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# (54) CAPACITIVE ULTRASONIC TRANSDUCER AND METHOD OF FABRICATING THE SAME

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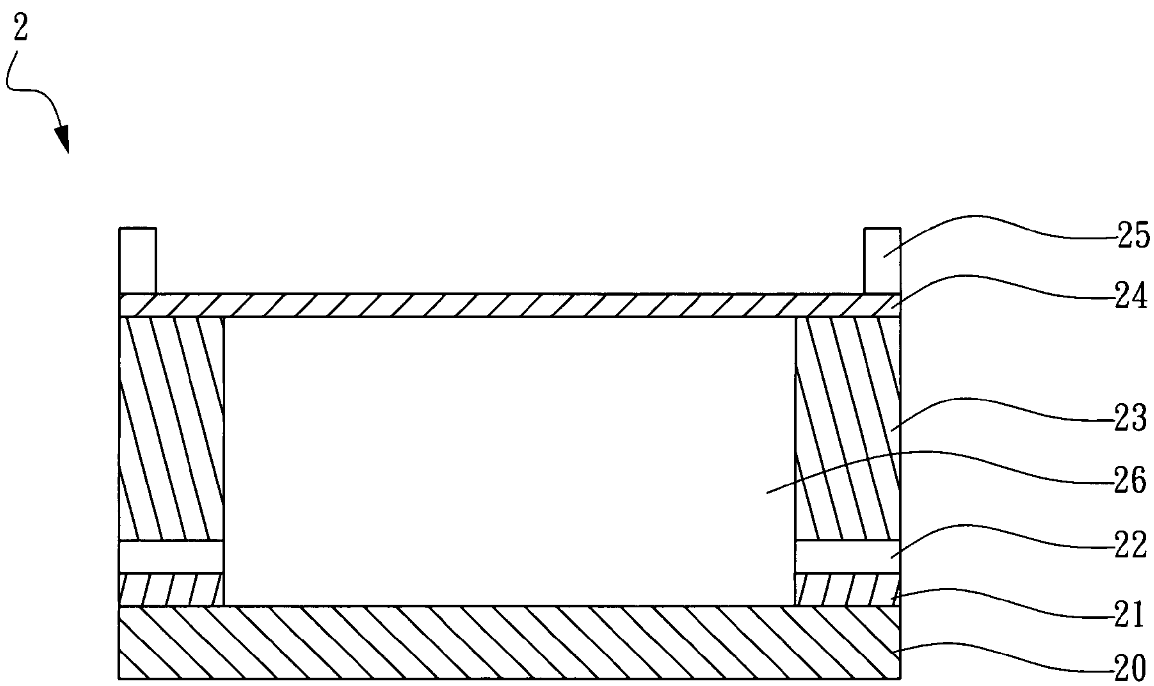
(57) **ABSTRACT**

A capacitive ultrasonic transducer and method of fabricating the same are disclosed, whereas the capacitive ultrasonic transducer is a stacking of multiple metal layers. The fabrication method of the invention is characterized in that: the structure and cavity of excitation are formed by lithographing and etching the sacrificial layer and other stacking layers, whereas the sacrificial layer and the other stacking layer are made of metal, and moreover, a protective bulk is formed on the capacitive ultrasonic transducer by a means of metal depositing. It is noted that not only the structure of capacitive ultrasonic transducer of the invention has a bulk for protection, which is different to that of a conventional capacitive ultrasonic transducer, but also the method of fabricating the same can do without the steps of electrode formation, high-temperature processing and annealing, which enable the method to have simplified process and thus cost less than that of conventional methods. The capacitive ultrasonic transducer can be integrated into a variety of integrated circuit that enables the same to be vastly implemented in consumer electronic products, and products of bio-medical science and other engineering fields.



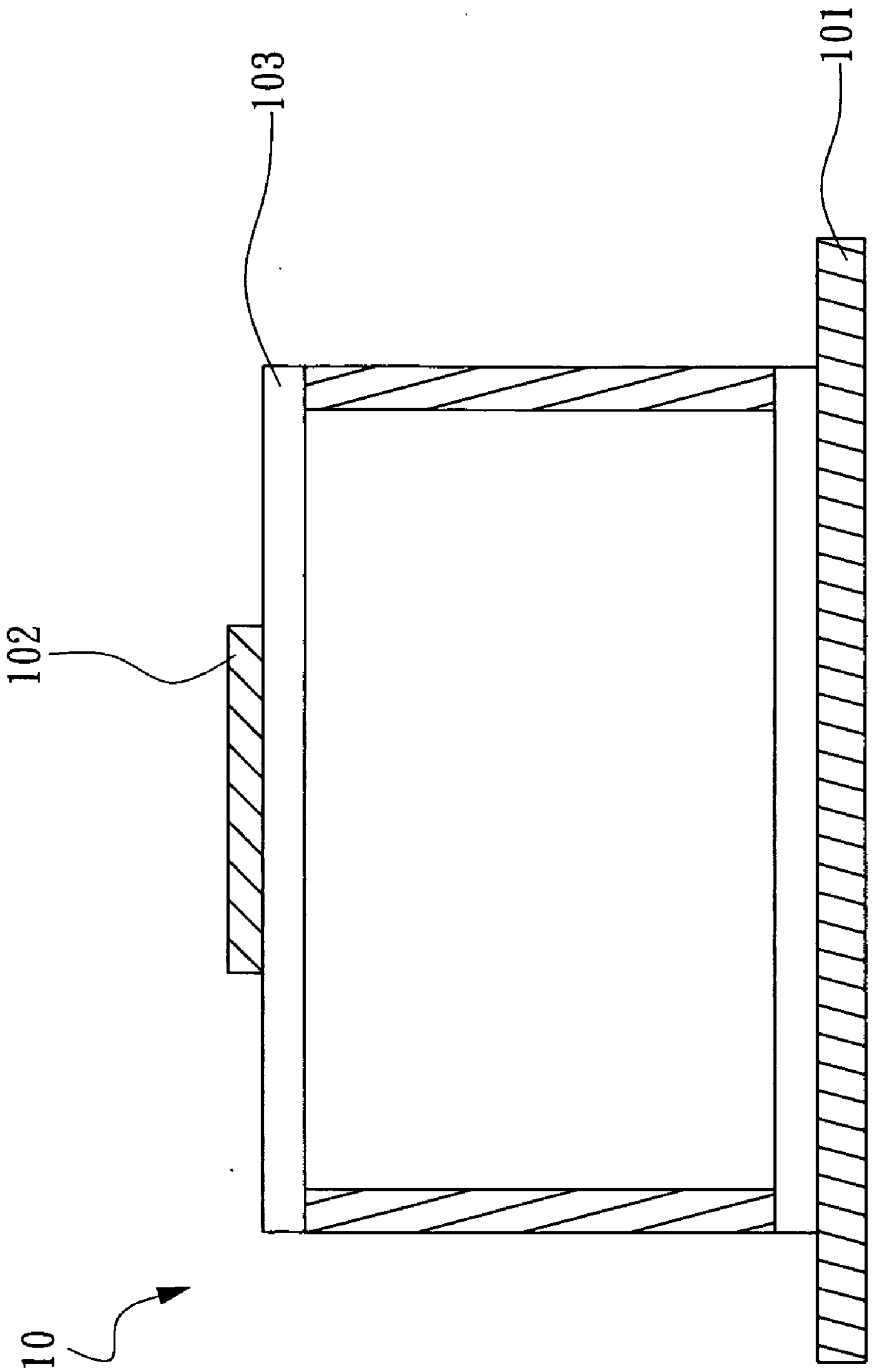



FIG. 1A(Prior Art)

