METALS AND MATERIALS International, Vol. 12, No. 1 (2006), pp. 81~84

Fabrication of a Probe Needle using a Tubular Cathode by Electrochemical Etching

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To fabricate a probe needle, a tubular cathode was applied by electrochemical etching. A tungsten wire was used as an anode, and a stainless steel tube was used as a cathode, respectively. The stainless steel tube was partially immersed into a sodium hydroxide solution. After the tungsten wire was aligned at the center of the stainless steel tube, electricity was supplied from an external power source. During the experiment, the level of solution that was inside the stainless steel tube rose higher than that of the outer solution of the stainless steel tube, due to bubbles generated on the inner surface of the stainless steel tube, and the inner solution increased in volume. Using this process, the length of the probe needle tapering could be controlled without using a vertical loading system or controller.

Keywords: probe needle, electrochemical etching, tubular cathode, nano technology

1. INTRODUCTION

A probe card is a vital component in a probe system, which is used for testing integrated circuits (ICs) and flat panel display (FPD). A probe card is composed of several parts of which the probe needle is the most important device.

As can be seen in Fig. 1, probe needles are used to inspect interconnections in an IC. A probe needle is a wire that has a tapered shape and minute tip at one end. The diameter of a probe needle is generally 100 ~ 200 μm, and the diameter of the probe needle's tip is estimated to be about 30 μm.

Various mechanical processes have been attempted for probe needle production. Thus far, however, reproducibility of quality probe needles has been very low, and obtuse tips or multiple tips are not uncommon [1]. Therefore, an electrochemical etching method has been widely explored for probe needle production to establish a precise method of fabricating probe needles with desirable characteristics, such as geometrical symmetry, acute angles, and fine shapes [2].

Conventionally, an electrochemical etching method requires two electrodes (cathode and anode), electrolyte (aqueous solution), external electricity, and auxiliary methods. The anode for a probe needle is connected with the positive terminal and the cathode for a counter electrode is connected with the negative terminal of the external electric source. The selection of the material for the probe needle is based on various mechanical properties. Suitable materials for a probe needle include W, Be-Cu, Pd, and Pt-Ir. Among these materials, tungsten is generally chosen for the probe needle, because of its sufficient durability and wear resistance [3]. In the electrochemical etching of tungsten, the electrolyte is generally a sodium hydroxide solution and tungsten oxide which is formed when hydroxide anion is dissolved as tungsten salts.

Electrochemical reactions that occur in tungsten etching are listed below.

$$W + 6OH^- \rightarrow WO_3 + 3H_2O + 6e^- \quad (1)$$
$$WO_3 + 2NaOH \rightarrow Na_2WO_4 + H_2O \quad (2)$$
$$W + 2NaOH + 6OH^- \rightarrow Na_2WO_4 + 4H_2O + 6e^- \quad (3)$$
$$6Na + 6H_2O + 6e^- \rightarrow 6NaOH + 3H_2 \quad (4)$$
$$W + 2NaOH + 2H_2O \rightarrow Na_2WO_4 + 3H_2 : \text{Overall reaction}$$

With the conventional electrochemical etching method of probe needles, both a vertical loading system and a controller are necessary to control the tapered probe tip. While the external electricity is being supplied, probe needles are submerged into the electrolyte or withdrawn from the electrolyte gradually to form a tapered shape. The rate of submersion or withdrawal controls the tapered length of the probe needle, and a specific voltage is supplied for a smooth surface. However, as we will show, it is possible to a tapered probe needle without a vertical loading system and a controller by using a tubular stainless steel cathode. When the electro-

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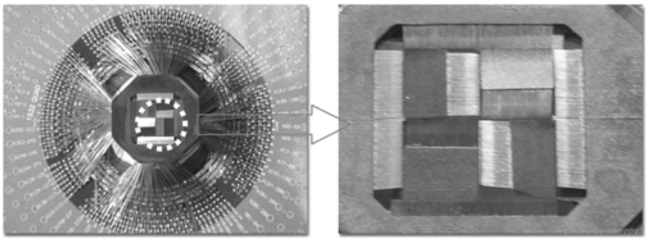

Fig. 1. Probe needles and probe cards for testing IC chip.

chemical reaction occurs, the bubbles generated on the inner surface of the stainless steel tube raises the inner electrolyte level gradually by the volumetric expansion of electrolyte as seen as Fig. 2.

