Dwell Time Adjustment for Focused Ion Beam Machining

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Focused ion beam (FIB) machining has potential of micro/nano fabrication for hard brittle material because removal method is physical sputtering. Usually, micro/nano scale pattering of hard brittle materials is very difficult to fabrication using mechanical polishing or dry etching. Most of the results on FIB machining are silicon substrate and limited shape.[1] Therefore, versatile method for FIB machining is required. Our previous paper has established the dwell time adjustment for mechanical polishing.[2] In this paper, micro/nano fabrication of hard brittle material is carried out by FIB machining with dwell time adjustment.

The dwell time adjustment is convolution model derived from Preston's hypothesis. More specifically, the target removal shape is convolution of the unit removal shape and dwell time is calculated by four algorithms. 1) Method A is calculating the target removal shape by the FFT calculation technique. 2) Method B is calculating the target removal shape by the constraint problem calculation technique. 3) Method A-B is calculating the target removal by Method A and calculating the target removal shape by Method B. 4) Method B-A is calculating the removal shape by Method B and calculating the target removal shape by Method A.

The unit removal shape was Gaussian shape with 125 nm full width half maximum and the target removal shape was hemispherical shape with 3 μm diameter and 220nm depth from center of cutting circular plane. Mechanical polished glassy carbon (GC) substrates (TOKAI CARBON Co.) were used as specimens. GC samples were sputtered by using FIB equipment (JEOL JFIB-2300) at an acceleration voltage of 30 kV, an ion beam current of 87 pA and an ion species of Ga^{+}. Fabricated patterns were observed with atomic force microscope (Shimadzu SPM-9600). Figure 1 shows dwell time distribution and estimated target removal shape at each method. In these figures, only A or B method cannot obtain smooth dwell time distribution, thus, combination of both two methods is very effective. Figure 2 shows AFM images of FIB machined GC substrates at each method. In these figures, method A-B is the most similar shape. However, obtained depth was smaller than the target depth. This reason is re-deposition of sputtered atoms. In conclusion, method A-B is the most effective technique for FIB machining.

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[1] Jin Han, Hiwon Lee, Byung-Kwon Min , Sang Jo Lee, Microelectron. Eng. **87** (2010) 1-9.
[2]S. Satake, K. Yamamoto and S. Igarashi, Commun. Comput. Phys., **1** (2006), pp. 701-715.

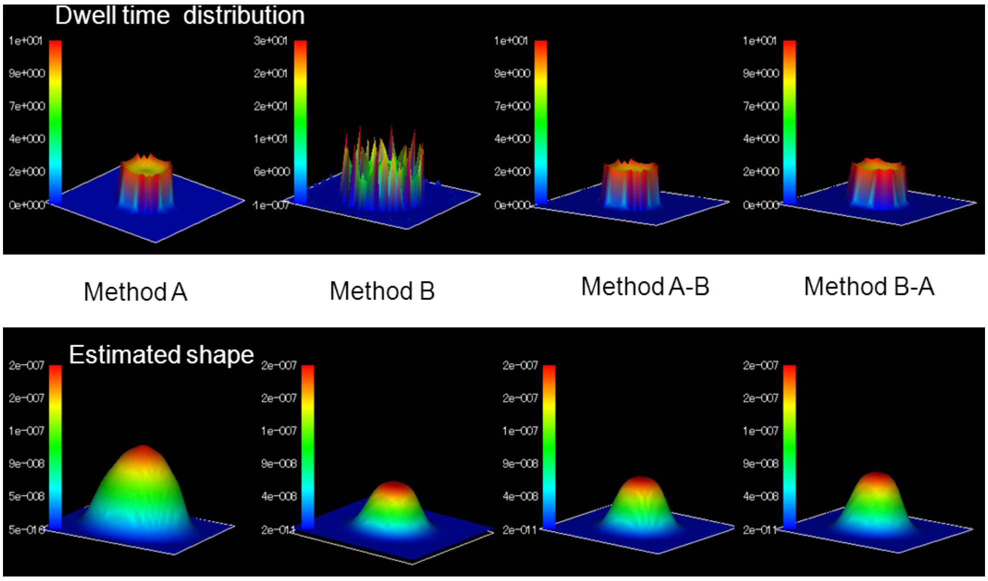

Figure 1: Dwell time distribution (upper figures) and estimated target removal shape (lower figures) at each methods.

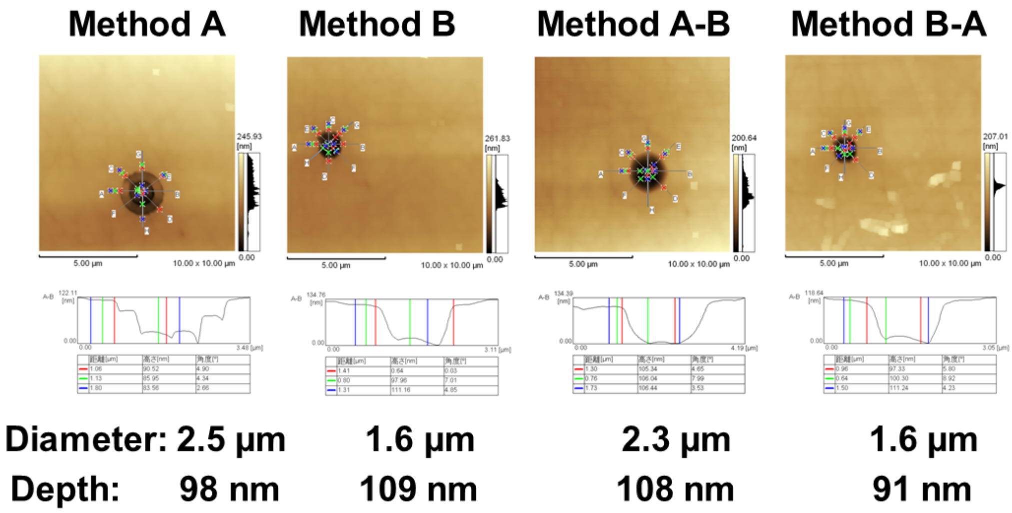

Figure 2: AFM images of FIB machined GC substrates at each method.