YE-P-165

Optical Beam Enhanced Defect Detection With Electron Beam Inspection Tools

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Abstract – This paper presents an approach to enhance the defect detection sensitivity with the use of electron beam inspection tool in presence of optical light illumination. Optical light is believed to interact with reversed biased NMOS devices and gate oxide under inspection which either induces photocurrent across junction on NMOS, or stimulates leakage current across thin gate oxide. This enhances the voltage contrast between defective open contacts and normal contacts, and makes the detection of corresponding voltage contrast defects more sensitive and reliable.

INTRODUCTION

Static random access memory (SRAM) tungsten chemical mechanical polish (WCMP) is the most commonly used layer for e-beam inspection (EBI). The major advantages of EBI over optical inspection lie on its capability of detecting electrical defects such as open and short as voltage contrast (VC) defects. Those defects buried underneath conducting plugs or associated with high aspect ratio structures such as via or contact cannot be detected by optical inspection systems.

It is well known that positive mode or extraction mode EBI has high sensitivity to capture P+/N-well plug open defect [1]. However, it suffers low sensitivity in detecting N+/P-well plug open. To improve this situation, different approaches have been developed, either charges surface negatively to forward bias the N+/P-well junction, known as Negative Mode ™ inspection [2], or apply strong extraction field to reversely breakdown N+/P-well junction [3]. These two techniques either suffer high risk of wafer arcing damage as extremely high electrical field is created in the vicinity of wafer, or need two separate inspections to detect P+/N-well plug open and N+/P-well plug open.

Fig. 1 illustrates the VC behaviors at positive mode EBI. Fig. 2 (a) shows a positive mode EBI review image of a SRAM area. Plugs connected to N+/P-well appear relatively dark as associated junctions are reverse biased, while plugs connected to P+/N-well appear bright as forward biasing helps the release of positive charging. There are two abnormal contacts as indicated as A and B. A is an open plug lands on N+/P-well and appears slightly darker than normal ones, while B is an open plug lands on P+/N-well and appears dark in contrast with the bright normal ones. It is difficult to maintain balanced detecting sensitivity for these two types of open plugs.

This paper reported a third approach of EBI with the assistance of optical light illumination. The method is first reported by Larry [4] in 1990, the purpose of optical beam is to illuminate the area of interest to create photovoltaic effect, in the same time, SEs excited by primary electron beam form an image of bright or dark representing the voltage variation on the surface.

