Fabrication of a functional micro-cantilever for M/NEMS applications

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In this research, the fabrication of a functional micro-cantilever has been proposed for M/NEMS applications. The micro-cantilever system consists of a main cantilever and four sub-cantilevers. The four sub-cantilevers are arranged at the end of the main cantilever. The arrangement was focused to characterise the conducting property of micro/nano-sized particles. A thermal actuator was also integrated on each sub-cantilever to add actuating capability. Hence the arranged cantilevers can be used as a micro-gripper to move a micro scale material. Resistivity measurement on a metal particle is successfully performed using the functional micro-cantilever system.

Key words : **Micro-cantilever, Micro-gripper, M/NEMS**

1. INTRODUCTION

The micro electro mechanical systems (MEMS) technology has been developed at the various requests of environmental and internal sensors, machining of silicon and metal derivatives, optical and biomedical systems, and microfluidics. The microfabrication technology is the engine behind the functional integration and miniaturization of electronics. From early 1960s to the mid-1980s, the fabrication technology of integrated circuits rapidly matured after decades of research following the invention of the first semiconductor transistor.

Actuation of microscale devices and structures can be achieved by injecting or removing heat. Changes in temperature profile in turn result in mechanical displacement or force output, through thermal expansion, contraction, or phase change. The temperature of a microstructure can be raised by absorption of electromagnetic waves, joule heating, conduction, and convection heating. Cooling can be achieved via conduction dissipation, convection dissipation, radiation dissipation, and active thermoelectric cooling. Thermal actuation is used in commercial MEMS products.

In this paper, we propose a new type of micro four-point probe (μ4PP) to measure electrical properties of sample surfaces with different shapes. A thermal actuator is integrated on each sub-cantilever. Hence, the device can be used as a micro-gripper to move small subjects.

2. DESIGN AND FABRICATION

2.1 Design considerations

The electrical conductivity of thin films, semiconductor wafers, and electronic components are commonly measured using the four-point probe method. Usually, the two outer most electrodes serve as current injector and collector, while the resulting voltage drop is measured in a currentless fashion via the inner electrodes. This method practically eliminates measurement errors due to contact resistances between the electrodes and the sample. This is some interest in the miniaturization of the device to obtain much higher sensitivity and less damage to the sample surfaces. For a cantilever-based electrode, the spring constant and the cantilever deflection determine the electrode contact force through Hooke's law. Several attempts based on silicon micromachining have been made to improve 4PP characteristics, including a desire to decrease its probe-to-probe spacing for further application.

We suggest a new 4PP design as shown in Figure 1, a new fabrication method for in-plane tips – the main cantilever supports four sub-cantilevers with the in-plane tip where the ends of the four sub-cantilever tips are facing each other.

6 masks are designed for the new type of μ4PP. New type of μ4PP is designed an array v-groove to increase cantilever displacement, main cantilever and probe fabrication, Ion- implantation for thermal actuation, oxide mask for insulation, metal mask to measure resistance of substrate and back-side mask to make cantilever shape. Thermal bimorph consists of two materials joined along their longitudinal axis serving as a single mechanical element.

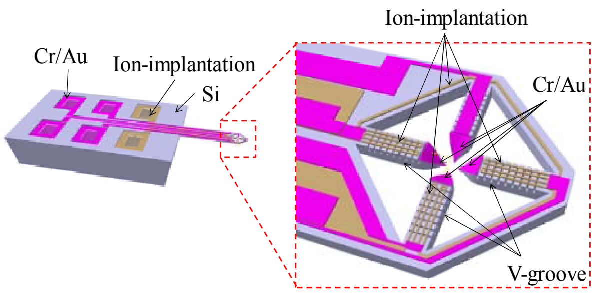

Figure 1. A schematic diagram of a new type micro four-point probe.

2.2 Fabrication

The μ4PP is fabricated by conventional silicon processing techniques. The process flow is represented in Figure 2. A 4inch SOI (Silicon On Insulator) wafer with 2000Å of thermally grown oxide on both sides is used as initial substrate. The oxide is patterned after the photolithography by wet etching in buffered hydrofluoric acid (BHF) to form the mask for the v-groove shape. And then etched in a TMAH (trimethyl ammonium hydroxide) solution at 80℃. The v-groove pattern is to increase cantilever displacement. After the SiO_2 is removed a thin layer of silicon rich silicon oxide is then deposited on both sides of the wafer. A new fabrication method is only developed to make the in-plane tip. The process flow for the in-plane tip fabrication is represented in Figure 3. First, the shape of the in-plane tip is defined in SiO2 by photolithography. Then, the SiO2 is wet-etched until the neck width of the base shaped mask is 0. After removing the photoresist in acetone, silicon is dry-etched using an SF-based RIE. Finally, the SiO2 is removed in a solution of buffered hydrofluoric acid, which defines the in-plane tip at the free end of the sub-cantilever. This novel process produces a very sharp tip end and eliminates the use of special equipment such as an e-beam lithography system.

