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STEM Scanning Mode Observation of Semiconductor Devices

Nathan Wang, Jin Wu, Judy Tseng, George Ji, Sabbas Daniel

Cypress Semiconductor Corporation, San Jose, CA 95134

With dramatic shrinkage of the cell geometry of semiconductor devices, a SEM, including a FESEM, has been pushed to its resolution limit. On the other side, a TEM provides a better resolution, but its long Turn Around Time (TAT) of sample preparation limits the instrumental application. Since TAT has been playing an important role in modern R & D competition, combination of fast sample preparation with high resolution observation has a huge demand. Scanning Transmission Electron Microscope (STEM) is an instrument that can provide the combination of the fast turn around time and high resolution, because STEM has high accelerating voltage, can be easily switched between transmission and scanning modes, and is equipped with a bulk sample holder.

HITACHI HD-200, 200 KV STEM, was used for the experiment. A small dish that contains the sample can be removed from the bulk sample holder for easy sample handling. Figure 1 shows the bulk sample holder and the dish with a polished cross-section wafer sample for observation. This little dish handles a sample size up to 5mm by 9 mm by 0.7 mm. A small fragment of wafer can be loaded into the system for top down observation directly. A STEM imaging is compared with a FESEM imaging in figure 2. Only the STEM can reveal the small hole next to the contact hole. Figure 3 shows the comparison of the resolution of FESEM and STEM imaging of the polished sample. It is obvious that the 200 KV STEM has much better resolution than that of a regular FESEM. This group of images demonstrates how accelerating voltage effects resolution of a SEM. The other characteristic of STEM is deep penetration of its beam, which provides more inside sample information that is useful for failure analysis [2].

Although the scanning mode of the STEM does not have extremely high resolution as a TEM, its special useful function compensates some weakness of a TEM. In modern semiconductor devices, features have become so small that is often necessary to check the target location with high resolution equipment during sample preparation. It is well known that a TEM collects the transmitted signals that represent the information of the volume of a small sample, so a TEM cannot tell where exactly is target position related to the two surfaces of the sample. Scanning mode of a STEM can easily solve this problem by checking the both sides of surface feature. The other example is shown in figure 4 in which TE and SE modes were used to image the same via void. The goal is to find out if a thin layer of TiW under the via is punched through or not during process. TEM image provides with wrong information because one surface of the sample is still outside of the via. SEM image clearly reveals punching through of the layer. It is the advantage of SEM over TEM as 2dimensinal image over 3dimensional image [3]. Beam absorption is another problem that TEM has during imaging heavy metal such as tungsten. To view its grain size is always an issue for TEM. With sample decoration and scanning mode viewing, the problem can be easily solved (Figure 5). Sample decoration can also be used for viewing of junction. STEM is a powerful analytical tool due to its ability of switching between TE and SE modes, so it takes advantage of both characteristics of transmission mode and scanning mode.

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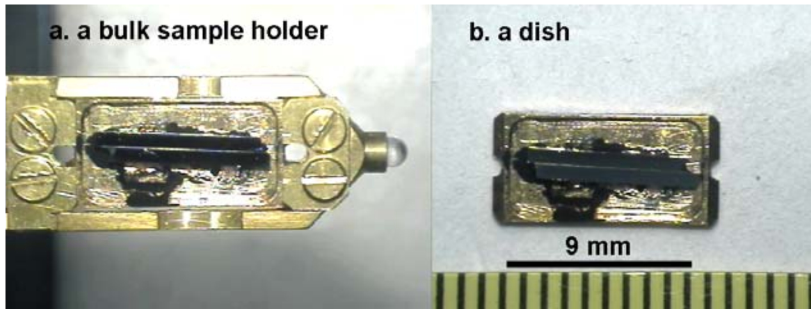

FIG. 1. a) A bulk sample holder with a dish attached and b) A dish

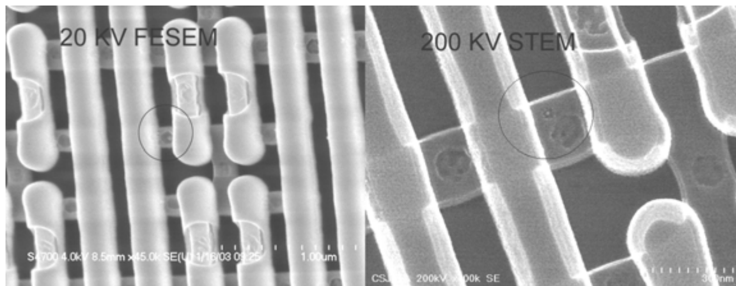

FIG. 2. a) STEM image showing a small hole at side of a contact hole; b) 20 KV FESEM image showing the same hole.

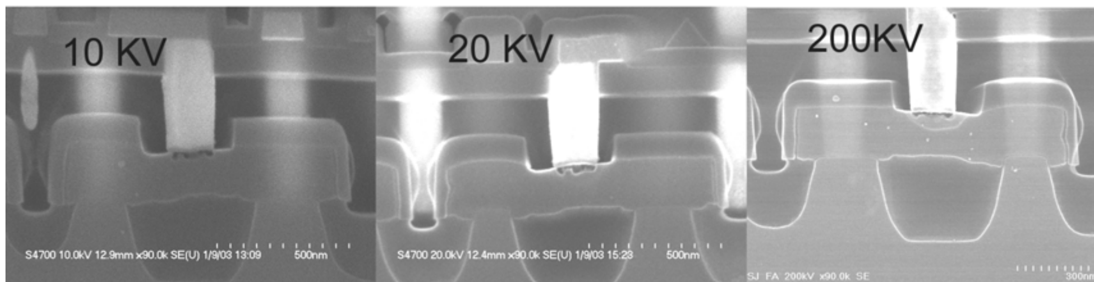

FIG. 3. The resolution comparison of polished sample

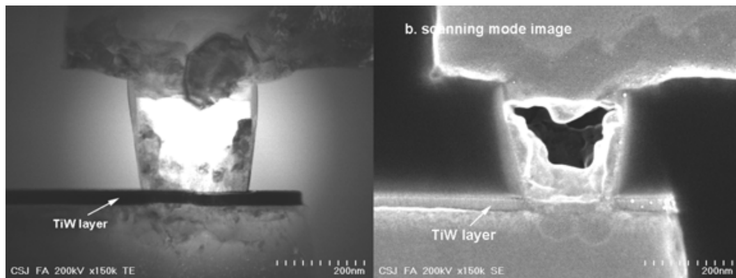

FIG. 4. Comparison of transmission image with scanning image to view the same via void.

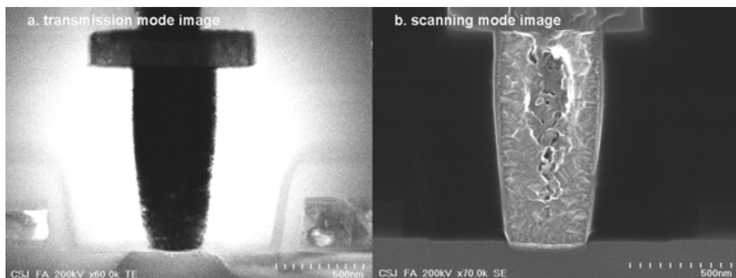

FIG. 5. Comparison of transmission image with scanning image to view tungsten plug

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