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DdProber : Self-sensing AFM type Nano-prober

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Abstract

Nano-prober has the increasing importance for advanced semiconductor device process. Conventional SEM type Nano-prober face the problems, device degradation with electron bombardment and resolution limit. The AFM Nano-prober can work in air, so it is so easy to use for its operation. We report the new type AFM Nano-prober that applied the self-sensing type AFM. This method has the simple structure and easy to use. In the case of Nano-prober that constructed with multiple AFM, this simple method is best choice in this purpose.

I. INTRODUCTION

With device size shrinkage, the manufacturing of semiconductor device is much difficult and the new investigation tool, Nano-prober became more important. Below 90nm process node, SEM(Scanning Electron Microscope) has the poor of resolution and TEM(Transmission Electron Microscope) has become the main tool for device observation, but TEM has the limit as the destructive method. In such case, Nano-prober is the best solution for the failure isolation. For example, SRAM failure isolated at bit-size with electrical measurement of the conventional tester, but the transistor level uncertainty still remains. Direct electrical device measurement with Nano-prober is the only tool for the solution of this isolation. Therefore, the detail information of transistor performance with Nano-prober shows the performance failure as the transistor, TEM observation as the physical analysis, is more accurate. Without this isolation, TEM observation probably lose the cause of fail for the uncertain position of TEM specimen that damaged the remains transistor in this failure bit. For this importance the Nano-prober application is spread, however the difficulty of Nano-prober operation is the obstacle for the application. The new type AFM Nano-prober has the potential with its easy-to-use operation.

II. SELF-SENSING AFM

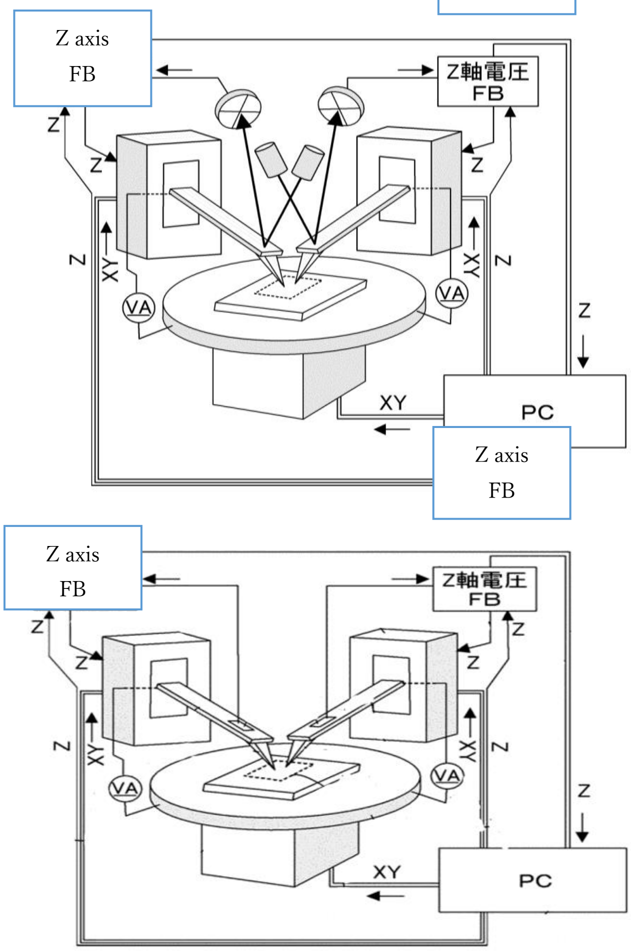
The self-sensing AFM use the piezo resistivity including the cantilever itself for the tension sensing. [1,2] The conventional AFM, the optical lever method using the laser optics, has the difficulty to use as the Nano-prober, the multiple probe AFM. The cantilever of the self-sensing AFM can construct the system more simply and more robust to operate without optical alignment. There are some AFM type Nano-prober products using the tungsten probe with small mirror, however they are very expensive and difficult for operation.

Compare to the conventional AFM Nano-prober, our self-sensing AFM system is reasonable price and easy to operation for its simply method. Its cantilever is also simple and easy to mass production as the popular MEMS type cantilever.

Fig.1 shows the schematic explanation of the difference between the conventional AFM Nano-prober and our self-sensing AFM Nano-prober.

Fig.1 Schematic view of the difference of optical type AFM, Nano-prober(upper figure) and self-sens e Nano-prober(down figure)

Z axis
FB



III. Cantilever and Probing System

This cantilever is made by MEMS line and has the potential for reasonable price with mass production. Si MEMS (Micro electronical mechanical systems) cantilever is assembled to epoxy base, so it is easy to handling, such as attach and detach. Fig.2 shows the photo image of cantilever.