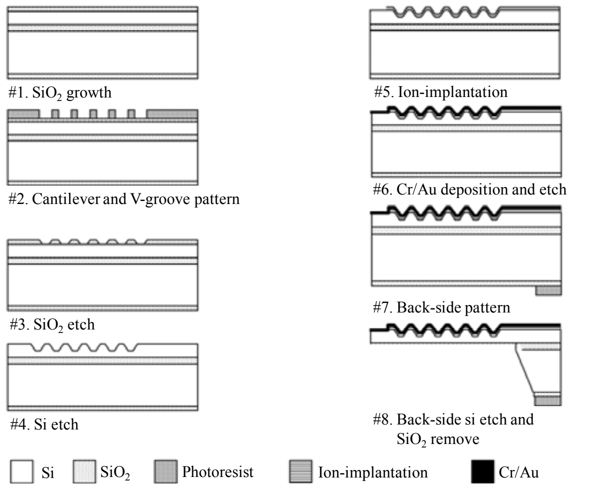

Figure 2. Fabrication of the μ4PP.

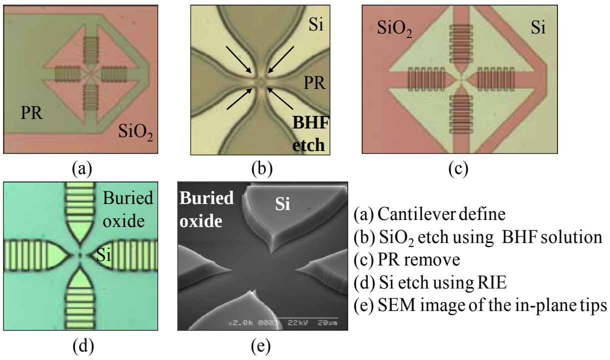

Figure 3. Process flow for the in-plane tip fabrication.

And we fabricated the Ion-implantation pattern for thermal actuation. This actuation is moved by Joule heating. Then we patterned the oxide for insulation between Ion-implantation and metal line. After then metal (Cr/Au) is deposited using E-beam evaporator. For measurements in ambient conditions a typical layer sequence of 500 Å Cr/ 1500 Å Au is chosen, due to the excellent contact properties and low stress, resulting in a negligible bending of the electrodes. The Cr layer serves as an adhesion layer between the SiO_2 surface and the Au layer. Finally, back-side silicon has been completely etched by RIE (Reactive Ion Etching). The µ4PP we have fabricated initial cantilever spring constant is about 9 N/m and could be decreased to 2 N/m by using fabrication process. It can be more sensitivity and flexible cantilever structure. The µ4PP device is shown in Figure 4.

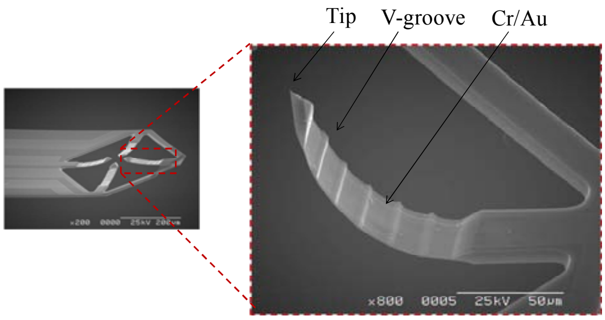

Figure 4. SEM image of a functional micro-cantilever.

3. EXPERIMENTAL RESULTS

The experimental setup for the characterization of the fabricated µ4PPs consists of a probe station with source-meter and voltage-meter. Figure 5 shows a schematic diagram of the experimental setup. Source meter and voltage meter is contact to device a flow of electricity and measure the voltage. After set up the system we experimented to measure of a silver paste.

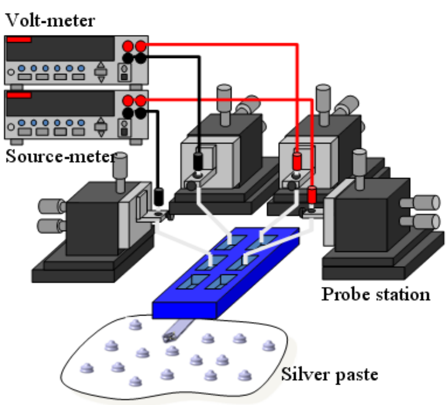

Figure 5. An experimental setup to measure electrical property.

The experimental conditions are as follow; The current source is in the range from 0.1 to 10 mA. The space of tip to tip is 9 µm. And then resistance has been evaluated. The measured resistivity of the metal object is almost the same as that of the value provided by the company. Figure 6 shows the experimental I-V relations of the silver paste particle samples.

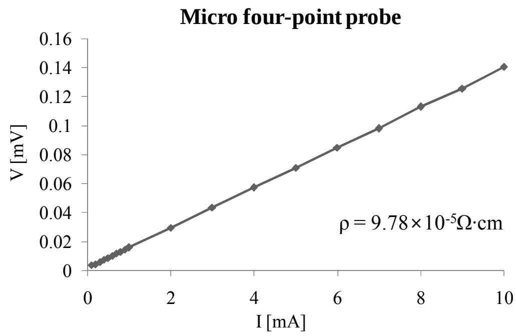

Figure 6. Resistivity measurement using the fabricated µ4PP.

4. CONCLUSIONS

We fabricated a new type of 4PPs to measure electrical property of sample surface with various structures and apply to M/NEMS applications. Each sub-cantilever is integrated a thermal actuator for using micro-gripper. The µ4PP is successfully fabricated using a conventional silicon microfabrication technique. And a new process is developed to fabricate a in plane tip.

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