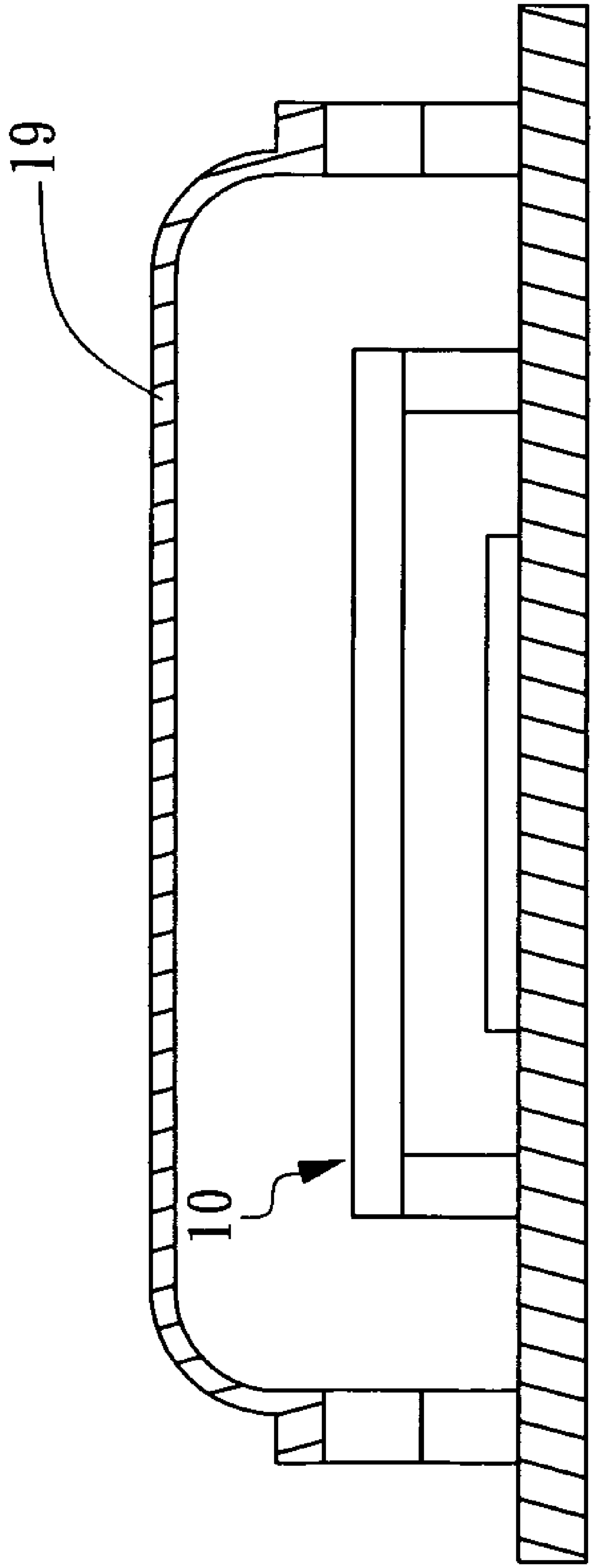



FIG. 1B(Prior Art)

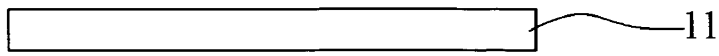



FIG. 2A
(Prior Art)

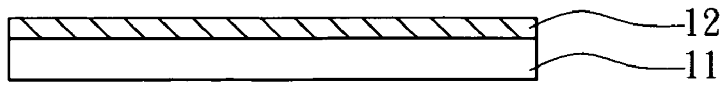



FIG. 2B
(Prior Art)

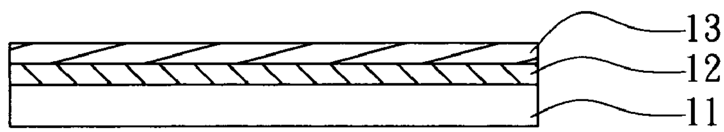



FIG. 2C
(Prior Art)

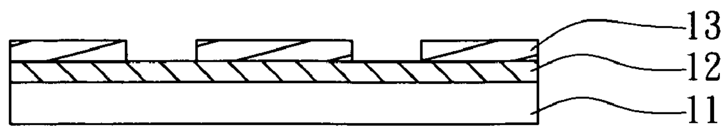



FIG. 2D
(Prior Art)

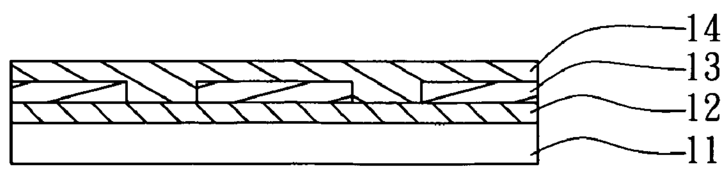



FIG. 2E
(Prior Art)

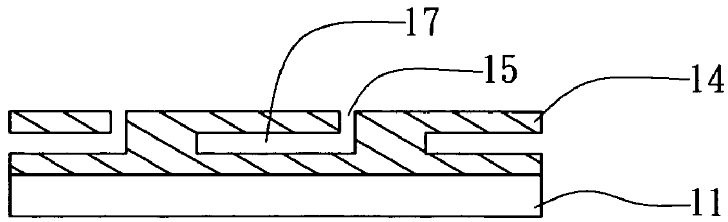



FIG. 2F
(Prior Art)

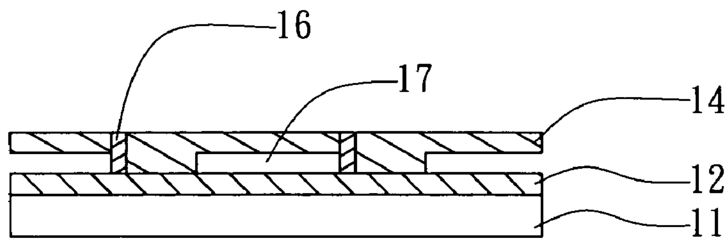



FIG. 2G
(Prior Art)

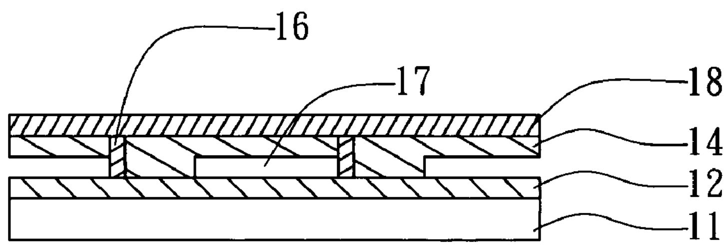



FIG. 2H
(Prior Art)

