APPLICATION NOTE

Deposition and in-situ measurement of a 1kOhm pull-up resistor at FIB angle tilt position

INTRODUCTION

In the field of semiconductors development, the ability to interact and modify specific nodes of an integrated circuit (IC) at different stages of its development, test or debugging phase is of high importance. Among the different necessary techniques, nanoprobers have established themselves as premium tools to characterize local features of an IC, as the sharp probes (down to few nanometers) can efficiently apply and measure electrical signals directly at the region of interest. Imina Technologies' miBot is an example of such probers. With its nanometer resolution, high stability and positioning flexibility it can quickly establish reliable contacts with the smallest features of ICs. Another important tool in semiconductor development 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, if such application needs to be done in conjunction with a nanoprober, the probing system must comply with the tilting requirements of the stage. It needs to be possible to 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), without making collisions between the probing system and the FIB, the pole piece or any other detectors/parts in the chamber. In this note, we report an example of such application: the deposition of a 1kOhm pull-up resistor between two nodes. The resistor is deposited at FIB tilt angle while the miBots measure the value of the resistor while its being deposited. Once the desired value of 1kOhm is reached, the FIB induced deposition is stopped.

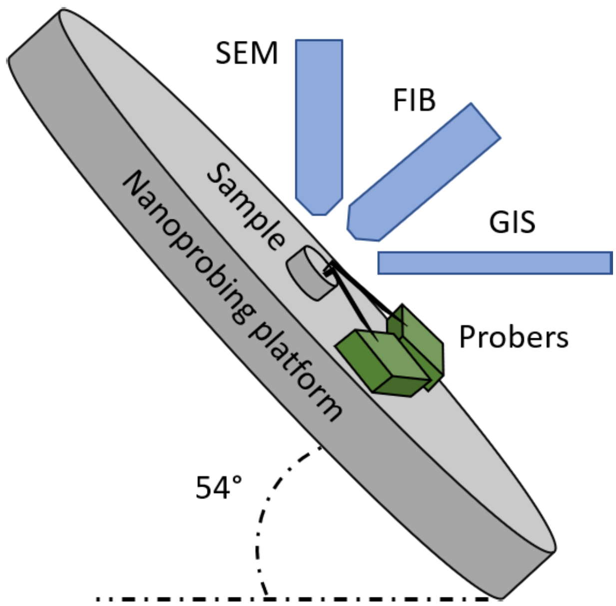

Figure 1. Schematic of the nanoprobing platform tilted to FIB position.

EXPERIMENTAL SETUP

A FIB-SEM microscope equipped with a gas injection system (GIS) from Carl Zeiss AG was used for this experiment. The miBot probers from Imina Technologies SA were 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 semiconductor parametric analyzer from Tektronix Inc was electrically connected to the probes through the flange feedthrough connectors.

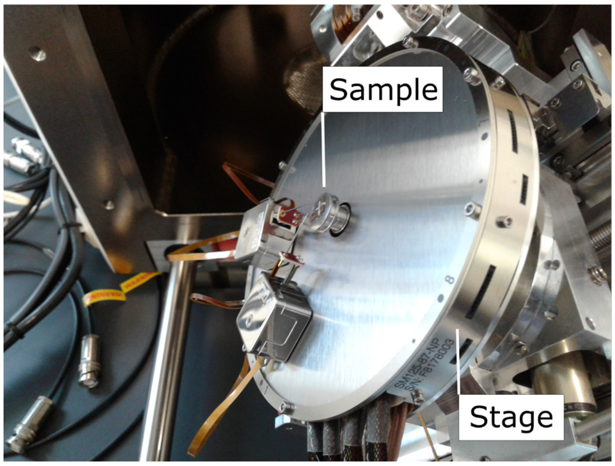

Figure 2. a) miBot mounted in the Zeiss Auriga. Tilted at 54° with the two probers at the lowest position to avoid collision.

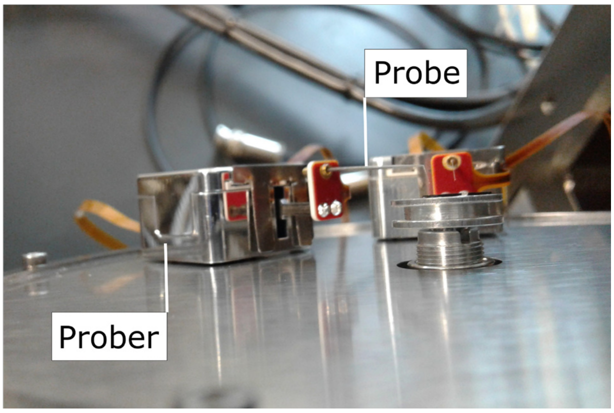

Figure 2. b) miBot mounted in the Zeiss Auriga. With the probes in the same plane as the prober's roof to allow short working distances.

RESISTOR AND CHARACTERIZATION

The deposition process consists of injecting with the GIS a precursor gas that is decomposed at the surface by an external energy source. Either the electron beam or the FIB can be used for that purpose, although the FIB provides faster deposition rates. The process described in this case study is divided into three main steps: 1) deposition of the resistor terminal pads connected to the two networks; 2) deposition of a baseline resistor using the electron beam; 3) deposition of the resistor with the FIB with live monitoring of its value.

To get access to the networks, the FIB was first used to remove the passivation layer at the locations where the resistor terminals will be placed. Two micron-sized pads were then deposited at these locations to ensure good contact with both networks and provide convenient access to the resistor terminals while it is being deposited.

