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doi:10.1017/S143192761800466X
Microsc. Microanal. 24 (Suppl 1), 2018

Development of Automated Micro-Sampling System and Application to Semiconductor Devices

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FIB (Focused Ion Beam)-SEM (Scanning Electron Microscope) instruments equipped with an FIB micro-sampling system have been used for making lamellae for TEM (Transmission Electron Microscope) or STEM (Scanning Transmission Electron Microscope) observations [1]. The micro-sampling technique allows to pick up a lamella at site specific position using a mechanical needle, so it ensures high positional accuracy for each pickup. However, there are problems. The operator must manually control the needle three-dimensionally. Experience and skill needed for the operation conclude the quality of lamellae. Skilled operator must attend the instrument, so he or she can't do other works during the process. In this study, automated micro-sampling (Auto-MS) function [2] was developed to reduce the burden of operators, with keeping lamella quality uniformly and improving work efficiency.

The Auto-MS function was installed in an NX2000 FIB-SEM-Ar/Xe Triplebeam system. Figure 1 shows procedure of the Auto-MS. Process from sample pickup to welding on mesh (NANOMESH) is automated in this function. Following three parameter groups must be set beforehand: 1) registration of grid position, 2) registration of FIB process position and pattern, and 3) assignment of grid position and lamella position. Assist wizard and recipes for different sample conditions are prepared for easy operation. Flatness of sample surface was required, and it could be restrictions to apply this technique for other samples. Three experiments were performed in this study: I) evaluation of standard recipe for Si, II) application to a semiconductor device of non-flat surface with periodic holes on it, and III) combination of Auto-MS function and auto thinning function.

Figure 2 shows an Auto-MS process for a Si chip. Stage moved to registered FIB process position, and processes including bottom cut were executed. Then, the tip of needle was automatically recognized and approached to the sample (a). Needle was connected, the support bridge was cut, and the sample was automatically picked up (b). Stage moved to the grid positon to fix a lamella, corner positions of lamella and grid were automatically recognized, the lamella approached to the grid (c). The lamella was attached to the grid and needle was cut to release. The needle automatically retreated to initial position (d).

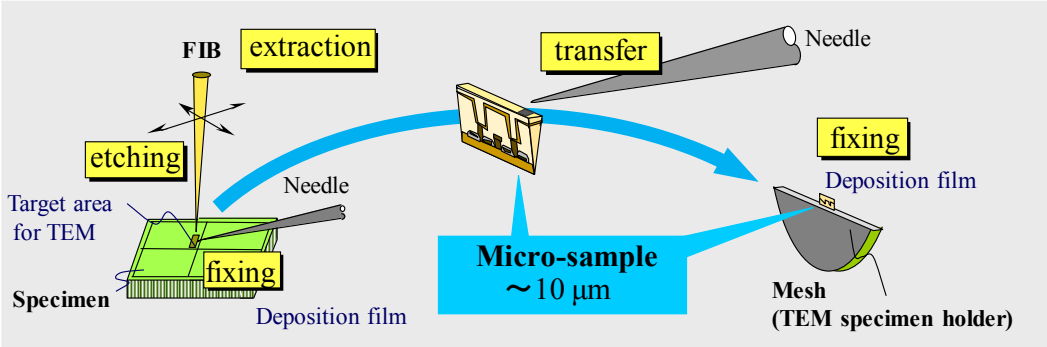
Figure 3 shows the result of Auto-MS system trials from a 3D NAND flash memory. The recipe was modified, because the target position of the 3D NAND was too deep for standard recipe. Periodic holes on the surface caused misrecognition as they were the mark pattern for drift correction (a), but it was overcome by mark fabrication. The Auto-MS successfully picked up five lamellae (b-f) consecutively.

Finally, combination the Auto-MS and the auto thinning process for SRAM was carried out. The Auto thinning function of lift out system using a glass probe to pick up a lamella from a bulk sample was modified to adopt for the Auto-MS. After the successful consecutive five lamellae pickup, auto thinning process was performed for these five lamellae. Presently, manual settings are necessary between Auto-MS and Auto thinning process. Figure 4 shows one of the results. Auto thinning was performed on a lamella (a), target via line was correctly thinned (b), and a gate was clearly observed in 200 kV BF-STEM image (c).

The Auto-MS function was developed and applied to semiconductor devices. The Auto-MS enables stable consecutive operation and flexible recipe modification. The combination of Auto-MS system and auto thinning system worked well after manual adjustments. This system can contribute to reduce operator's burden with uniform lamellae quality kept and overall process efficiency improved [3].