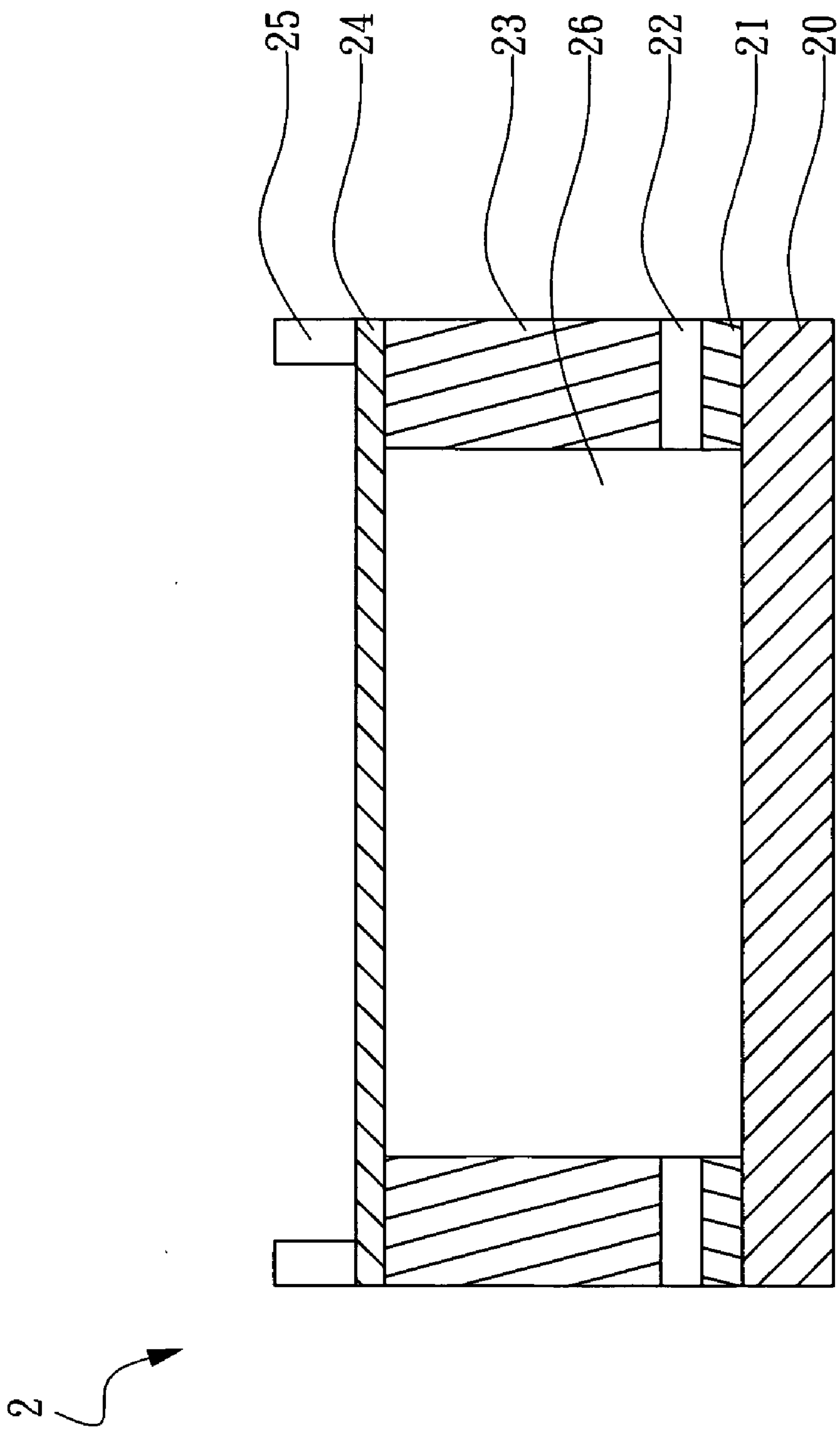



FIG. 3

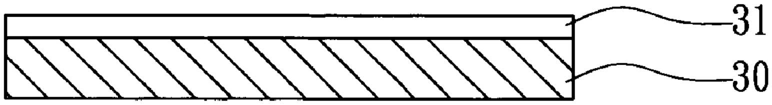



FIG. 4A

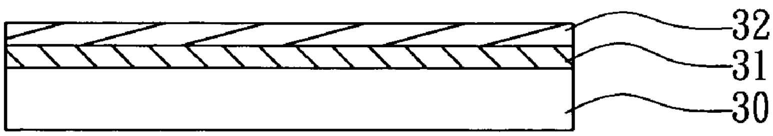



FIG. 4B

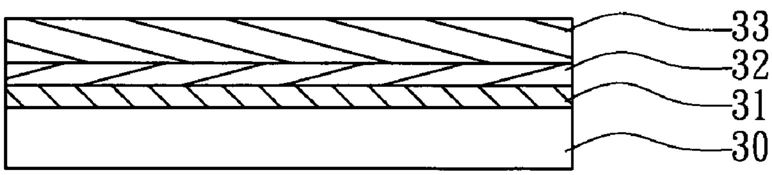



FIG. 4C

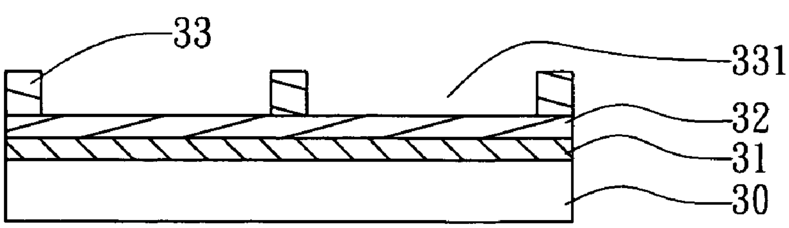



FIG. 4D

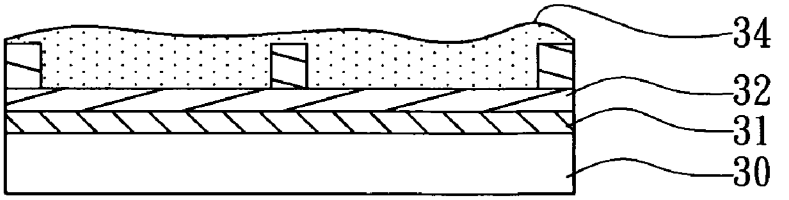



FIG. 4E

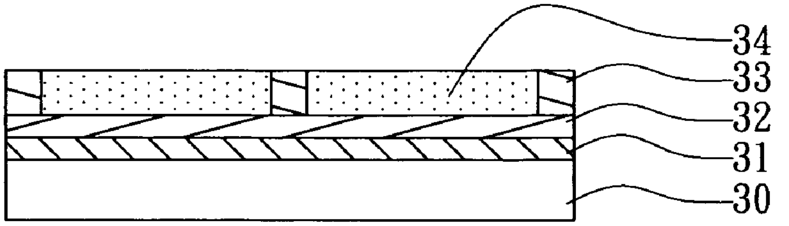



FIG. 4F

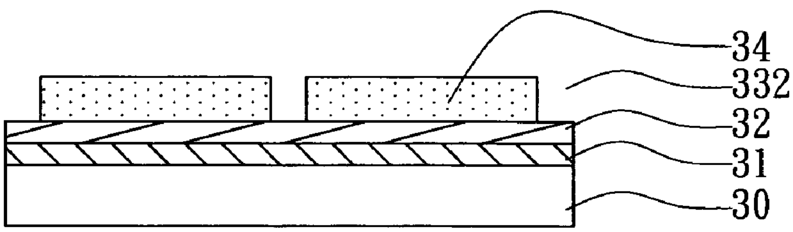



FIG. 4G

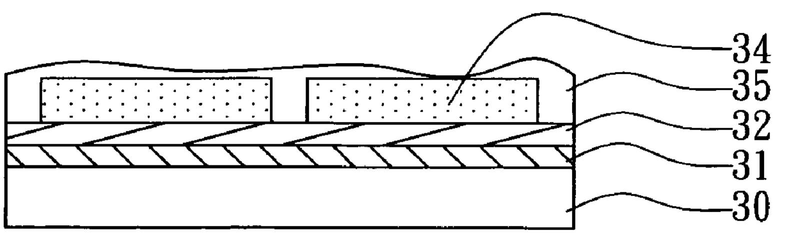



FIG. 4H

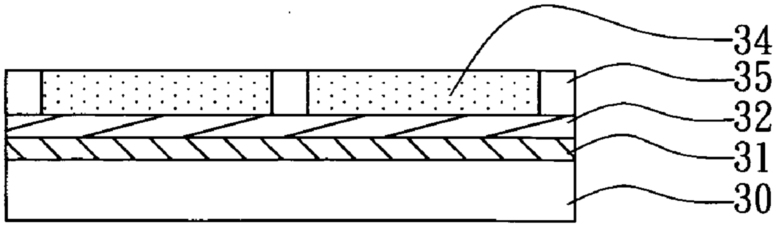



FIG. 4I

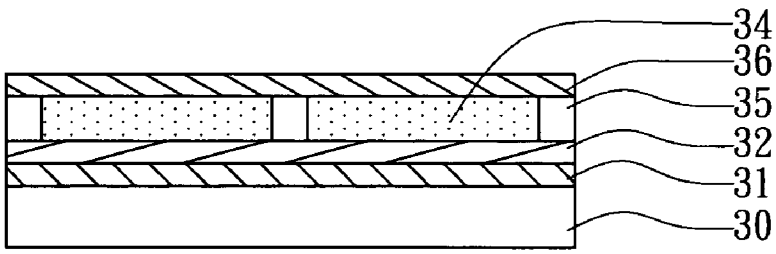



FIG. 4J

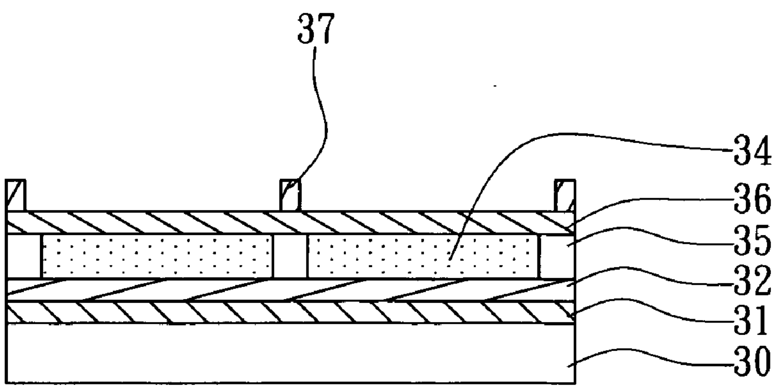



FIG. 4K

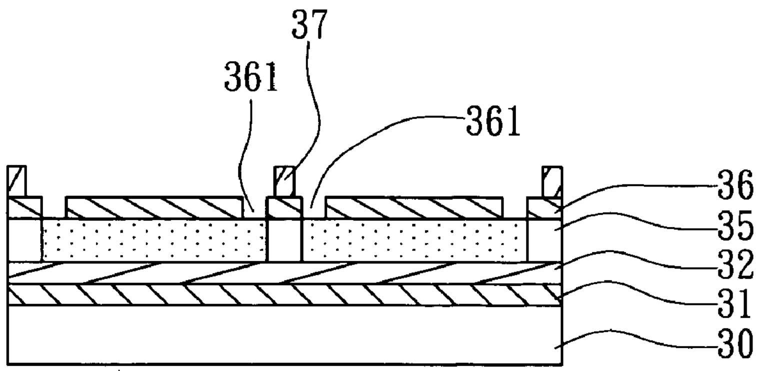



FIG. 4L

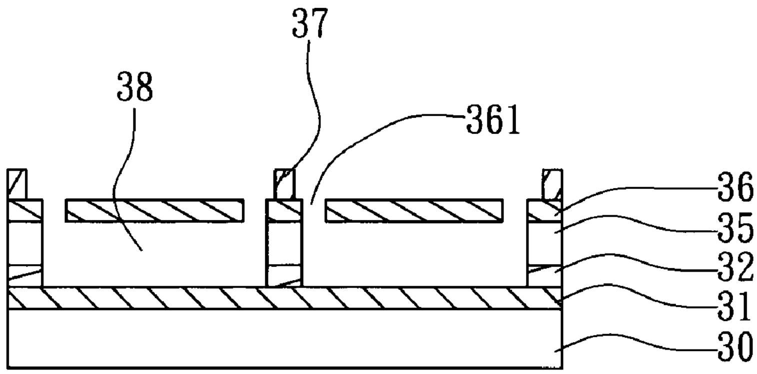



FIG. 4M

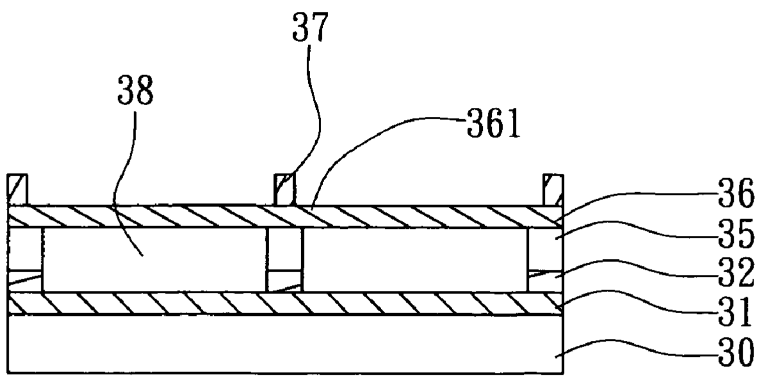



FIG. 4N

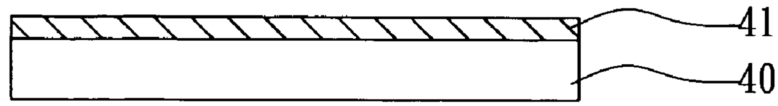



FIG. 5A

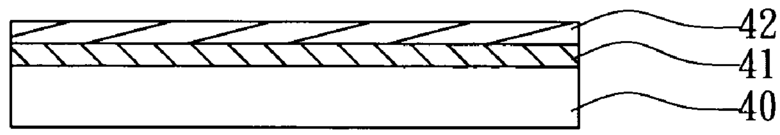



FIG. 5B

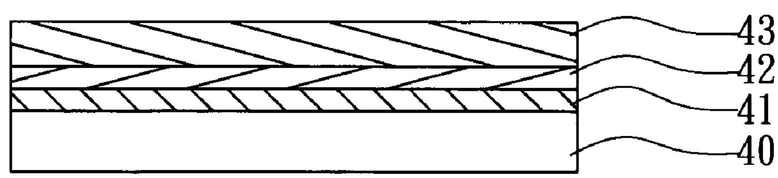



FIG. 5C

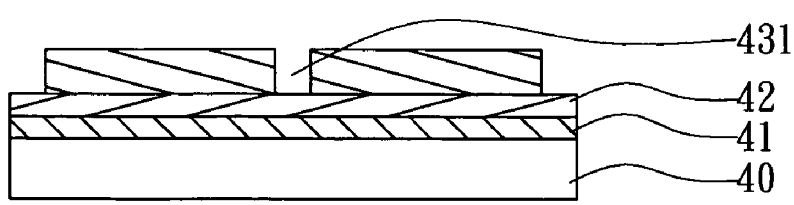



FIG. 5D

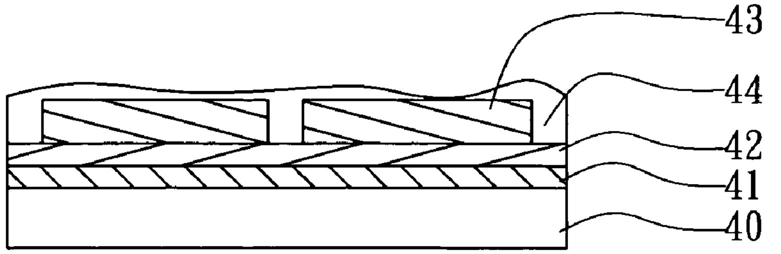



FIG. 5E

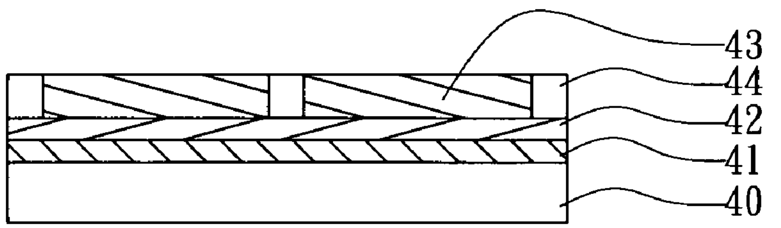



FIG. 5F

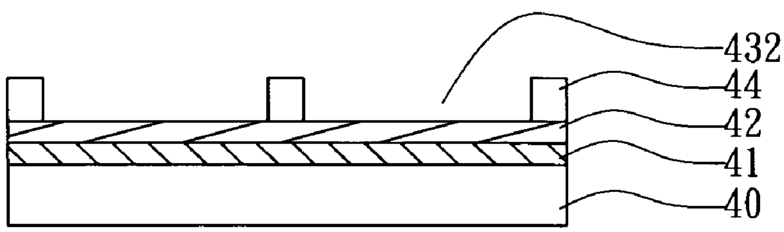



FIG. 5G

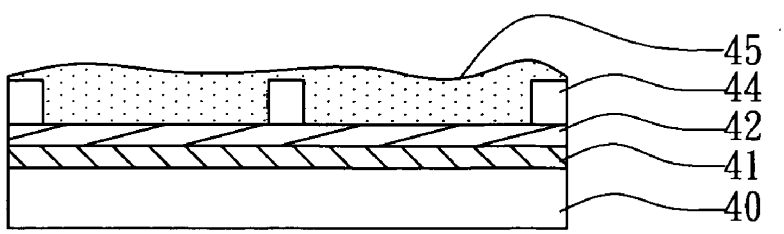



FIG. 5H

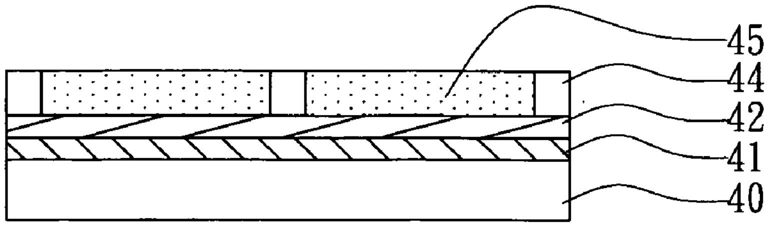



FIG. 5I

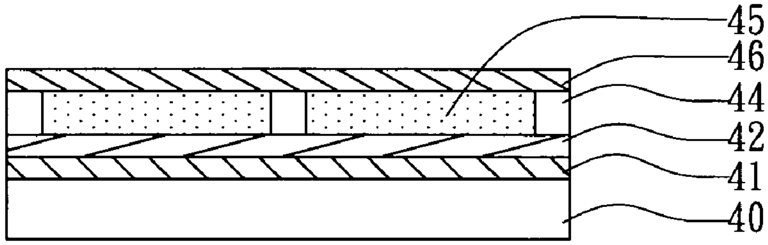



FIG. 5J

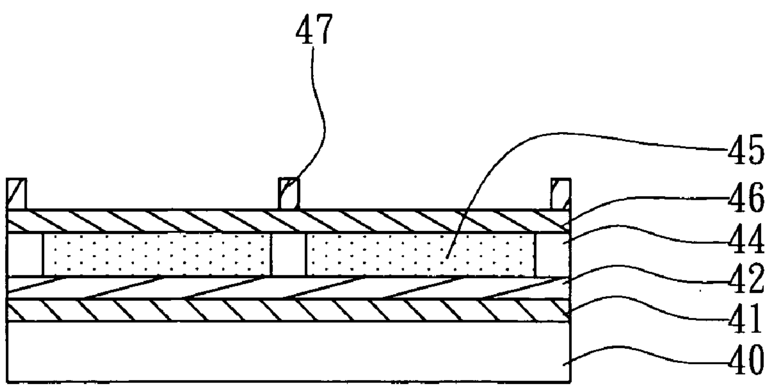



FIG. 5K

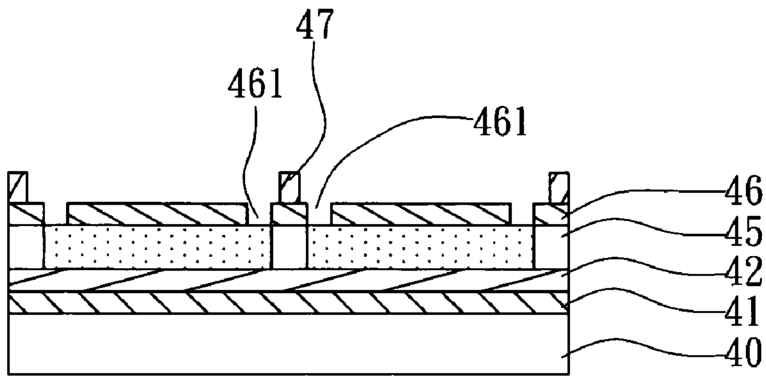



FIG. 5L

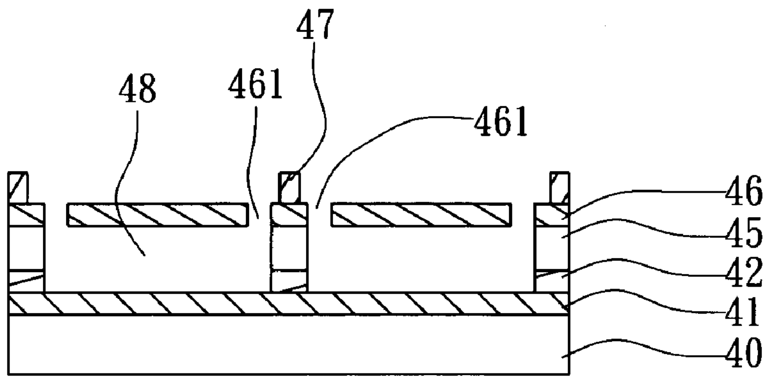



FIG. 5M

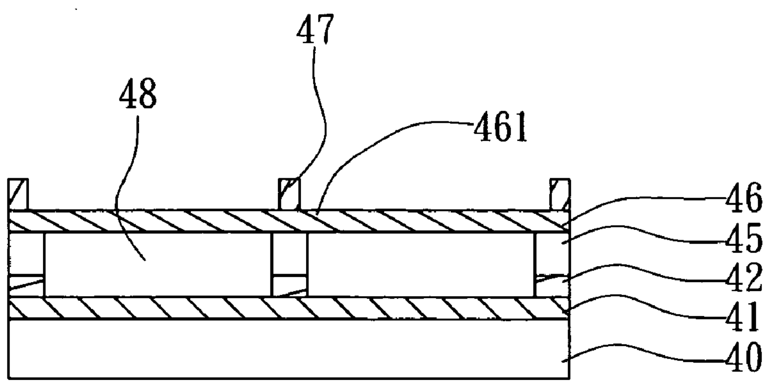



FIG. 5N

# CAPACITIVE ULTRASONIC TRANSDUCER AND METHOD OF FABRICATING THE SAME

## FIELD OF THE INVENTION

[0001] The present invention relates to a capacitive ultrasonic transducer and method of fabricating the same, and more particularly, to a capacitive ultrasonic transducer, which is substantially a stacking of multiple metal layers having structures and cavities of excitation being formed therein by electrochemical depositing/etching and lithographing, and thus the method for fabricating the aforesaid transducer can waive the steps of electrode forming and annealing.

## BACKGROUND OF THE INVENTION

[0002] Ultrasonic imaging has found widespread use in industrial and medical applications. Flaw detection, thickness measurement, and diagnostic imaging are just a few of the tools utilizing this technology. All information acquired by the ultrasound system passes through the transducer before being processed and presented to the operator. Therefore, the performance characteristics of the transducer can significantly influence system performance, especially