

Passive Voltage Contrast Applications with Helium Ion Microscopy Imaging

Deying Xia^{1*}, Shawn McVey¹, Chuong Huynh¹, Wilhelm Kuehn¹, and Doug Runt¹

¹ Carl Zeiss SMT Inc., PCS Integration Center, One Corporation Way, Peabody, MA, USA.

* Corresponding author: deying.xia@zeiss.com

Passive voltage contrast (PVC) imaging has been used in many applications such as fast failure analysis of metal connections in semiconductors [1] [2] and easy visualization of nanofabrication [3]. Both gallium focused ion beams and scanning electron microscopes have been used for defect localization with PVC imaging. Helium ion microscope (HIM) imaging provides an alternative way for PVC applications in defect localization, nanofabrication and enhancement of imaging visualization [4]. PVC using HIM imaging has advantages such as low sputtering, high resolution and good voltage contrast.

HIM images using PVC can easily examine possible defect locations in metal connections, associated with shorts and opens. Figure 1 shows such examples for thin TiN nanostructures on silicon oxide layer on Si substrate. Figure 1.A shows the image of metal nanostructures in defect-free region and Figure 1.B shows the failure of metal connection as dark stripes. At one end of a dark stripe, the defects are easy to locate as shown with white arrows in Figure 1.C. PVC in HIM image is sufficient for quick checking in fast mode over a large area and further defect localization in nanoscale.

PVC using HIM imaging can be also used to verify successful nanofabrication of metal connections. On above sample, neither He or Ne ion beams could effectively isolate metal connections due to re-deposition issues. With XeF₂ gas assistance, it is easy to form electrical isolation for metal connection using He or Ne ion beam as confirmed from voltage contrast due to formation of volatile by-products. HIM images in Figure 2 show obvious dark voltage contrast after gas-assisted ion beam etching of metal connections. Figure 2.A show the comparison of line milling to form isolated micro-pads using He ion beam with and without XeF₂ gas on H pattern. Similar PVC images on simple lined structures with Ne ion beam is observed as shown in Figure 2.B. With XeF₂ gas, the etching rate of metal is increased as well. Figure 2.C shows the good PVC imaging of nanofabrication of a segment indicated by white arrows on denser nanostructures with He ion beam etching with assistance of XeF₂ gas.

PVC using HIM imaging can also be applied to further diagnose hidden defect locations and enhance imaging view as shown in Figure 3. For a series of defects, it is easy to view the left-most and right-most defects. The neon ion beam irradiation could be introduced to localize the intermediate defects. After neon irradiation on the defective region, the voltage contrast segment disappeared as shown in Figure 3.B. By moving the image to right further along this stripe, the closest defect location was found at the starting point of voltage contrast segment. Figure 3.C shows the enhanced image contrast on five stripes after ion-beam induced deposition of a conductive connection.

References:

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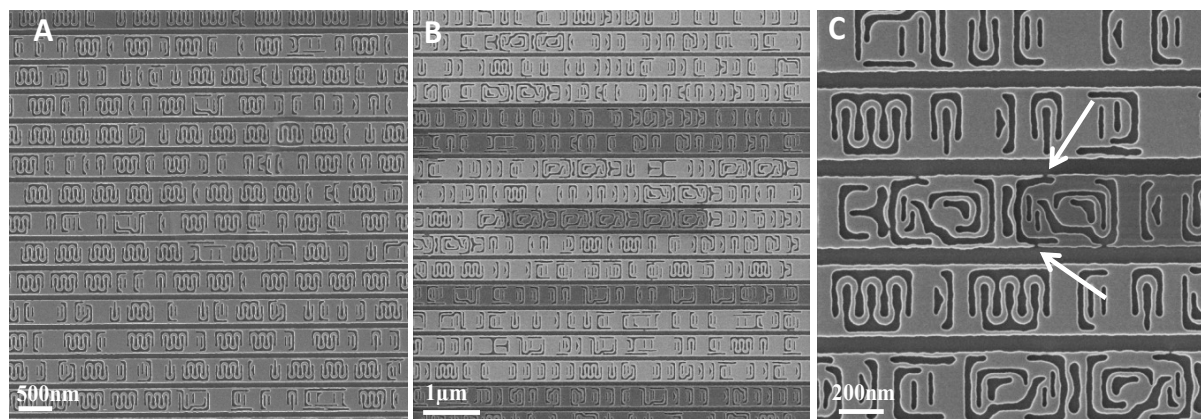


Figure 1. HIM images for (A) defect-free region; (B) defective region; (C) enlarged image showing the open defect locations (white arrows).

