IMINA TECHNOLOGIES

APPLICATION NOTE

Metal layers short localization with EBAC and FIB circuit modifications performed at 54° stage tilt

INTRODUCTION

In the field of semiconductors failure analysis (FA), the selection of the investigation technique to be used is heavily dependent on the required time per analysis and the accuracy of the results obtained. A recent trend to optimize these two variables is to combine the use of different tools and techniques to get more accurate data at a faster rate. As an example, passive voltage contrast (PVC) alone was used to determine opens and shorts in a circuit, which is now being replaced by a combination of nanoprobing and Electron Beam Absorbed Current (EBAC) measurements. In this technique, two probes are landed, one on a local signal line and one at the ground of the sample. These probes collect the charges generated by the electron beam and absorbed by the sample. If there is a low resistive path between the area where the beam is injecting charges and the signal probe, this area will appear bright on the image. However, if there is no direct path to the signal probe, the charges will sink to the ground probe, causing the corresponding area appearing dark on the image. This allows the user to determine with high accuracy which lines of a circuit are connected to each other, making it an indispensable tool to detect shorts and opens on otherwise difficult to analyze circuit. Another important tool in FA investigations is the Focused Ion Beam (FIB), as it has become the standard tool to artificially create opens and shorts in a circuit as well as to prepare Transmission Electron Microscope (TEM) lamellas. However, most FIB uses are done under a stage tilt angle of 50-54°, which corresponds to the position where the ions are hitting the sample surface perpendicularly. Therefore, the probing system must comply with the tilting requirements of the stage and bring the sample to a working distance (WD) of 5mm, which is usually the coincidence point between the electron beam and the ion beam (Figure 1).

This needs to be done without making collisions between the probing system and the FIB, the pole piece or any other detectors/parts in the chamber. A workflow combining nanoprobing, EBAC and FIB will undeniably benefit the semiconductor FA community as it allows greater accuracy and flexibility compared to applying each of these techniques independently. However, the turn-around time allocated for analysis must remain as short as possible. One way to achieve this is to align the different tools once and perform all the required measurements within that alignment. This means bringing the sample under 5mm working distance (WD) at a tilt of 54° and using both the nanoprobing system and EBAC

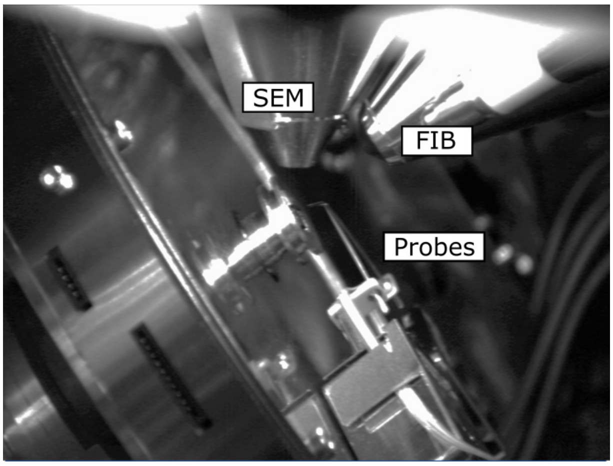

Figure 1. Chamber scope view of the platform tilted at 54°.

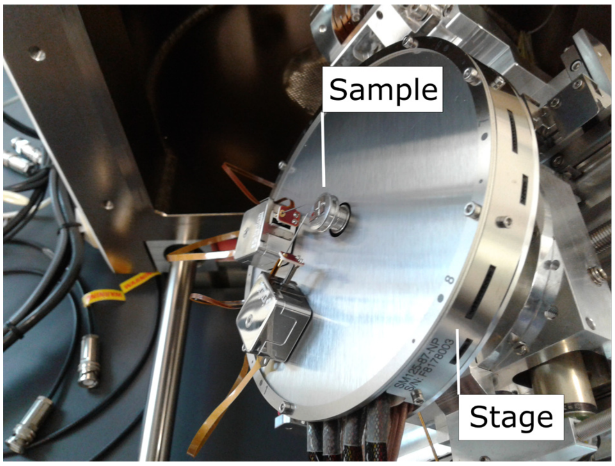

Figure 2. a) miBot mounted in the Zeiss Auriga. Tilted at 54° with the two probers at the lowest position to avoid collision.

in this configuration. The nanoprobing system must therefore be able to move and land probes while the microscope stage is at the FIB tilt position. In this note, we developed a workflow capable of such performances and applied it to a typical case of FA : an investigation of the localization of a short between two metal layers using EBAC and FIB metal line cutting.