when the miniaturization of ultrasonic transducer is the trend of future development. It possesses several advantages over other techniques, like x-rays or magnetic resonance imaging (MRI), including being noninvasive, relatively inexpensive, portable, and capable of producing a tomographical image—an image of a two-dimensional slice of the body. Another very important advantage is that ultrasound produces images fast enough to monitor the motion of structures within the body, such as a fetus or a beating heart. Close attention should be paid to the design and fabrication of a proper transducer for the application, taking into consideration the performance of the imaging system as a whole.

[0003] Currently, the most commonly seen ultrasonic transducers are piezoelectric ultrasonic transducers, which require ceramic manufacturing processes and have acoustic impedance similar to a solid mass that it is not suitable for operating in a gaseous or liquid ambient. Therefore, capacitive micromachined ultrasonic transducers (CMUTs) have been considered an attractive alternative to conventional piezoelectric transducers in many areas of application, since the acoustic impedance match of a CMUT to air/liquid is closer than that of piezoelectric ultrasonic transducers, due to the small mechanical impedance of the thin transducer membrane. In addition, CMUTs provide the following advantages over piezoelectric transducers: (1) CMUTs can be batch produced with a standard IC process and thus integrated with IC devices, which is difficult with piezoelectric transducers since they require to be processed by a high-temperature process; (2) The frequency generated by a CMUT is in a frequency range of 200 KHz~5 MHz while a piezoelectric transducer is operating at a frequency range of 50 KHx~200 KHz, that has restricted the application of the piezoelectric transducers to a smaller area than that of the CMUTs.

[0004] Please refer to FIG. **1**A, which is schematic view of a conventional capacitive ultrasonic transducer. The configuration of the conventional capacitive ultrasonic transducer **10** is similarly to a parallel plane capacitor, by which a thin film is enabled to vibrate ultrasonically as alternating voltage signals are being applied on a fixed electrode **101** and another electrode **102** arranged on the thin film **103**.