References:

[1] T. Ohnishi, H. Koike, et al., Proc. 25th Int. Symp. Testing and Failure Analysis, (1999), p.499.
[2] S. Tomimatsu, M. Sato, T. Asahata and H. Suzuki, Abstract of NANOTS2014, p.99.
[3] "Triplebeam" is a registered trademark of Hitachi High-Tech Science Corporation in the United States and Japan.



FIB micro-sampling method (Hitachi patent: JP6105530 and others)

Figure 1. The procedure of Auto micro-sampling system.

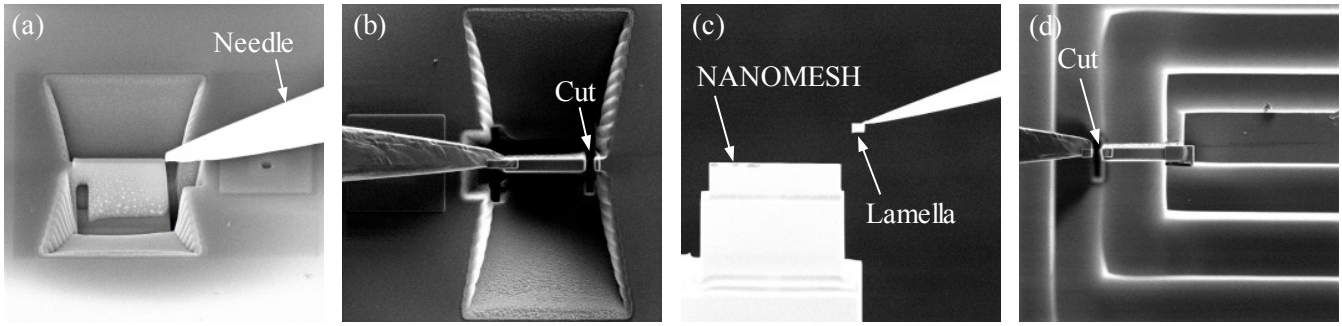


Figure 2. Auto-MS process for a Si chip

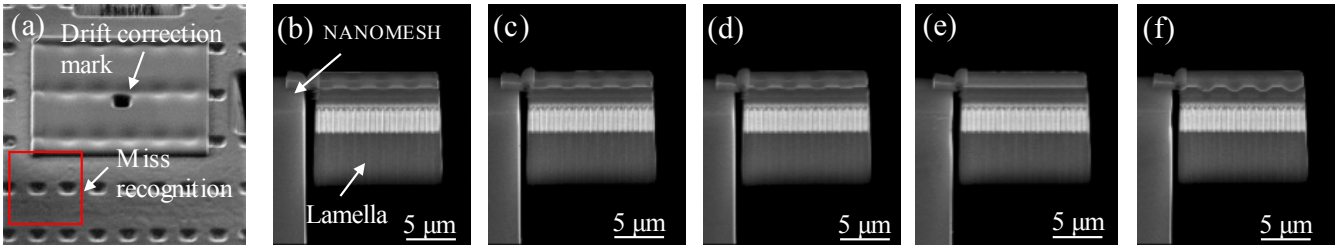


Figure 3. 3D NAND flash sample overview (a) and result of consecutive five Auto-MS trials (b-f)

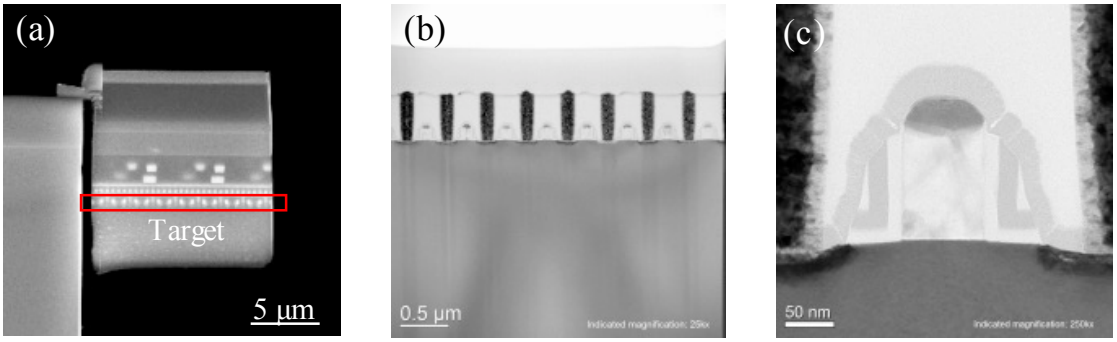


Figure 4. Result of the combination of Auto-MS (a) and auto thinning process (b, c)

https://doi.org/10.1017/S143192761800466X Published online by Cambridge University Press