EXPERIMENTAL SETUP

A FIB-SEM microscope equipped with a gas injection system from Carl Zeiss AG was used for this experiment. A nanoprobing solution from Imina Technologies SA was installed on the motorized sample stage and electrically connected through a port of the chamber with a custom flange. Two probes were mounted on one side of the platform to allow for easy tilting in the opposite direction of their placement. The probers move freely over the platform and stick to it with a small magnet enclosed under their body. These magnets are strong enough to allow the probers to climb the 54° slope imposed by the FIB tilt position but are located far enough from the beams to not disturb them in any ways. The needles were mounted on the probers such that the roof of the probers is on the same plane as the needles when the prober arm is horizontal (Figure 2).

This configuration allows imaging at short WD (5mm in this case, but as low as 2mm for other applications) when tilted by avoiding collisions between the probing system and the pole piece of the microscope. Outside of the microscope chamber the EBAC system from Point Electronic GmbH was electrically connected to the probes through the flange feedthrough connectors.

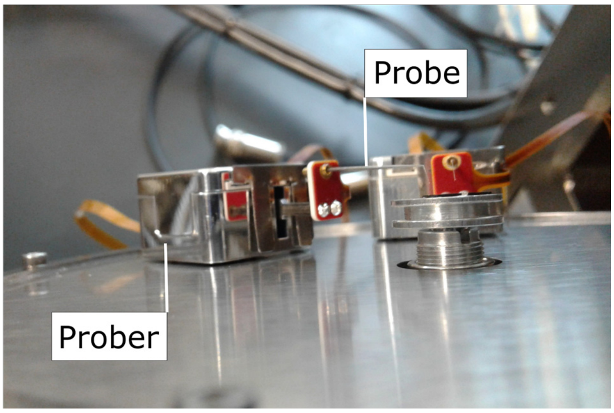

Figure 2. b) miBot mounted in the Zeiss Auriga. With the probes in the same plane as the prober's roof to allow short working distances.

IDENTIFICATION OF FAULTY NETWORK

Localizing shorts in integrated circuits is part of the daily routine of many semiconductor failure analysts as it is the first step before further defect investigation. EBAC imaging for highlighting interconnected networks, and FIB for cutting lines, are premium tools for shorts localization. Figure 3 illustrates the principles of that process. The "green" metal line has an unwanted connection with the "red" metal line. A nanoprobe in contact with the first line is used to produce EBAC images of the interconnected lines. To identify if the short is located at a crossing point, the red line is FIB cut close to where it crosses the green line. After the cut, if the inferior fraction of the red line overlapping the green line does not appear in the EBAC image anymore, there is no short between the lines at this location (Result 2). On the contrary, if this fraction remains visible, it means the short is located at this crossing point (Result 1).

In this case study, we describe the defect localization of a short on an ASIC from the automotive industry which was identified to behave abnormally. After electrical characterization at the bond pad level, it appeared that one of the signals does not switch correctly and instead keeps a constant low. The chip was decapsulated and mounted on a SEM stub using conductive glue. As in the first case study, after identifying the corresponding network on the chip, an opening in the passivation layer was made using the FIB. A contact pad was deposited to give access to the network via nanoprobing.

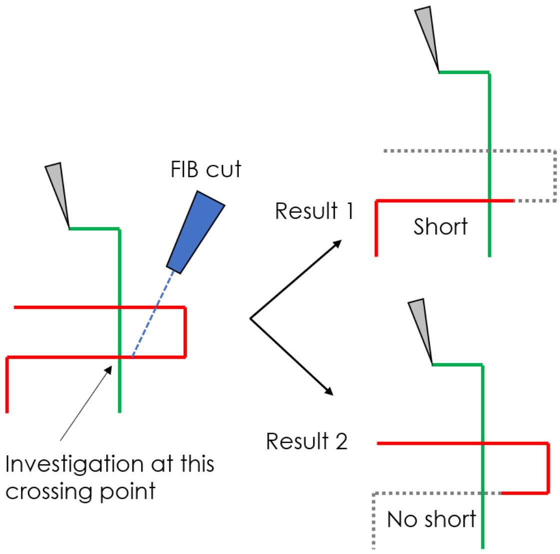

Figure 3. Schematic of the procedure used to determine if a short is located at a specific crossing point. If the crossing point can still be seen on the EBAC image after the cut, the short location has been identified.