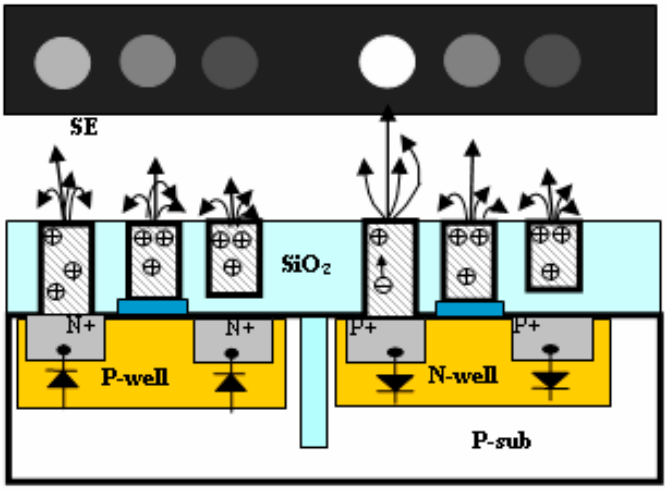


Fig.1 Illustration of VC on normal and open W-plug contacts to PMOS and NMOS

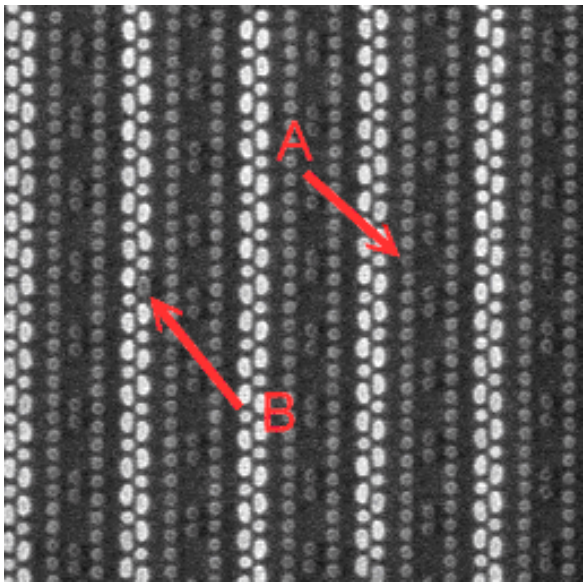
EXPERIMENTS & RESULTS

Setup

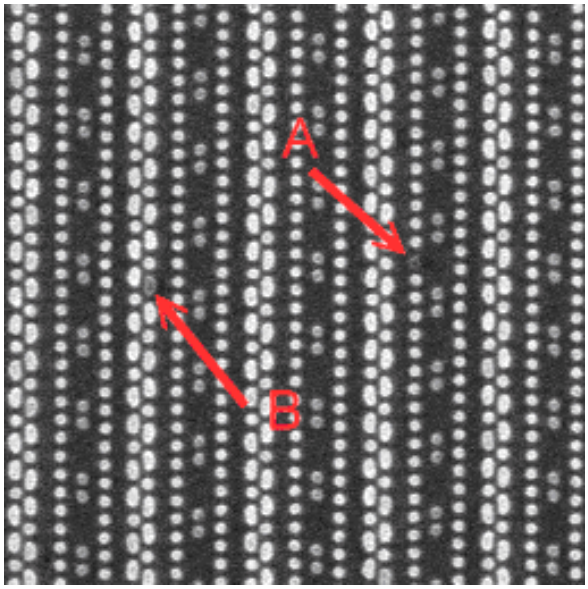
HMI eScan 315 series EBI system is used in this study for its high resolution and sensitivity. A red laser diode is equipped to illuminate the sample while capturing SEM images. The area of illumination is fixed and large enough to cover the field of view of SEM, and the power of the laser can also be controlled to reach an optimal effect.

Case 1

For the same case as indicated in Fig.2(a), if the area of interest is illuminated by an optical beam while imaged with EBI, normal N+ plugs will gradually turn from dark to bright as the illumination power increases, and finally reach a status that all N+ plugs appear as bright as that of P+ plugs. Fig.2 (b) shows the VC image in presence of 5mW 650nm laser beam illumination. However, the abnormal plugs of open contact will not be affected by the laser beam, this makes the two abnormal plugs A and B dropped about 50% comparing to their normal counterparts. As the result, balanced detection sensitivity for open defects on both PMOS and NMOS can be achieved.



(a) With laser off, grey level on defective plug A dropped by only 30% while B dropped by 54%



(b) With laser on and powered to certain level, grey level on defect A dropped by approximately 50% while on B also dropped by 50%

Fig.2 Enhancement of the voltage contrast of open N+ contact plug to NMOS by illuminating the area under e-beam inspection with laser beam simultaneously

This phenomenon can be explained in Fig.3. Irritating reverse biased PN-junction with optical beam of energy higher than band gap will induce photocurrent over the short circuit. This helps to drain off the accumulated charges on the normal N+/P-well plug. Thus contrast between normal and open plug is greatly enhanced.

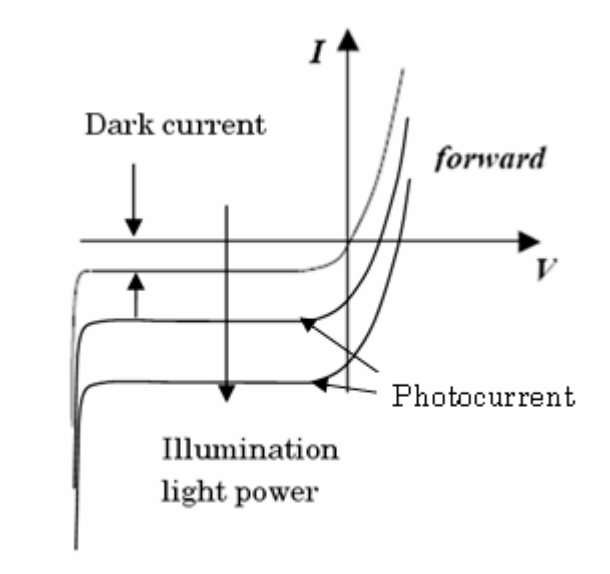
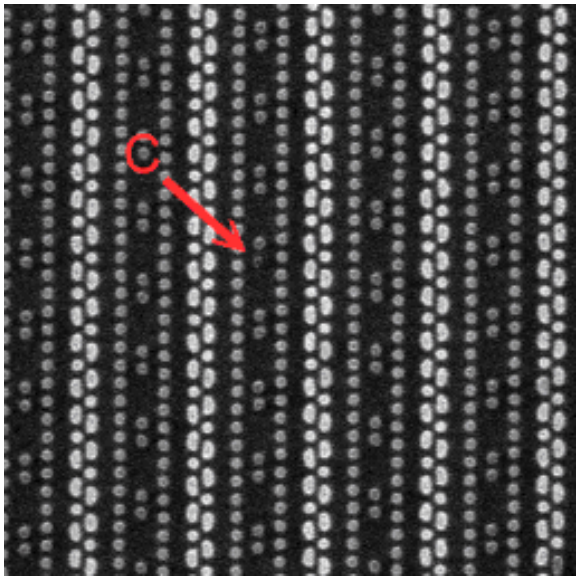


