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Anti Curtaining Effect (ACE) Technology for producing ultra-thin TEM lamella

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1. INTRODUCTION

The processing of cutting edge devices in a FIB-SEM often requires specialized techniques and specific functions for producing ultra-thin TEM lamella. In addition to this, special care is required to reduce artifacts. A commonly encountered FIB artifact at the milled surface is due to the fact that some milling surfaces are comprised of materials that sputter at different rates, and therefore often results in what's known as the "curtaining effect."

One of the effective approaches is Backside Lift-Out specimen preparation*[1] for devices such as planar-NAND flash memory. This technique can avoid curtaining effects on specific parts of the lamella caused from metal lines. In this case, a flip movement of the Lift-Out grid and a Lift-Out probe rotation are necessary. Sample preparation of 3D-NAND flash memory needs an additional approach. Because of its stacked device structure, multi directional irradiation of FIB or Ar beam will be necessary. These functions have to combine according to the kind of samples. In this article, Anti Curtaining Effect (ACE) Technology will be reviewed.

2. ACE TECHNOLOGY

2.1 Components of the technology

Three unique components of FIB-SEM system help the ACE technology. First one is a Lift-Out probe with rotation axis. It can rotate the pickup sample and attach it to the Lift-Out grid with correct angle for Backside Lift-Out. Second one is a 7-axis stage with sample eucentric flip and swing motions. Movement of Flip-axis can adjust the angle of Lift-Out grid at the sample fixing step, or set the tilt angle between the beam and the cross section. Movement of Swing-axis can adjust the angles of multi directional irradiation of ion beams. Third one is a Ar beam system for removing the damaged layer caused by FIB milling. These items combine according to the kind of samples, and are used.

The latest function of the ACE Technology is a sample attitude control. The 7-axis stage consists of a usual 5-axis (XYZRT) stage and a 2-axis (Flip,Swing) sample holder. Fig.1

shows movement of Lift-Out grid mounted on the 2-axis holder. Operation of each axis keeps the sample eucentric. This is important for suitable beam irradiation and avoids redeposition phenomena.

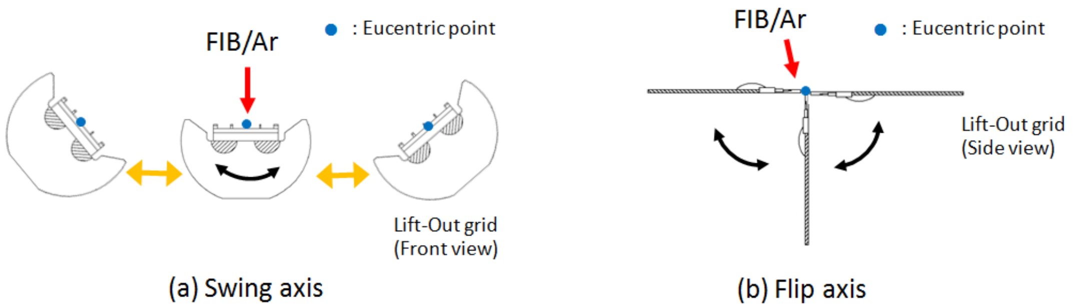


Figure 1. 2-axis motions of Lift-Out grid

2.2 Effectiveness of multi directional beam irradiation

Fig.2 shows a TEM lamella processed by multi directional beam irradiation. This sample was picked up from a DRAM chip using in-situ Lift-Out technique and was irradiated by Low energy (5kV)FIB with ±15 degree sample swing.

Fig.3 shows the effectiveness of multi directional beam irradiation. Single directional beam irradiation creates heavy artifacts on the TEM lamella (a). Even if the sample is ordinary upside Lift-Out sample, multi directional beam irradiations creates a flat surface (b).

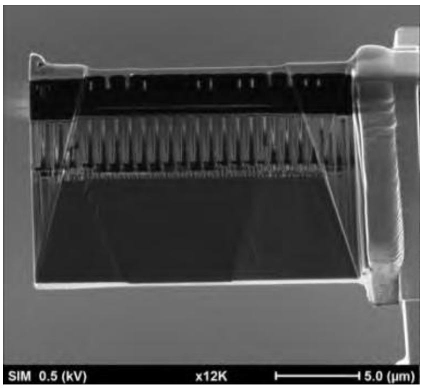
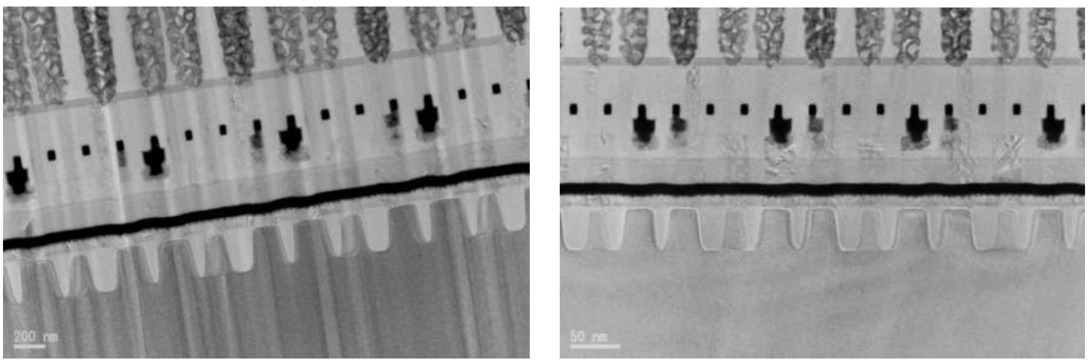


Figure 2. View of TEM lamella



(a) Without ACE Technology (b) With ACE Technology

Figure 3. Comparison of 200kV TEM Image with and without use of ACE technology

3. CONCLUSION

ACE (Anti Curtaining Effect) Technology, which reduces FIB related artifacts, has been developed. The 7-axis stage, automated sample orientation control and combined triple beam FIB-SEM configuration, all of which essentially make up the ACE Technology. These functions and components have to combine according to the kind of sample and the required quality of the TEM lamella.

REFERENCES

[1] Schwarz, Microscopy and Microanalysis, Vol. 9, 116-117 (2003)