickel.

8. The method of claim **1**, wherein depositing at least one layer of gold on the nickel-plated surface comprises immersing a monolayer of gold along the nickel-plated surface.

9. The method of claim **1**, wherein a thickness of copper along the surface of the base member is approximately 15 microinches.

10. The method of claim **1**, wherein a thickness of nickel along the copper-coated surface is approximately 150 micro-inches.

11. The method of claim **1**, wherein a thickness of gold along the nickel-coated surface is approximately 5 micro-inches.

12. The method of claim **1**, wherein the base member is cut from a larger bulk member.

13. The method of claim **1**, wherein inspecting the copper plated on the surface of the base member comprises at least one of verifying a thickness of copper plated on the base member and verifying a uniformity of plating along the base member.

14. The method of claim **13**, wherein, if the base member does not meet at least one threshold requirement of the inspection, the method further comprises re-plating copper on the surface of the base member using an electroless plating process.

15. The method of claim **1**, wherein the base member comprises cylindrical shape.

16. The method of claim **15**, wherein the copper, nickel and gold are deposited along exterior and interior surface of the base member.

17. The method of claim **1**, wherein at least one electrode is deposited on a plurality of base members using a batch procedure.

18. The method of claim **17**, wherein the plurality of base members is positioned on a wire rack.

19. The method of claim **17**, wherein the plurality of base members is positioned in a barrel system.

* * * * *

专利名称(译)	电镀或涂覆超声换能器的方法		
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IPC分类号	H01L41/297 C23C18/54 C23C18/18 C23C18/16 H01L41/29 A61B8/00 B06B1/06 C23C18/36 C23C18/38		
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摘要(译)

根据一些实施例，一种在超声换能器的基座构件上沉积至少一个电极的方法包括使用第一蚀刻剂至少部分地蚀刻基座构件的表面，使用第一催化剂催化基座构件的表面，使用化学镀工艺在基底构件的表面上镀铜，检查镀在基底构件表面上的铜，使用第二蚀刻剂至少部分地蚀刻镀铜表面的表面，催化镀铜使用第二催化剂的表面，使用化学镀工艺在镀铜表面上镀镍，并在镀镍表面上沉积至少一层金。