RESULTS

To produce the EBAC images, the probe connected to the input high of the EBAC amplifier was first landed on the contact pad, while the other probe connected to the input low of the amplifier was put in contact with the local ground of the circuit. As a matter of comparison, Figure 4 shows on the left, an image of a functioning device with only one highlighted metal line and, on the right, an image of the failing device with many highlighted lines. This means that not only the suspected network (Signal A) is lighted up, but also another network at a superior metal level (Signal B), clearly suggesting that the two are shorted. The networks cross each other at four different locations where the short could be located, hence all four sites were investigated.

The short investigation procedure was followed. The microscope stage was tilted to FIB position at 54° and the probes were aligned and landed on their respective contacts (ground pad and Signal A). For each crossing point, rapid EBAC images were taken at intervals during the FIB milling of Signal B and used to determine when the track is successfully cut. High quality EBAC images, taken at the FIB tilt position before and after each cut, are reported in Figure 5. At crossing points #1 and #2, Signal B did not turn dark after the FIB cuts, indicating that there is no short at these locations. After the cut at crossing point #3, Signal B did turn dark except for its part directly located near this crossing point, clearly highlighting the behaviour of a short at this crossing point. This conclusion is also confirmed by the EBAC image made after the third cut at crossing point #4: only Signal A is lighted up as the short was isolated. At this point, a semiconductor FA engineer has high confidence that the defect in his faulty device was localized with precision. He can proceed with further investigations to characterize the source of this defect, for instance by making cross sections in the area of the crossing point or by preparing TEM lamella.

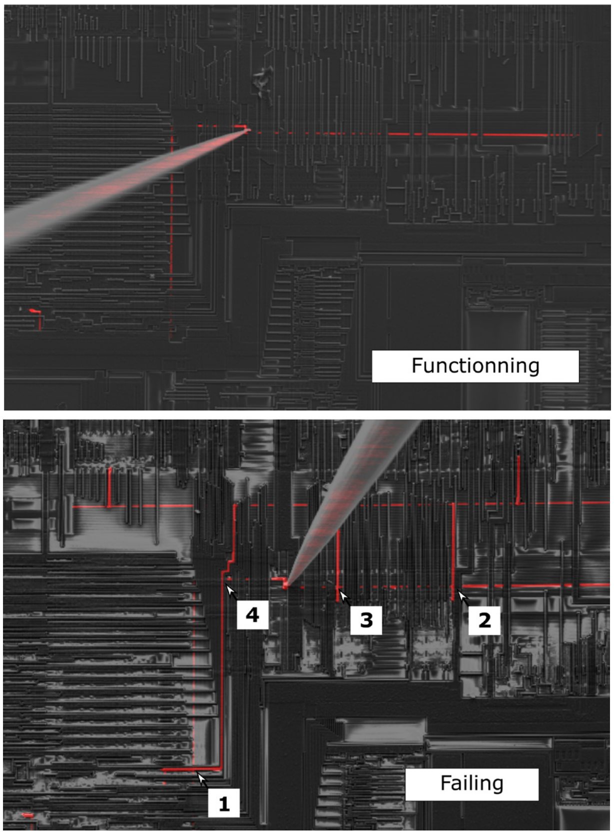

Figure 4. EBAC pictures of the suspected network taken on both a functioning device (up) and the failing device (bottom).

CONCLUSION

In this note, we presented a workflow that combines FIB, EBAC, and nanoprobing techniques. The entire procedure was performed at the FIB tilt position (54°), avoiding the need to bring the motorized microscope stage back to horizontal position for probing after each FIB process. This provides several advantages, starting with the length of investigations which is greatly reduced. Avoiding unnecessary movements also has the positive side effect that it reduces the risk of collisions inside the microscope chamber. This showed that the miBot is a tool of choice for failure analysis procedures involving EBAC and FIB modifications.