Simultaneously, nano probe, which is used to evaluate and analyze a surface at the nano scale is considered to be indispensable for nano technology. In many high-tech industries, probe manufacturing technology is essential to complete nano probe technology [4-6].

Therefore, we propose a probe manufacturing method that can be used to produce a nano probe needle, which can be utilized in a micro system.

In this study, a tungsten wire was used for a probe needle and a stainless steel tube was used for a counter electrode. In addition, the change of the tapered length and the shape of the probe needle were observed by varying the immersion depth of the stainless steel tube and tungsten wire and by varying the supplied voltage.

2. EXPERIMENTAL PROCEDURE

A tungsten wire electroplated with nickel is generally used as a probe needle, because soldering on the tungsten is practically impossible. Since nickel is not resolved in the sodium hydroxide solution, however, it is necessary to resolve the nickel layer prior to the electrochemical etching. To remove the nickel, chemical etching was performed using a 50 % HNO_3 solution, and the experimental conditions for this are listed below.

Etchant concentration: 50 % (HNO_3 : H_2O = 1 : 1)
Solution temperature: 30 ^{o}C
Immersion time: 60 s
Immersion depth: 20 mm

After this procedure, to fabricate the probe needle, a 10 % sodium hydroxide solution was used as an electrolyte, with a stainless steel tube used as a cathode and a tungsten wire used as an anode. There was no agitation of the electrolyte, and all of the experiments were performed at room temperature. A schematic of the experimental apparatus is shown in Fig. 3.

For a smooth surface morphology of the probe needle, electrochemical etching was performed potentio-statically at various voltages to determine an appropriate voltage. At the most suitable voltage, to control the required tapered length of 1,750 μm, the immersion depth of the tungsten wire and the stainless steel tube was varied.

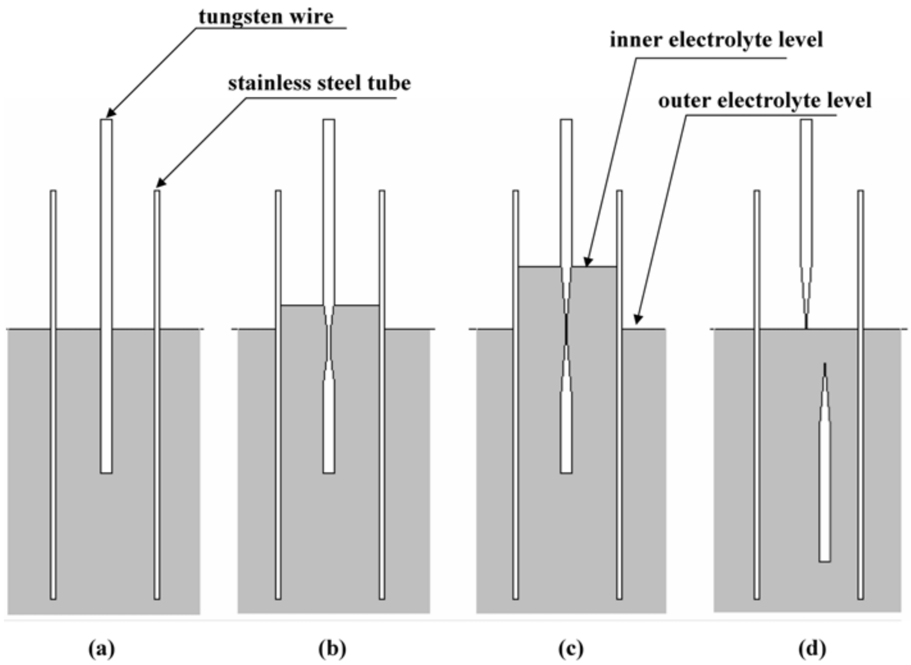

Fig. 2. Schematic of the manufacturing process of a probe needle: (a) initial stage, (b) intermediate stage 1, (c) intermediate stage 2, and (d) final stage.