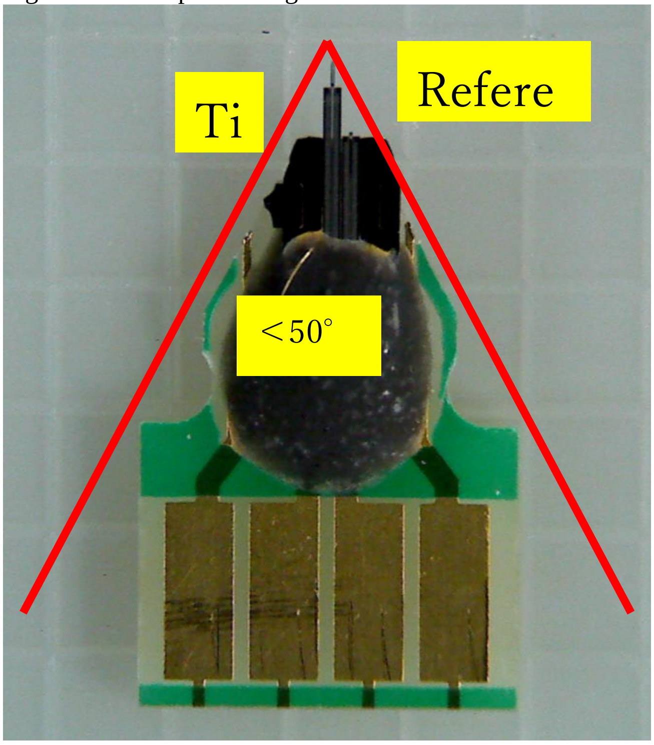


Fig.2 Cantilever image

The cantilever is made inside 50 degrees from tip that is fabricate as Tip-view type AFM cantilever. The cantilever is controlled by piezo actuator with the tip tension sensing by the force mearing circuit as the resistivity change, dealing the AFM operation. With AFM image cantilevers make a contact as the probe head. After probing, electrical performance is measured with semiconductor parameter analyzer such as B1500 (Keysight). During the electrical measurement, piezo sensor circuit is kept at the guard bias for reduction leakage current.

Probing system is very compact with simple sensing mechanism, self-sensing AFM. Controller unit is set under the table and its foot-print is only 0.7 x 1.3 m^2. Fig.3 shows the whole product of this Nano-prober. The system is controlled by PC and all probe stages and sample stage are controlled with closed loop with encoder resolving 1nm. There are 4 probes and 6probes options for the applications with the same shield box.

After setting the sample on the stage, any operation is controlled by PC and any movement of cantilever stages with XYZ axis and sample stage with XY axis keep the feed-back on each encoder data which resolution is up-to 1nm. And all operations are controlled by PC and operator is supported instruction system of its graphical user interface.

Fig.3 Nano-probing system whole image (upper image) and drive part (lower image)

IV. Cantilever positioning and alignment

Cantilevers positioning is operated by PC with encoder data. At first cantilever positioned in Fig.4 with encoder data and the tip recognition program controls the tips position up-to 1 um distance each other with the optical image. Then AFM images acquitted by each cantilever are overlapped with operator’s instruction. Then cantilevers are moved with CAD (computer aided design) data to the mearing transistor electrode that are usually nearest neighbor electrode, for example ~100nm distance with the 14nm processed SRAM.

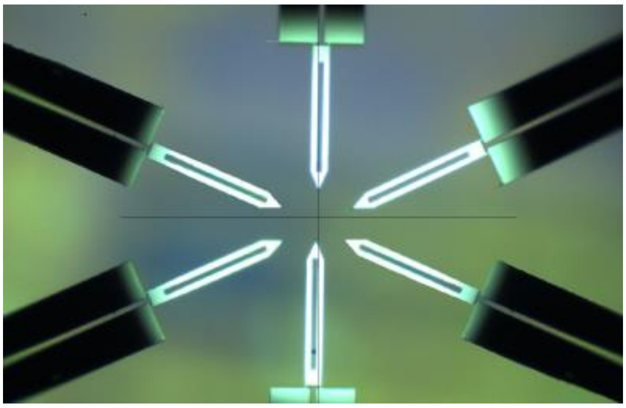


Fig.4 Cantilever positioning

After positioning of cantilever 1um distance between each other, all cantilevers get the AFM images of alignment mark. Then these AFM images are overlapped by PC with the operator direction. With this overlapped image indicate the tips positions with 1nm resolution. These aligned tips move to failure bit position with CAD data and get AFM images to check the precious position of the electrode of the potential failure transistor and then probing. See Fig. 5

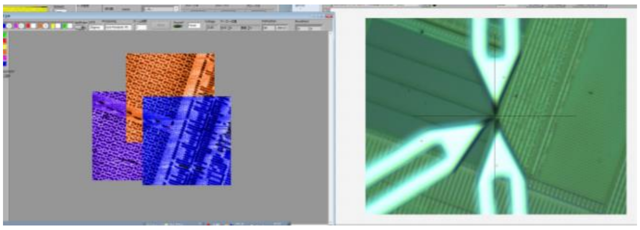


Fig.5(a) Overlapped AFM images on the alignment mark

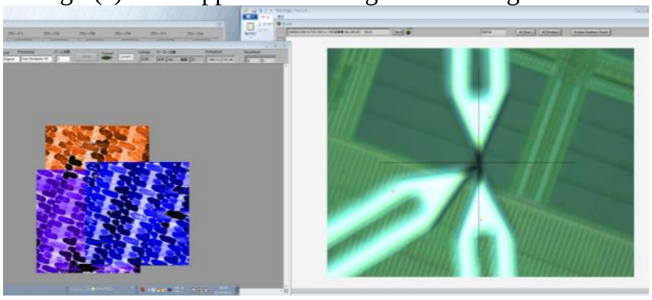


Fig.5(b)Oberlapped AFM images on the failed bit

V. Probing and Electrical measurement

After positioning, cantilevers probe to electrodes of the transistor with 100nN probing tension and then the contacts of each probe are checked with the current through the backside.