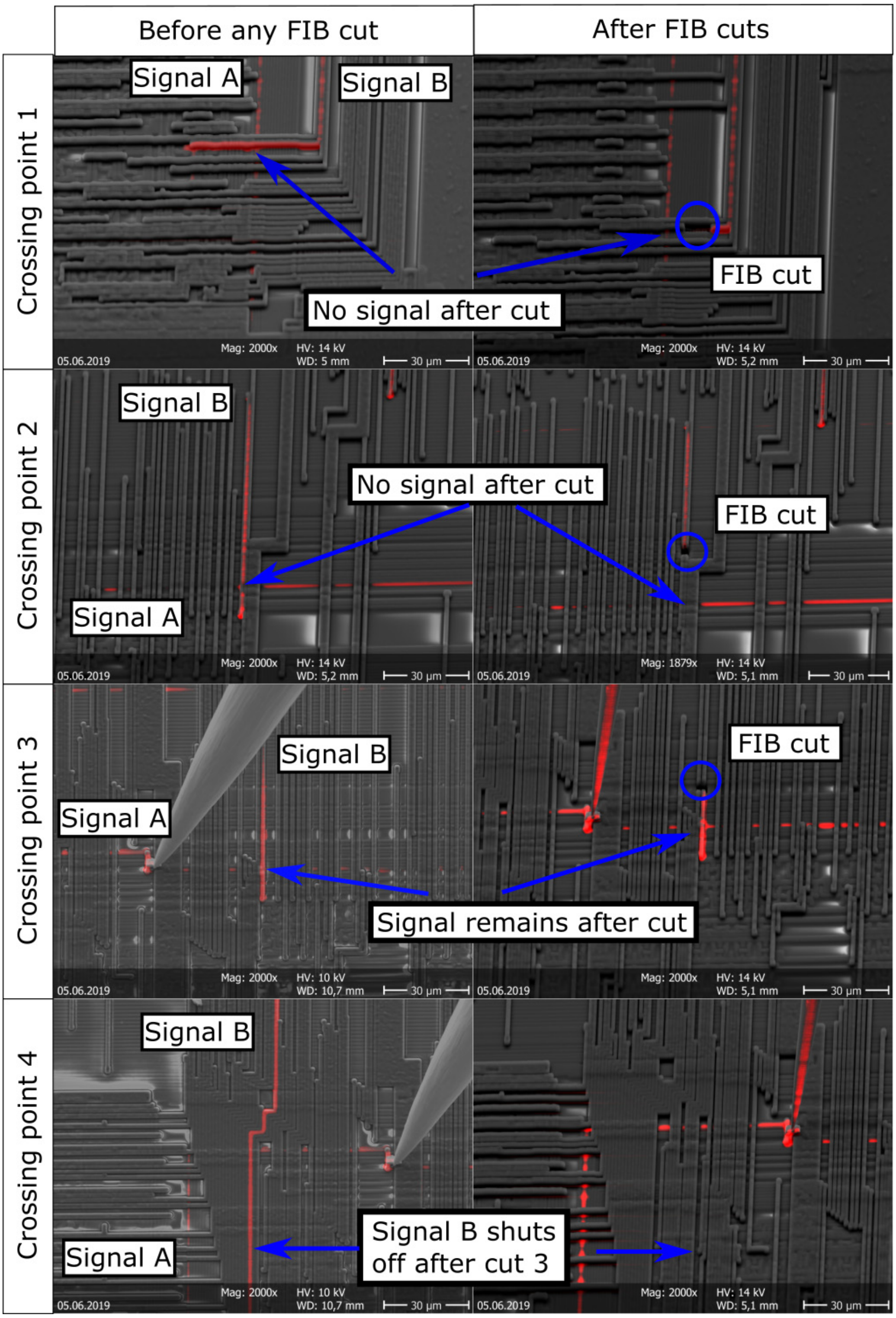

Figure 5. EBAC images of crossing points before (left) and after the FIB cut (right). At crossing points #1 and #2, the FIB cut shuts off the part of the faulty network (Signal B) crossing with the valid network (Signal A), indicating there is no short at these two locations. At crossing point #3, the FIB cut does not shut off the part of Signal B indicating the presence of a short. The last row confirms the short is localized at crossing point #3 as Signal B has turned dark.

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