Micropiercing of titanium foil by combination of a roll press method and dry etching

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The micropiercing processing to the thin metal foil is useful for MEMS and bio-MEMS applications, for instance, battery assembly, surface electrode of solar cell, catalyst carrier and barrier membrane for guided tissue regeneration (GTR) have micro-holes. These porous metal foils equipped with all of corrosion resistance, oxidation resistance, light weight and high strength performances are ideals. Therefore, titanium (Ti) is an optimum material. However, micropiercing of Ti foil is difficult because of its hardness. To improve this issue, we previously reported that roll-to-substrate technique for Ti foil-piercing process[1, 2]. This method has several advantages such as low pressure and continuously piercing. However, this method has two disadvantages. One is a burr generation at backside surface. Another is a curl of pierced foil. These problems come from a deformation of Ti foil after piercing, thus, only RTS press cannot avoid them. To solve them, we proposed micropiercing of Ti foil by combination of the RTS process and dry etching process.
Figure 1 shows the appearance of the mold (8 mm^2). The mold was tungsten carbide material cross-cut by diamond blade. The mold patterns were 29 μm × 24 μm rectangles with a 100 μm pitches. Figure 2 summarizes the experimental procedures. First, a Ti foil (20-μm-thick) is set on the mold and low pressure is applied to the Ti foil by the roll as the stage moved. The load was 520N. In this load, Ti foil did not perforate. The pressed Ti sheet was then peeled from the mold. At this time, indentations produced by roll press are formed. Finally, these thinnest parts (backside of pressed surface) are removed by inductively coupled plasma (ICP) etching (ELIONIX Inc. EIS-700). Gaseous species is C_4F_8 and machining time is 40 minutes. Figure 3 shows SEM image of Ti foil after the dry etching. An etching amount was 9.7 μm. The through-hole size was a 39 μm × 34 μm rectangle with a 100 μm pitch. By using this method, an aperture ratio was 92% and there are a few curls to the Ti foil. Moreover, the burr height was reduced to 1/9 compared with only RTS (see Figure 4). This process and Ti pierced Ti foil is very useful for making a dental GTR barrier membrane.

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[1] R. Fukuyama, J. Taniguchi, K. Yoshikawa, H. Yagishita, "Micropiercing of titanium foil by a roll press method." *Microelectronic Engineering* 139 (2015): 53-59.
[2] R. Fukuyama, J. Taniguchi, K. Yoshikawa, H. Yagishita, "Pierce characteristics of titanium foil with roll press method." *Microelectronic Engineering* 150 (2016): 74-83.

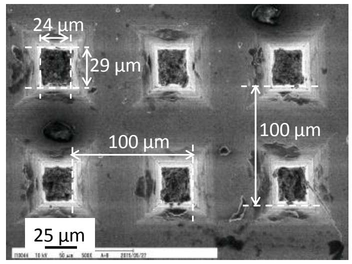

Figure 1: Details of mold used in roll press technique: SEM image of tungsten carbide mold produced by blade cross-cutting.

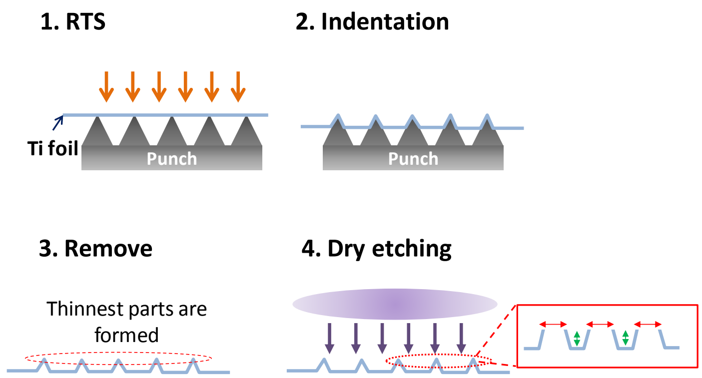

Figure 2: Summary of experimental procedures.

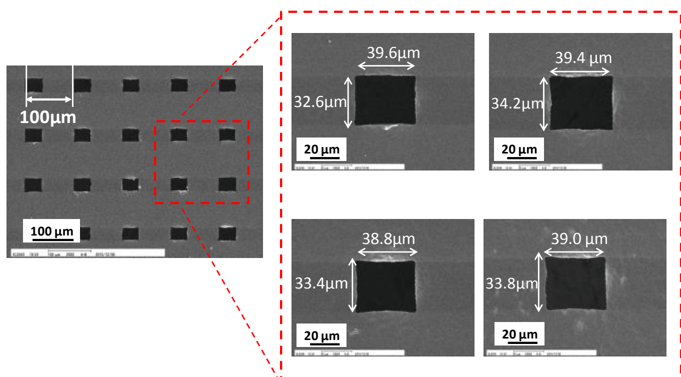

Figure 3: SEM image of processed Ti foil for 40 minutes by C_4F_8 ICP etching: Gaseous species: C_4F_8, ICP RF: 300 W, Sample RF: 300 W, Gas flow rate: 100 sccm

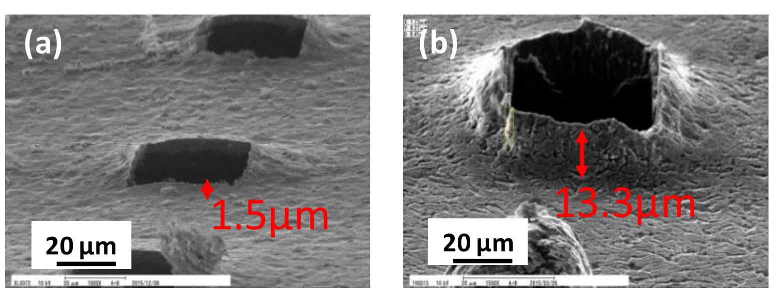

Figure 4: SEM image of the burr height; (a) RTS + Dry etching; (b) only RTS