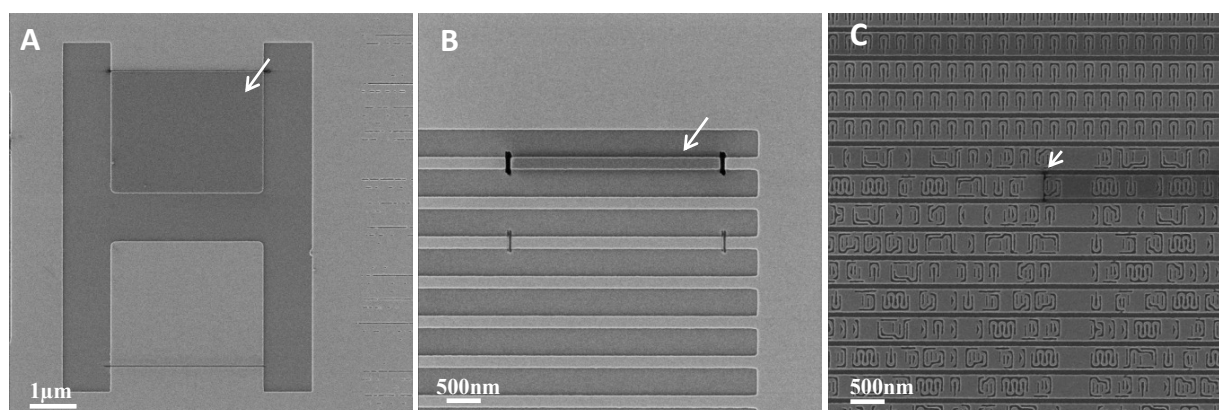


Figure 2. HIM images with XeF_2 assisted ion beam etching (A) comparison of with/without XeF_2 gas on H pattern using He ion beam (white arrow showing with XeF_2 gas); (B) comparison of with/without XeF_2 gas on line structures using Ne ion beam (white arrow showing with XeF_2 gas); (C) isolated segment formation on denser nanostructures as white arrows indicate.

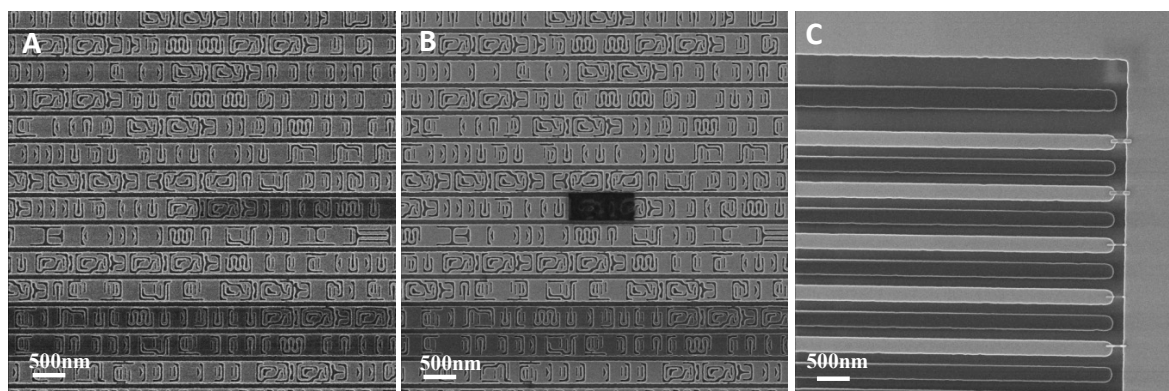


Figure 3. HIM images (A) before neon ion irradiation; (B) after neon ion irradiation; (C) after ion-beam deposition of conductive carbon connection.