[0005] There are many methods for fabricating conventional ultrasonic transducer currently available. One of which is the fabrication method shown in FIGS. **2**A~**2**H, which are diagrams depicting the successive steps of fabricating a conventional ultrasonic transducer. The fabrication method shown in FIGS. **2**A~**2**H is first developed by Jin, et al. at 1998, and is adapted for making an ultrasonic transducer suitable for operating in a gaseous or liquid ambient by the use of a technique of surface micromachining. The processing flow of the aforesaid method starts at the step shown in FIG. **2**A, where a highly silicon wafer **11** with high conductivity is provided and being used as a substrate; and then the flow proceeds to the step shown in FIG. **2**B. In FIG. **2**B, a layer of nitrides **12**, referred as first nitride layer, is formed on the substrate **11** at 800° C. ambient by a means of low-pressure chemical vapor deposition (LPCVC), and then the flow proceeds to the step shown in FIG. **2**C. In FIG. **2**C, a sacrificial layer **13** made of an amorphous silicon material is formed on the first nitride layer **12**, and then the flow proceeds to the step shown in FIG. **2**D. In FIG. **2**D, the sacrificial layer **13** is etched to form a plurality of hexagon islands by a means of dry etching, and then the flow proceeds to the step shown in FIG. **2**E. In FIG. **2**E, another layer of nitrides, referred as second nitride layer **14**, is deposited to cover the hexagon islands of the sacrificial layer **13** whereas a portion of the second nitride layer **14** is going to be used to form a plurality of thin films while another portion of the second nitride layer **14** is going to be used as frames for supporting the thin films, and then the flow proceeds to the step shown in FIG. **2**F. In FIG. **2**F, the second nitride layer **14** is etched to form a plurality of apertures **15** channeling to the corresponding hexagon islands of the sacrificial layer **13** and then the plural hexagon islands are removed by feeding a potassium hydroxide solution into the plural apertures **15** to form a plurality of excitation cavities **17** accordingly, and then the flow proceeds to the step shown in FIG. **2**G. In FIG. **2**G, the apertures are sealed by depositing silicon dioxide therein, and then the flow proceeds to the step shown in FIG. **2**H. In FIG. **2**H, a layer of aluminum **18** is coated on top of the structure of FIG. **2**G whereas the aluminum is being patterned to form top electrodes by a means of wet etching. It is know that the ultrasonic transducer made by the aforesaid method can have a dynamic range in excess of 110 dB is observed in air at 2.3 MHz, and a dynamic range in excess of 600 dB is observed in air at 3.5 MHz.