A thin layer of Platinum was deposited between the two freshly created pads using the electron beam (Figure 3). This layer serves both as a protective layer from possible unwanted milling from the FIB and as a baseline resistor to monitor the resistance during FIB-induced deposition. It is worth noting that ten minutes were required to deposit this first layer of approximately 60kOhm resistor using the e-beam, which justifies the use of the FIB to deposit the 1kOhm as its deposition rate is much higher. Once this baseline resistor was deposited, the stage with the probing system were tilted to FIB position at 54°, alongside the GIS nozzle, as shown on Figure 4.

Figure 3. Platinum layer deposited between the two pads using the electron beam.

At this tilt angle, horizontal alignment and landing of the probes in contact with the terminal pads was rapidly achieved with the nanometric motion resolution probers. Prior to the deposition, the baseline resistor was measured again, to check the good electrical connection between the probes. Platinum deposition was then initiated at the same time as a 1V bias was applied with the source-meter unit between the probes. The current flowing between them was continuously monitored during the deposition as depicted in Figure 5.

The FIB and gas insertion were stopped once the desired value of 1mA was reached. The obtained resistor was then measured at exactly 1.00 kOhm, which shows the advantage of being able to measure the resistor while it is being deposited.

DISCUSSION

As the deposition did not take place on an entirely flat substrate (Figure 6), the effect of the sample topography impacts the speed at which the resistance changes over time. In fact, since it takes more time to deposit Platinum on the vertical sides of the metal tracks, these areas act like bottle necks for the current, increasing the overall resistance. As the layer gets thicker, the topographic profile smoothens and this effect dampens, leading to a higher resistance change rate. This results in slope changes of the graph curve in Figure 5.

The resistance deposition process described in this study, from the baseline resistor deposition to the final resistor deposition took approximately 45 minutes. This fast pace was possible as all the steps were made in a row without having to tilt the sample back and forth between 0° and 54°. Live current monitoring during the resistor deposition also clearly provides a gain in accuracy of the resistance value which would be impossible to match if the probes could only be landed at 0° tilt.

CONCLUSION

In this note we presented a workflow that combines FIB, GIS, and the miBot from Imina Technologies. Because of the miBot ability to work under tilted position, the entire procedure is performed at the FIB tilt position (54°), avoiding the need to bring the motorized microscope stage back to horizontal position for nanoprobing after each FIB process. This provides several advantages, starting with the duration of the experiment which is greatly reduced. Avoiding unnecessary movements also has the positive side effect that it reduces the risk of collisions inside the microscope chamber. Finally, the ability of live monitoring the current flow with the miBots in the device under test during a FIB process, allowed us to reach higher accuracy in terms of performance of circuit modification.

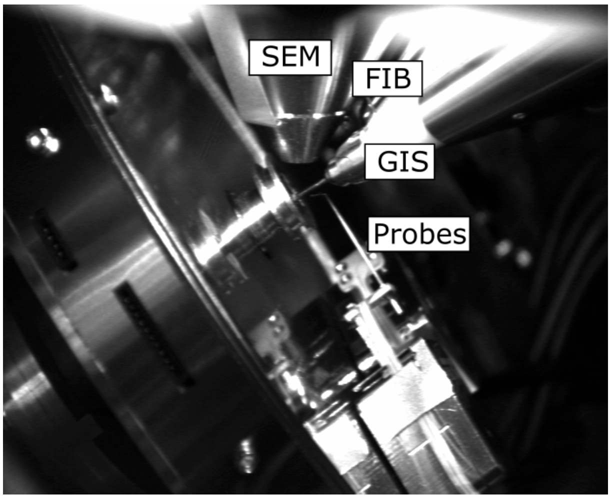

Figure 4. Chamber scope view of the platform in operating conditions at FIB tilt position with the GIS nozzle inserted.

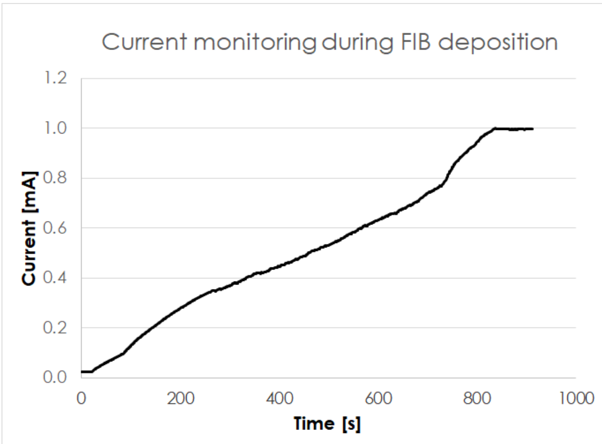

Figure 5. Live monitoring of the current in between the two probes while the resistor is being deposited.

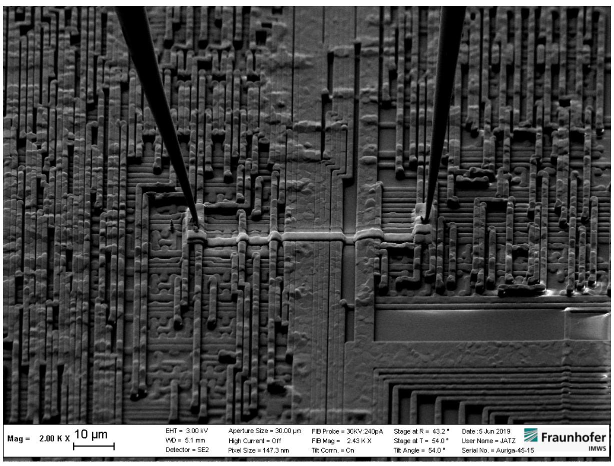

Figure 6. SEM image under 54° stage tilt of the resistor obtained at the end of the FIB induced deposition.

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