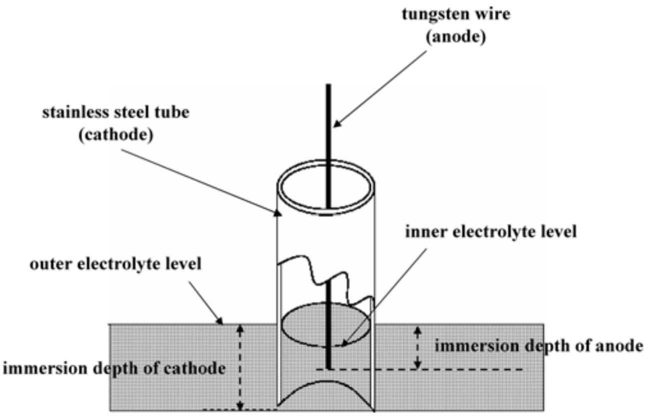

Fig. 3. Schematic of the apparatus and the definition of the immersion depth and the electrolyte level.

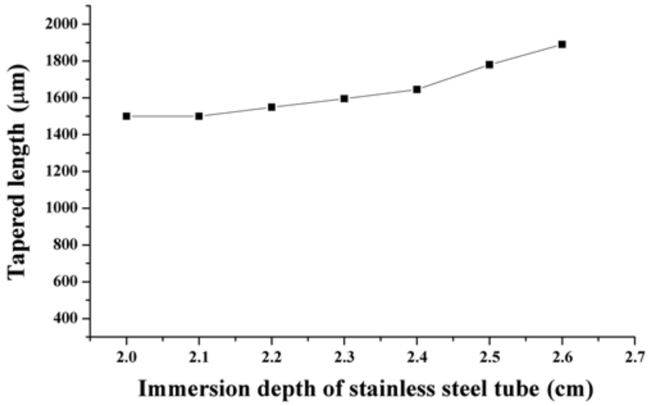

Fig. 5. The change of the tapered length of the probe needle relevant to the immersion depth of a stainless steel tube (cathode).

3. RESULTS AND DISCUSSION

3.1. Effect of the supplied voltage

The supplied voltage affected the surface morphology of the probe needle, and the experiments were carried out at various voltages. When the supplied voltage was between 12.5 and 13.5 V, the probe needle had a suitable and smooth surface morphology. However, a supplied voltage of above 13.5 V or below 12.5 V caused an irregular tip shape and pits on the surface.

Figure 4 shows the shape of a probe needle fabricated at various voltages. As can be seen in Fig. 4, the probe needle with the most suitable shape and smoothest surface was fabricated when the supplied voltage was 13 V. Therefore, we can conclude that 13 V is the proper voltage at which to fabricate a probe needle.

In the following experiments, the immersion depths of a tungsten wire and a stainless steel tube were varied to control the tapered length at a fixed voltage, 13 V.

3.2. Effect of the immersion depth of a stainless steel tube

Figure 5 shows the change of the tapered length of the probe needle as a function of the variation of the immersion depth of a stainless steel tube (cathode). As the immersion depth of the stainless steel tube increased, the counterpart area for the reaction was enlarged. Because of the increasing current, the electrochemical reaction became rigorous. As the immersion area was enlarged, the volume of electrolyte in the inner stainless steel tube also increased. Since the electrolyte level can be controlled by variation of the immersion depth, it is possible to control the length of probe needle tapering via the degree of immersion.

