Structure Stability of High Aspect Ratio Ti/Au Two-Layered Cantilevers for Applications in MEMS Accelerometers

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Abstract

Sensitivity of MEMS accelerometers is reported to be improved using movable structures composed of gold materials [1]. Gold materials are known to have high chemical stability, corrosion resistance, electrical conductivity and density, which are all advantageous when applied as electronic components. We have proposed the MEMS accelerometers fabricated by the multi-layer metal technology utilizing gold electroplating [2]. However, structure stability of the gold materials has never been investigated regarding to the reliability issue of MEMS devices. Based on Euler-Bernoulli beam theory [3], the structure stability is related to the Young’s modulus. Young’s modulus of gold is 78.5 GPa [4]. Therefore, the structure stability is expected to be higher when a two-layered structure composed of gold with a material having Young’s modulus higher than gold is used. In fact, the structure stability is found to be improved when a thin titanium layer is used as bottom layer of the two-layered structure [1,2]. However, there is still no report on structure stability of the Ti/Au two-layered structure with different aspect ratio. The information is necessary for practically application of the Ti/Au two-layered structures as movable structures in MEMS devices. Therefore, this paper reports the structure stability based on the results obtained from a 3D optical microscope and COMSOL Multiphysics simulation.

The structure stability was evaluated by observing shape of Ti/Au two-layered micro-cantilevers as shown in Fig. 1. Length (l) of the micro-cantilevers was varied from 100 μm to 1000 μm. Width (w) of the micro-cantilevers was 5 μm. Thickness of the Ti layer (tT) was 0.1 μm. Thickness of the Au layer (tA) was either 3 μm, 10 μm or 12 μm. The micro-cantilevers were fabricated on Si/SiO2 substrate. The titanium layer was deposited by sputtering, and the gold layer was deposited by electroplating. Details of the lithography and deposition processes could be found in a previous study [2]. The micro-cantilevers were annealed at 310 °C to be similar to the MEMS processes. A scanning electron microscope (SEM, S-4300SE, Hitachi) and a 3D optical microscope (OM, VHX-5000, Keyence) were used to observe the micro-cantilevers.

A SEM image of the two-layered Ti/Au cantilevers is shown in Fig. 2. The height (h) was defined as the distance from the top surface of the micro-cantilevers to the surface of the substrate, as shown in Fig. 1. Difference in the height (Δh) by the height at a point with x distance away from the fixed-end (h0) and the height at the fixed-end (h0) was calculated to show tip deflection of the micro-cantilever from the fixed-end measured by the OM. Δh’s of the micro-cantilevers with different thickness of the Au layer are shown in Fig. 3. The structure stability was found to be the highest for the micro-cantilevers with Au thickness of 12 μm. Fig. 4 shows the results of COMSOL Multiphysics simulation for the micro-cantilever with length of 1000 μm and Au thickness of 12 μm. The deflection was mainly caused by the different in thermal expansion coefficient between Ti (8.6 × 10^-5 K^-1) and Au (14 × 10^-5 K^-1). Although, the results obtained from COMSOL were different from those observed by the OM, the results are still valuable to show that there are other factors involved in deformation of the micro-cantilevers. For example, titanium could be oxidized easily when it is heat-treated in air, and high temperature can also accelerate formation of an intermetallic layer at the Ti/Au interface. Therefore, information of the TiO2 layer intermetallic layer, and heat-treatment conditions should be included in the COMSOL simulation to provide more reasonable results.

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