[0006] Furthermore, Cianci, et al. had developed a low-temperature process cooperating with a thermal annealing step for fabricating a capacitive ultrasonic transducer whereas the annealing is perform in a 510° C. ambient for 10 hours. By the aforesaid method, the pressure stress of the thin film of the capacitive ultrasonic transducer is eliminated while obtaining an ideal condition of preserving a slight tension stress exerting on the thin film. In addition, a further fabrication method of capacitive ultrasonic transducer is disclosed in U.S. Pat. No. 6,632,178, entitled "FABRICATION OF CAPACITIVE MICROMACHINED ULTRASONIC TRANSDUCERS BY MICRO-STEREOLITHOGRAPHY", that the method can enhance the sensitivity of the cavity by forming a raised bottom electrode in a cavities corresponding thereto by a means of micro-stereolithography, since the height of the raised bottom electrode can be controlled at will.

[0007] There are a variety of ultrasonic transducers currently available and also corresponding methods of fabricating the same. Most of which are made of silicon-based material that are being processed by either a means of surface micromachining or a means of bulk micromachining so as to enable the resulting ultrasonic transducer to have thinner oscillation film and smaller excitation cavity and thus enable the same to have high vibration frequency, enhanced sensitivity and high resolution. It is also because of that, all those prior-art processes of fabricating capacitive ultrasonic transducer are commonly troubled by the problems of high processing temperature, high residual stress, complicated process that is hard to controlled, and high cost. Especially the problem of high residual stress will cause the oscillation film to deform. Therefore, an additional thermal annealing procedure is required to reduce the residual stress and thus alleviate the deformation of oscillation film caused by the same. Nevertheless, the additional annealing step will inevitably cause the time and cost of the fabrication process to increase.

[0008] Furthermore, since the oscillation film of a prior-art capacitive ultrasonic transducer is substantially a layer of silicon nitride deposited by a means of low-pressure chemical vapor deposition (LPCVC), the high residual stress caused by the high temperature ambient required for enabling the LPCVC deposition of silicon nitride not only will adversely affect the quality of the resulting capacitive ultrasonic transducer, but also the geometric size of the oscillation film is restricted by the same. In addition, the aforesaid prior-art ultrasonic transducers can be sealed and protected by a microcap **19** as shown in FIG. **1**B. However, the additional microcap is going to cause some technical problems, such as the positioning and alignment during packaging, the status of surface adhesion including roughness, phase variation, etc.

[0009] Therefore, it is in great need to have an improved capacitive ultrasonic transducer and method of fabricating the same.

## SUMMARY OF THE INVENTION

[0010] In view of the disadvantages of prior art, the primary object of the present invention is to provide an improved capacitive ultrasonic transducer and method of fabricating the same, whereas the capacitive ultrasonic transducer is substantially a stacking of multiple metal layers so that the manufacturing cost of the same can be reduced since an additional step of electrode formation can be saved from the method of fabricating the same.

[0011] Another object of the invention is to provide a capacitive ultrasonic transducer and method of fabricating the same, wherein the capacitive ultrasonic transducer is comprised of a protective bulk, being used for protecting the oscillation film and the main body of the capacitive ultrasonic transducer.

[0012] It is further another object of the invention to a capacitive ultrasonic transducer and method of fabricating the same, whereas the capacitive ultrasonic transducer is substantially a stacking of multiple metal layers being deposited by an electrochemical means and the cavity and the main body of the capacitive ultrasonic transducer are formed by lithographing and etching the sacrificial layer and other stacking layers out of the stacking, so that the method of fabricating the capacitive ultrasonic transducer can do without the high temperature step and the annealing step required in prior art and thus not only the efficiency of the fabrication process is enhanced, but also the manufacturing cost is reduced.

[0013] To achieve the above objects, the present invention provide a capacitive ultrasonic transducer, comprising: an assembly of supporting frames, being formed on a substrate; and a metal layer, being formed on top of the assembly; wherein at least a cavity is formed by the enclosure of the metal layer, the assembly of supporting frames and the substrate.

[0014] In a preferred aspect, at least a bulk, which is preferably being made of nickel, is being formed on the metal layer at a position corresponding to each supporting frame.

[0015] In another preferred aspect, each supporting frame is made of a metal, preferably being nickel.

[0016] Furthermore, to achieve the above objects, the present invention provides a method for fabricating a capacitive ultrasonic transducer, comprising the steps of:

[0017] (a) forming an insulating layer on a substrate; (b) forming a first structure on the insulating layer by a means of electrochemical deposition while enabling the first structure to be configured with an assembly of supporting frames and the material of a sacrificial layer filling each space enclosed by each supporting frame by the depositing of the sacrificial layer on the assembly of supporting frames;

[0018] (c) polishing the surface of the first structure for enabling the assembly of supporting frames and the deposited sacrificial layer to coplanar;

[0019] (d) forming a first metal layer on the first structure by a means of electrochemical deposition; (e) polishing the first metal layer until a specific thickness of the same is achieved; and

[0020] (f) removing the sacrificial layer.

[0021] In a preferred embodiment, the step (b) of forming the first structure in the above fabrication method further comprises the steps of: (b1) forming a layer of photo resist on the insulating layer; (b2) removing a portion of the photo resist layer to form at least a cavity thereby; (b3) forming a sacrificial layer on the partially removed photo resist layer while enabling each cavity to be filled by the sacrificial layer; (b4) polishing the surface of the sacrificial layer for enabling the remaining photo resist layer and the sacrificial layer to coplanar; (b5) removing the remaining photo resist layer so as to form hollows in the sacrificial layer; and (b6) depositing a layer of a second metal on the sacrificial layer by a means of electrochemical deposition while filling the hollows with the second metal to form the assembly of supporting frames.

[0022] In another preferred embodiment of the invention, the step (b) of forming the first structure in the above fabrication method further comprises the steps of:

[0023] (b1') forming a layer of photo resist on the insulating layer;

[0024] (b2') removing a portion of the photo resist layer to create hollows for forming the assembly of supporting frames therein in a later step;

[0025] (b3') depositing a layer of a second metal on the hollowed photo resist layer by a means of electrochemical deposition while filling the hollows with the second metal to form the assembly of supporting frames;

[0026] (b4') polishing the surface of the second metal layer for enabling the remaining photo resist layer and the second metal layer to coplanar and thus completing the formation of the assembly of supporting frames;

[0027] (b5') removing the remaining photo resist layer to form at least a cavity; and

[0028] (b6') depositing the sacrificial layer by a means of electrochemical deposition while filling each cavity therewith.

[0029] Preferably, the above fabrication method further comprises the steps of:

[0030] (g) forming a layer of a third metal on the first metal layer for enabling at least a protective bulk to be formed at a position corresponding to each supporting frames of the assembly in a posterior process.

[0031] In a preferred aspect, each supporting frame is made of a metal, preferably being nickel.

[0032] In a preferred aspect, the sacrificial layer of made of copper.

[0033] In a preferred aspect, the step (f) of removing the sacrificial layer in the above fabrication method further comprises the steps of:

[0034] (f1) etching the first metal layer to form a plurality of apertures thereon while enabling each aperture to be channeled to the corresponding sacrificial layer.

After the sacrificial layer is etched away by the use of the plural apertures, the plural apertures are going to be filled by a posterior process, wherein the etching of the sacrificial layer is performed by a means of wet etching.