In the case of the contact failure, the contact re-operate until the good contacts of all electrodes are established.

The electric measurement has been done with semiconductor electrical analyzer. Fig.5 shows AFM images and IV curves of transistor performance. Usually AFM images are Topo images and current images through the backside.

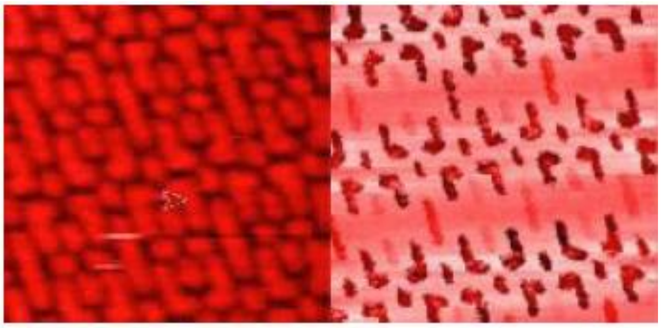


Fig.5 (a) Topo image and Current image of 22nm processed SRAM

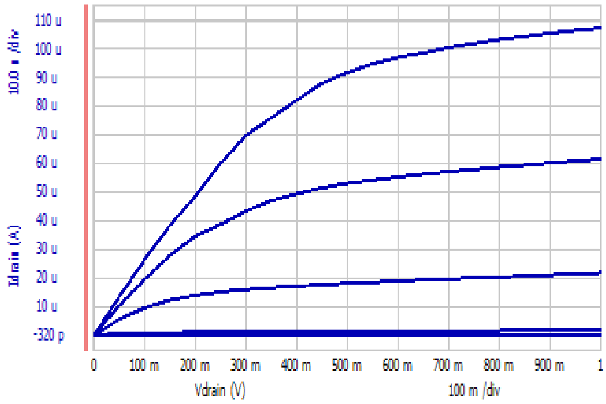


Fig.5(b) IV curves of transistor performance

VI. Specification

Table 1 Specifications of the self-sensing Nano-prober

Items	Specifications
Outline size（Drive part）	W450×H650×D710
（Control part）	W700×H700×D1250
Probe pressure（Probing / Imaging）	50nN～200nN / 0.5nM～5nN
Probing AFM image	Topographic image or electric current image
Technology node	Available to 22nm node
Exchange probe tip	Under 2 min.
Exchange sample	Under 2 min.
Effect of transistor	None（without damage of electron beam and needle pressure）
Repeatability	Good （without damage）
Contact holding time	Average of 10 min.
AFM image capture time	About 1 min.
Scan speed	10Hz （in the case of typical 2umx2um）
Leakage current	Under 0.1pA detectable
Maintenance	Basically none
Probe control method	PC control by AFM image
Additional equipment	Semiconductor parametric analyzer

VII. Conclusion

The self-sensing Nano-prober shows the high through-put of the evaluation of transistor performance that is taken for 10 minutes from sample setting to electrical measurement. The conventional SEM Nano-prober show the 90 minutes for this measurement. [4] So this self-sensing Nano-prober shows the higher through-put for Nano-probing. Without the through-put, AFM Nano-prober has the benefit for preventing the device degradation with the electrical bombardment.

Compare to the conventional AFM Nano-prober, self-sensing AFM Nano-prober has the benefits, such as maintenance-free. MEMS cantilever in this system has the potential for easy mass-production and easy development potential using the popular AFM MEMS cantilever technology, such as the nickel silicide cantilever.

In the future possibility, Nano-prober has the potential of the investigation tool in the mass production of semiconductor device. For this purpose, Nano-prober need the wafer acceptability and the mini-clean environment. Specially in this application, the self-sensing type AFM has the benefits, such as simply mechanism and maintenance free operation.

Acknowledgment

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References

[1] R. Shioda, A. Oki and Y. Amano, "DdProber : Self-sensing AFM type nano-prober" *Proceeding of Nano testing symposium* , Nov. 2015 pp.91~95

[2] R. Shioda, A. Oki and Y. Amano, "Self-sensing AFM type nano-prober" *Proceeding of Nano testing symposium*, Nov. 2014 pp.111~114

[3] http://waferintegra.jimdo.com/

[4] I. Yoshii, "Overview of nProber IITM SEM-Based Nanoprobing system for sub-14 nm Technology" nano-prober" *Proceeding of Nano testing symposium*, Nov. 2014 pp107~110