Rapid failure analysis for metal connection using voltage contrast images in helium ion microscopy

Deying Xia, Shawn McVey and Wilhelm Kuehn
Carl Zeiss Microscopy, LLC, Ion Microscopy Innovation Center,
One Corporation Way, Peabody, MA 01960
deying.xia@zeiss.com

As semiconductor process technology advances to reduce feature sizes, novel materials are introduced to increase functional device density. It is challenging to have facile approaches to evaluate new fabrication process and failure analysis methods. Traditionally, Ga focused ion beam (FIB) technology has been widely applied in the semiconductor industry for failure analysis, sample preparation, mask repair and circuit editing. Helium ion microscopy (HIM) has been developed for a wide range of applications in recent years with advantages of high resolution, less damages and implantation to surface and nanoscale fabrication compared to Ga FIB.

In this presentation, examples are given for HIM applications in failure analysis for metal connections. HIM images could easily exhibit the failure or disconnection in metal connection structures beyond details for metal nanostructure using voltage contrast. Figure 1.A shows the image of details in metal nanostructures with line width less than 20nm in good connection region after fabrication while Figure 1.B exhibits the failure of metal connection as dark stripes. At one end of dark stripes, the defects are easy to locate as shown in position P1 and red arrows in Figure 1.C. The P2 obviously shows one small isolation pad with both ends of defects. Therefore, with voltage contrast images, it is easy and fast to localize defects in metal connection after fabrication. However, it is also possible to have a series of defects along the dark stripe. With neon polishing on one end of such a stripe, it is easy to find the nearest defects along the stripes using HIM.

For circuit edit and failure analysis techniques, it is necessary to intentionally cut the metal or conductive connection. In such circumstances, voltage contrast images also are easy to verify the successful cut. HIM images in Figure 2 show obvious voltage contrast after gas-assisted (XeF_2) ion beam etching of metal. Figures 2A and 2B give examples on simple lined metal structures. L1 is short cut with 4μm distance while L2 is longer cut with 40μm distance. Figure 2C further confirms the change of voltage contrast images after metal cut on metal nanostructures. L3 shows short isolated stripe and L4 shows one end of isolated stripe after cut.

The voltage contrast method with HIM is also helpful to evaluate the new semiconductor processing yield and minimum dimension with metal connection. We believe it is also applicable for other conductive connections for failure analysis and verification of cut.

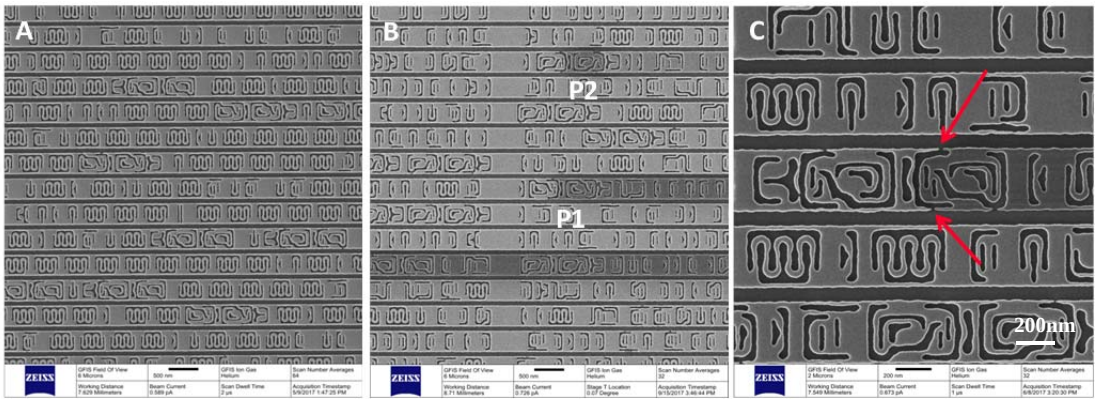

Figure 1: Helium ion microscopy images for metal nanostructures: (A) good connection region; (B) voltage contrast showing defected dark stripes; (C) enlarged image showing the defects on one end of dark stripe.

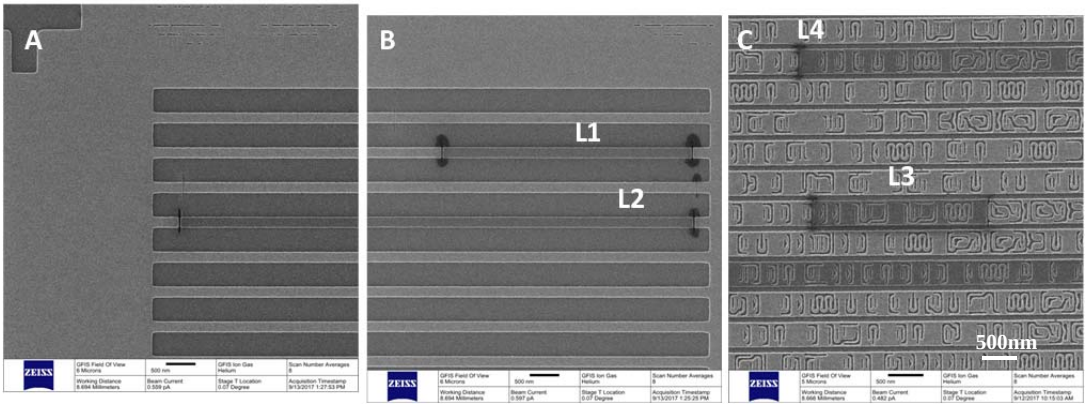

Figure 2: Helium ion microscopy images for gas-assisted ion beam etching metal connection: (A)-(B) lined metal structure; (C) metal nanostructures.