[0035] Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the present invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0036] FIG. 1A is a schematic view of a conventional capacitive ultrasonic transducer.

[0037] FIG. 1B is a schematic view of a conventional capacitive ultrasonic transducer with protective microcap.

[0038] FIG. 2A to FIG. 2H are schematic diagrams depicting a flow chart of a method for fabricating capacitive ultrasonic transducers according to prior art.

[0039] FIG. 3 is schematic view of a capacitive ultrasonic transducer according to a preferred embodiment of the invention.

[0040] FIG. 4A to FIG. 4N are schematic diagrams depicting a flow chart of a method for fabricating capacitive ultrasonic transducers according to a preferred embodiment of the invention.

[0041] FIG. 5A to FIG. 5N are schematic diagrams depicting a flow chart of a method for fabricating capacitive ultrasonic transducers according to another preferred embodiment of the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

[0042] For your esteemed members of reviewing committee to further understand and recognize the fulfilled functions and structural characteristics of the invention, several preferable embodiments cooperating with detailed description are presented as the follows.

[0043] Please refer to FIG. **3**, which is schematic view of a capacitive ultrasonic transducer according to a preferred embodiment of the invention. The capacitive ultrasonic transducer **2** of FIG. **3** comprises: an assembly of supporting frames **23**, being formed on a substrate **20**; a metal layer **24**, being formed on top of the assembly **23**; and a plurality of protective bulks **25**, each being formed on the metal layer **24** at a position corresponding to a supporting frame corresponding thereto; wherein at least a cavity **26** is formed by the enclosure of the metal layer **24**, the assembly of supporting frames **23** and the substrate **20**. Moreover, an insulating layer **21** and a seed layer **22** are successively formed and sandwiched between the assembly of supporting frames **23** and the substrate **20**. In a preferred embodiment of the invention, each supporting frame of the assembly **23** is made of a metal, preferably to be nickel, and the substrate **20** can be made of a silicon-based material, which can be adapted to be the electrode for driving the capacitive ultrasonic transducer **2**.

[0044] In addition, the metal layer **24** is used to act as the oscillation film and the driving electrode of the resulting capacitive ultrasonic transducer **2**, that it can be made of nickel in this preferred embodiment. Since the vibration of ultrasonic waves is generated by the oscillation of the metal layer **24**, it is importance to prevent the metal layer from being damaged by foreign objects during operating. Hence, a plurality of protective bulks **25** are formed on the metal layer **24**, each at a position corresponding to a supporting frame of the assembly **23** corresponding thereto, so that the metal layer **24** can be protected thereby. In this preferred embodiment, the protective bulk **25** is made of a metal, preferably to be nickel.

[0045] Please refer to FIG. **4**A to FIG. **4**N, which are schematic diagrams depicting a flow chart of a method for fabricating capacitive ultrasonic transducers according to a preferred embodiment of the invention. The flow starts at the step shown in FIG. **4**A. In FIG. **4**A, a substrate **30** is provided, which has an insulating layer **31** deposited thereon, and then the flow proceeds to the step shown in FIG. **4**B. In FIG. **4**B, a seed layer **32** is being deposited on the insulating layer **31**, and then the flow proceeds to the step shown in FIG. **4**C. In FIG. **4**C, a layer of photo resist **33** is formed on the seed layer **32**, and then the flow proceeds to the step shown in FIG. **4**D. In FIG. **4**D, an optic mask is employed to define a pattern of cavities **331** on the photo resist layer **33** by lithography, and then the patterned photo resist layer **33** is being etched to form a plurality of cavities **331** thereon, and then the flow proceeds to the step shown in FIG. **4**E. In FIG. **4**E, a sacrificial layer **34** is being formed by a means of electrochemical deposition while enabling each cavity **331** to be filled therewith, preferably the sacrificial layer **34** is made of a metal that can be cooper, and then the flow proceeds to the step shown in FIG. **4**F. In FIG. **4**F, the resulting structure of FIG. **4**E is being polished for enabling the sacrificial layer **34** and the photo resist layer **33** to coplanar, and then the flow proceeds to the step shown in FIG. **4**G.

[**0046**] In FIG. **4**G, the remaining photo resist layer **33** is removed so as to form hollows **332** in the sacrificial layer **34**, and then the flow proceeds to the step shown in FIG. **4**H. In FIG. **4**H, a second metal layer **35** is deposited on the sacrificial layer **34** by a means of electrochemical deposition while enabling the hollows **332** to be filled therewith, preferably the second metal is nickel, and then the flow proceeds to the step shown in FIG. **41**. In FIG. **41**, the resulting structure of FIG. **4**H is polished for enabling the second metal layer **35** and the sacrificial layer **34** to coplanar, and then the flow proceeds to the step shown in FIG. **4**J. In FIG. **4**J, a first metal layer **36** is formed on the coplanar structure of FIG. **41** by a means of electrochemical deposition and then the formed first metal layer **36** is being polished until a specific thickness of the same is achieved, preferably the first metal is nickel, and then the flow proceeds to the step shown in FIG. **4**K. In FIG. **4**K, a third metal layer is formed on the first metal layer **36** by a means of electrochemical deposition and then the third metal layer is first being polished to a specific thickness, and then a portion of the polished third metal layer is removed so as to form a plurality of protective bulks **37**, each at a position corresponding to the remaining second metal layer **35** corresponding thereto, preferably the third metal is nickel, and then the flow proceeds to the step shown in FIG. **4**L.

[**0047**] In FIG. **4**L, a plurality of apertures **361** are formed on the first metal layer **36** and are channeled to the corresponding sacrificial layer **34**, and then the flow proceeds to the step shown in FIG. **4**M. In FIG. **4**M, a plurality of cavities **38** are formed by wet-etching the remaining sacrificial layer **34** while etchant is fed to the sacrificial layer **34** through the plural apertures **361**, and then the flow proceeds to the step shown in FIG. **4**N. In FIG. **4**N, the plural apertures **361** are filled so as to seal the plural cavities **38**, preferably the apertures are filled by an isotropic material of good coverage that further has the same electrochemical characteristic as that of the first metal layer.

[**0048**] Please refer to FIG. **5**A to FIG. **5**N, which are schematic diagrams depicting a flow chart of a method for fabricating capacitive ultrasonic transducers according to another preferred embodiment of the invention. The flow starts at the step shown in FIG. **5**A. In FIG. **5**A, a substrate **40** is provided, which has an insulating layer **41** deposited thereon, and then the flow proceeds to the step shown in FIG. **5**B. In FIG. **5**B, a seed layer **42** is being deposited on the insulating layer **41**, and then the flow proceeds to the step shown in FIG. **5**C. In FIG. **5**C, a layer of photo resist **43** is formed on the seed layer **42**, and then the flow proceeds to the step shown in FIG. **5**D. In FIG. **5**D, an optic mask is employed to define a pattern of an assembly of supporting frames on the photo resist layer **43** by lithography, and then the patterned photo resist layer **43** is being etched to create hollows **431** for forming the assembly of supporting frames therein in a later step, and then the flow proceeds to the step shown in FIG. **5**E. In FIG. **5**E, a second metal layer **44** is being formed by a means of electrochemical deposition while enabling the hollows **431** to be filled therewith, preferably the second metal layer **44** is made of nickel, and then the flow proceeds to the step shown in FIG. **5**F. In FIG. **5**F, the resulting structure of FIG. **5**E is being polished for enabling the second metal layer **44** and the photo resist layer **43** to coplanar, and then the flow proceeds to the step shown in FIG. **5**G.

[**0049**] In FIG. **5**G, the remaining photo resist layer **43** is removed so as to form cavities **432** in the second metal layer **44**, and then the flow proceeds to the step shown in FIG. **5**H. In FIG. **5**H, a sacrificial layer **45** is deposited on the second metal layer **34** by a means of electrochemical deposition while enabling the cavities **432** to be filled therewith, preferably the sacrificial layer **45** is made of copper, and then the flow proceeds to the step shown in FIG. **5**I. In FIG. **5**I, the resulting structure of FIG. **5**H is polished for enabling the second metal layer **44** and the sacrificial layer **45** to coplanar, and then the flow proceeds to the step shown in FIG. **5**J. In FIG. **5**J, a first metal layer **46** is formed on the coplanar structure of FIG. **5**I by a means of electrochemical deposition and then the formed first metal layer **46** is being polished until a specific thickness of the same is achieved, preferably the first metal is nickel, and then the flow proceeds to the step shown in FIG. **5**K. In FIG. **5**K, a third metal layer is formed on the first metal layer **46** by a means of electrochemical deposition and then the third metal layer is first being polished to a specific thickness, and then a portion of the polished third metal layer is removed so as to form a plurality of protective bulks **37**, each at a position corresponding to the remaining second metal layer **35** corresponding thereto, preferably the third metal is nickel, and then the flow proceeds to the step shown in FIG. **5**L.