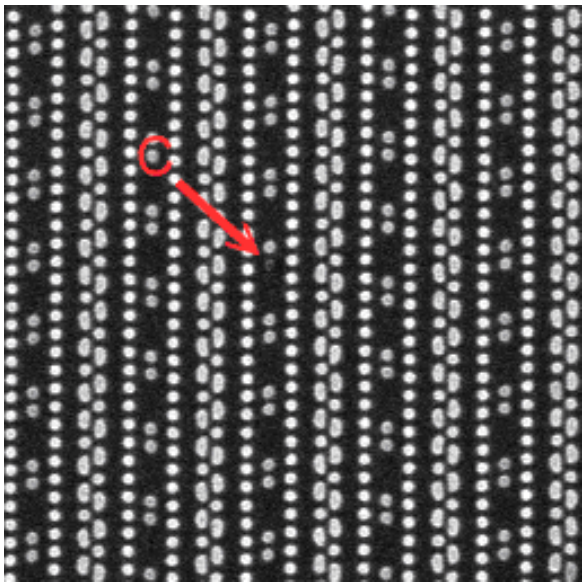
Fig.3 typical PN-junction IV-curve under light illumination

Case 2

Here is another example of laser beam illumination which boost gate leak thus reveal gate contact open. Fig.4 (a) shows the VC image without laser illumination. Normal gate plugs appear dark as positive charging accumulation and difficult be released to substrate via gate oxide, the abnormal open gate contact also show up slightly darker, as arrow indicated. The difference in gray level due to the contact open is only about 34% from normal. When laser is on, the laser light more or less stimulates gate oxide leak and draw away accessory positive charges on normal gate, normal gate plugs are light up, as shown in Fig.4 (b), but the open gate plug is almost not affected. A measurement shows that the open gate plug grey level dropped 50% from the normal.



(a) With laser off, and open gate contact appears darker than normal, but not significantly



(b) With Laser on and powered to certain level, normal gate becomes bright and makes the open gate contact standout.

Fig.4 Enhancement of the voltage contrast of open contact to gate by illuminating the area under e-beam inspection with laser beam simultaneously

Inspection Results

A real inspection is performed on a SRAM area of a wafer with and without laser illumination, significant differences in results are obtained as indicated in Fig.5. As discussed in case 1, laser light stimulates the photo current of reverse biased N+/ P-well diode to a significant high level, all normal N+ plug appear bright as no positive charging accumulated. If there is any junction leak or short circuit happened to the N+ plug, it will be difficult to be pick up with laser on. On the other hand, while the detectability of P+ plug open is almost untouched under laser illumination, the N+ plug open defects see a significant jump in detection sensitivity, and also one gate plug open is added to the chart.

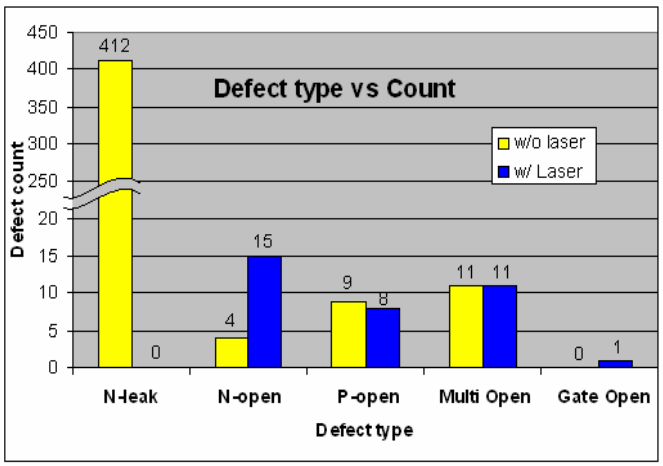


Fig.5 Detectability and sensitivity change with and without laser illumination.

CONCLUSIONS

The studies presented in this paper show the enhancement of detection sensitivity of particular DOIs in SRAM WCMP in presence of optical beams illumination. Particularly it helps to boost and balance the detection sensitivity of the same type of defect, such as contact under-etch or plug open, and extends the capability of EBI in voltage contrast defect detection. Though experiments are based on SRAM WCMP, there should be more potential applications of this technique in semiconductor manufacturing.

REFERENCES

[1] H. Liu, et.al., "High-resistance W-plug monitoring with an advance e-beam inspection system" Proc. of SPIE, Vol. 6162, 61524A, 2006.

[2] S. Lei, et. al., "Contact leakage and open monitoring with an advanced e-beam inspection system", Proc. of SPIE, Vol. 6518, 65184I, 2007.

[3] P. S. Lee, "Defect type identification using hyper-extraction field", US Pat No. 6720779B1, Apr. 13, 2004

[4] Larry D. Flesner, "Scanning electron microscope by photovoltage contrast imaging" US Pat. No. 4902967, Fed.20 1990