3.3. Effect of the immersion depth of a tungsten wire

Figure 6 shows the change of the tapered length of the probe needle as a function of the immersion depth variation of a tungsten wire (anode). In agreement with previous results, when the immersion depth of an anode increased, the active area for the reaction was enlarged. Comparing Fig. 6 to Fig. 5, the effect of immersion depth of a tungsten wire was more pronounced than that of a stainless steel tube. Because the electrochemical reaction depends on the area of anode and the immersion depth of a tungsten wire, the amount of bubble generated on the stainless steel tube was volumetrically larger in the variation of the immersion depth of a tungsten wire than that of a stainless steel tube.

Ultimately, the required tapered length of 1,750 µm, was

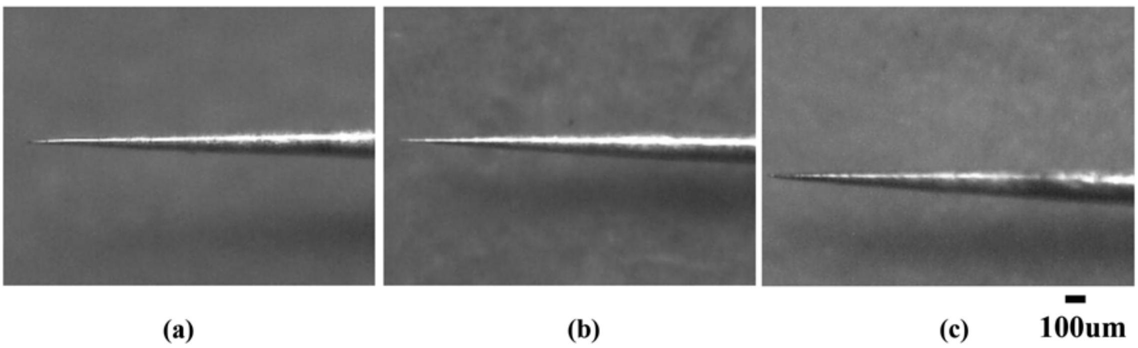

Fig. 4. Micrographs of the probe needles fabricated under various voltages; (a) 12.5 V, (b) 13 V, and (c) 13.5 V.

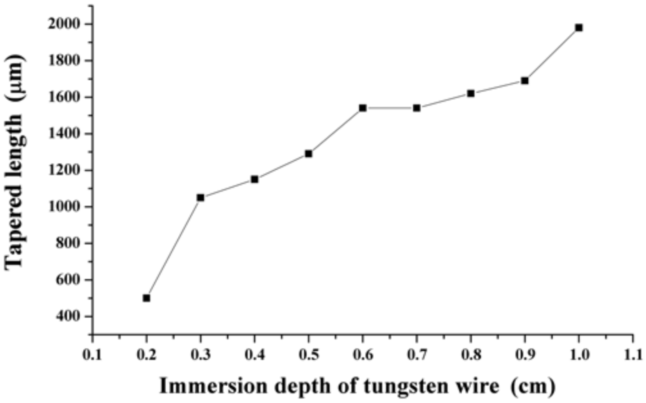

Fig. 6. The change of the tapered length of the probe needle relevant to the immersion depth of a tungsten wire (anode).

obtained by varying the immersion depth of a tungsten wire with a fixed immersion depth of a stainless steel tube, 24 mm, at a constant voltage, 13 V. During the electrochemical etching, the current was increased to 1.5 A and it took 8 s to complete the process.

4. CONCLUSIONS

We have demonstrated that it is possible to control the tapered length of a probe needle by regulating the inner electrolyte level relative to the change of the immersion depth of a stainless steel tube and a tungsten wire. It was due to the volumetric expansion of the electrolyte by bubbles generated in the inner surface of the stainless steel tube. Through trial and error, a voltage level of 13 V was found to be suitable to fabricate the probe needle.

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