[**0050**] In FIG. **5**L, a plurality of apertures **461** are formed on the first metal layer **46** and are channeled to the corresponding sacrificial layer **45**, and then the flow proceeds to the step shown in FIG. **5**M. In FIG. **5**M, a plurality of cavities **48** are formed by wet-etching the remaining sacrificial layer **45** while etchant is fed to the sacrificial layer **45** through the plural apertures **461**, and then the flow proceeds to the step shown in FIG. **5**N. In FIG. **5**N, the plural apertures **461** are filled so as to seal the plural cavities **48**, preferably the apertures are filled by an isotropic material of good coverage that further has the same electrochemical characteristic as that of the first metal layer.

[**0051**] From the above description, it is noted that the capacitive ultrasonic transducer is made by an improved fabrication method combining the techniques of electrochemical deposition and super fine polishing, whereas the oscillation film and the electrodes of the resulting capacitive ultrasonic transducer is formed by the use of lithography, electroplating, evaporation deposition, sputtering deposition and technology of sacrificial layer. Moreover, since the cavity of the capacitive ultrasonic transducer of the invention is formed by etching a metal sacrificial layer, the cavity can be formed in any shape at will, which is further has structure characteristics of low stress and high density. Furthermore, since the removal of the sacrificial layer in the fabrication method of the invention is achieved by wet etching that is implemented by channeling apertures to the corresponding sacrificial layer for filling etchant thereto, not only the efficiency of the removal of sacrificial layer is enhanced, but also the formation of cavity is improved.

[0052] In addition, the protective bulks can protect the capacitive ultrasonic transducer effectively, such that the problems caused by the microcap used in the conventional transducer can be avoided. Yet, since the fabrication method of the invention use an electrochemical means for fabricating the oscillation film of the capacitive ultrasonic transducer, the resulting oscillation film will have better mechanical properties that it is easier to control the stress, density and thickness thereof. In order to achieve an oscillation film of specific thickness, the deposited film is further processed by a mean of super fine polishing.

[0053] To sum up, the capacitive ultrasonic transducer of the invention is characterized by two features, which are (1) the oscillation film is made of a metal; and (2) the capacitive ultrasonic transducer is configured with protective bulks. In addition, since the fabrication method of the invention uses a means of electrochemical deposition for forming the main structure of a capacitive ultrasonic transducer that can be achieved without the steps of electrode formation, high temperature processing and annealing, not only the manufacturing cost is reduced and the manufacturing process is simplified, but also the packaging problem troubling the conventional capacitive ultrasonic transducer is solved,

[0054] While the preferred embodiment of the invention has been set forth for the purpose of disclosure, modifications of the disclosed embodiment of the invention as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the spirit and scope of the invention.

What is claimed is:

**1**. A capacitive ultrasonic transducer, comprising:

an assembly of supporting frames, being formed on a substrate; and

a metal layer, being formed on top of the assembly;

wherein at least a cavity is formed by the enclosure of the metal layer, the assembly of supporting frames and the substrate.

**2**. The capacitive ultrasonic transducer of claim 1, wherein at least a bulk is being formed on the metal layer at a position corresponding to each supporting frame.

**3**. The capacitive ultrasonic transducer of claim 2, wherein the bulk is made of nickel.

**4**. The capacitive ultrasonic transducer of claim 1, wherein each supporting frame is made of a metal.

**5**. The capacitive ultrasonic transducer of claim 4, wherein the metal is nickel.

**6**. The capacitive ultrasonic transducer of claim 1, wherein the metal layer is made of nickel.

**7**. A capacitive ultrasonic transducer, comprising:

an assembly of supporting frames, being formed on a substrate;

a metal layer, being formed on top of the assembly; and

at least a bulk, each being formed on the metal layer at a position corresponding to each supporting frame;

wherein at least a cavity is formed by the enclosure of the metal layer, the assembly of supporting frames and the substrate.

**8**. The capacitive ultrasonic transducer of claim 7, wherein the bulk is made of nickel.

**9**. The capacitive ultrasonic transducer of claim 7, wherein each supporting frame is made of a metal.

**10**. The capacitive ultrasonic transducer of claim 9, wherein the metal is nickel.

**11**. The capacitive ultrasonic transducer of claim 7, wherein the metal layer is made of nickel.

**12**. A method for fabricating a capacitive ultrasonic transducer, comprising steps of:

(a) forming an insulating layer on a substrate;

(b) forming a first structure on the insulating layer by a means of electrochemical deposition while enabling the first structure to be configured with an assembly of supporting frames and the material of a sacrificial layer filling each space enclosed by each supporting frame by the depositing of the sacrificial layer on the assembly of supporting frames;

(c) polishing the surface of the first structure for enabling the assembly of supporting frames and the deposited sacrificial layer to coplanar;

(d) forming a first metal layer on the first structure by a means of electrochemical deposition;

(e) polishing the first metal layer until a specific thickness of the same is achieved; and

(f) removing the sacrificial layer.

**13**. The method of claim 12, wherein the step (b) of forming the first structure in the fabrication method further comprises steps of:

(b1) forming a layer of photo resist on the insulating layer;

(b2) removing a portion of the photo resist layer to form at least a cavity thereby;

(b3) forming a sacrificial layer on the partially removed photo resist layer while enabling each cavity to be filled by the sacrificial layer;

(b4) polishing the surface of the sacrificial layer for enabling the remaining photo resist layer and the sacrificial layer to coplanar;

(b5) removing the remaining photo resist layer so as to form hollows in the sacrificial layer; and

(b6) depositing a layer of a second metal on the sacrificial layer by a means of electrochemical deposition while filling the hollows with the second metal to form the assembly of supporting frames.

**14**. The method of claim 13, the method further comprising a step of:

(g) forming a layer of a third metal on the first metal layer for enabling at least a protective bulk to be formed at a position corresponding to each supporting frames of the assembly in a posterior process.

**15**. The method of claim 14, wherein the first metal layer, the second metal layer and the third metal layer are all made of nickel.

**16**. The method of claim 12, wherein the step (b) of forming the first structure in the fabrication method further comprises steps of:

(b1') forming a layer of photo resist on the insulating layer;

(b2') removing a portion of the photo resist layer to create hollows for forming the assembly of supporting frames therein in a later step;

(b3') depositing a layer of a second metal on the hollowed photo resist layer by a means of electrochemical deposition while filling the hollows with the second metal to form the assembly of supporting frames;

(b4') polishing the surface of the second metal layer for enabling the remaining photo resist layer and the second metal layer to coplanar and thus completing the formation of the assembly of supporting frames;

(b5') removing the remaining photo resist layer to form at least a cavity; and

(b6') depositing the sacrificial layer by a means of electrochemical deposition while filling each cavity therewith.

**17**. The method of claim 16, the method further comprising a step of:

(g) forming a layer of a third metal on the first metal layer for enabling at least a protective bulk to be formed at a position corresponding to each supporting frames of the assembly in a posterior process.

**18**. The method of claim 17, wherein the first metal layer, the second metal layer and the third metal layer are all made of nickel.

**19**. The method of claim 12, the method further comprising a step of:

(g) forming a layer of a third metal on the first metal layer for enabling at least a protective bulk to be formed at a position corresponding to each supporting frames of the assembly in a posterior process.

**20**. The method of claim 19, wherein the first metal layer and the third metal layer are made of nickel.

**21**. The method of claim 12, wherein each supporting frame is made of a metal.

**22**. The method of claim 21, wherein the metal is nickel.

**23**. The method of claim 12, wherein the sacrificial layer is made of copper.

**24**. The method of claim 1, wherein the step (f) of removing the sacrificial layer in the above fabrication method further comprises the steps of:

(f1) etching the first metal layer to form a plurality of apertures thereon while enabling each aperture to be channeled to the corresponding sacrificial layer.

**25**. The method of claim 24, wherein the plural apertures are going to be filled by a posterior process being performed after the step (f1).

**26**. The method of claim 12, wherein the removing of the sacrificial layer is performed by a means of wet etching

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