Application report

Date: 14.01.2014

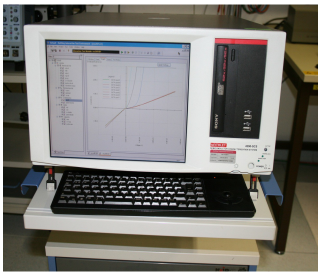
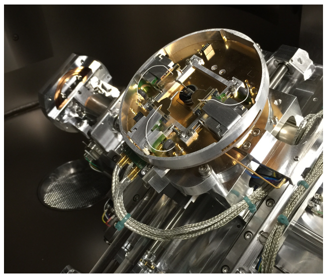
Title: Analysis of semiconductor failures using Kleindiek EBIC/RCI amplifier and Zeiss Auriga

Authors: Igor Doncov, Michael Charpentier, Marc Penderak

ABSTRACT:
In the following report three typical applications of using the SEM (Scanning Electron Microscope) based EBIC/RCI method in semiconductor failure analysis are presented. The results were obtained during evaluation of the Kleindiek EBIC/RCI amplifier at the ELMOS Semiconductor AG failure and physical analysis labs.

1 System Setup

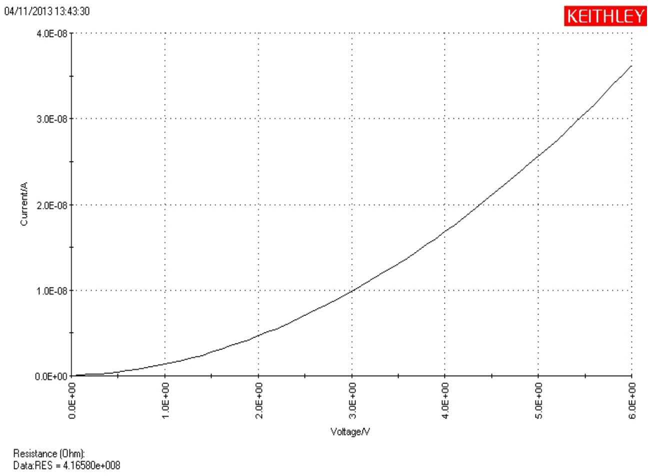
- Zeiss Auriga
- Kleindiek Prober Shuttle
- Kleindiek EBIC/RCI Amplifier
- Keithley 4200 SCS parameter analyzer for electrical characterization and check of probe tip contacts

			
Figure1: Zeiss Auriga Dual Beam FIB/SEM	**Figure2:** Keithley 4200 Semiconductor Parameter Analyzer	**Figure3:** Kleindiek EBIC/RCI Amplifier	**Figure4:** Kleindiek Prober Shuttle

2 EBAC analysis of capacitor defects

Problem description:
Yield loss caused by leakage currents in nA range on capacitor test structures (see Fig1). Already performed OBIRCH (Optical Beam Induced Resistance Change) and photon emission analysis did not yield any results on the affected devices.

For the EBAC analysis on these devices the investigated capacitor structure was connected via 2 probe tips to the Kleindiek EBIC/RCI amplifier (see Fig6).
The AC mode of the amplifier turned out to be best suited for detecting capacitor oxide related defects. Signal intensity was optimized by varying the amplifier parameters (gain, offset, cap,res …) and the SEM parameters (acc. voltage, beam current, scanning time/direction).
After gathering some experience with the influence of the different variable parameters it was easy to get high quality images suitable as a basis for further physical preparation steps (see Fig8+9).
Furthermore the very precise localization compared to OBIRCH and photon emission analysis reduced the final preparation effort for time consuming cross section or STEM analysis at the physical failure site (see Fig10).



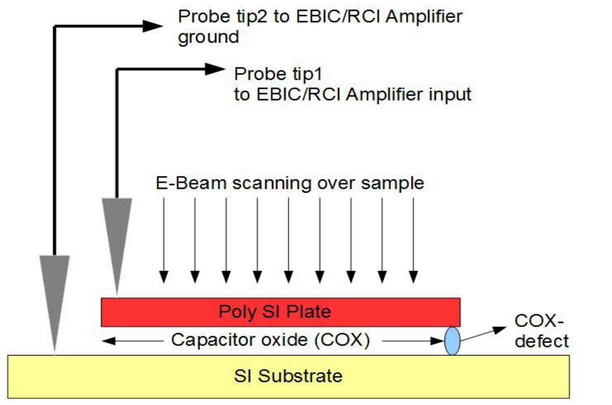
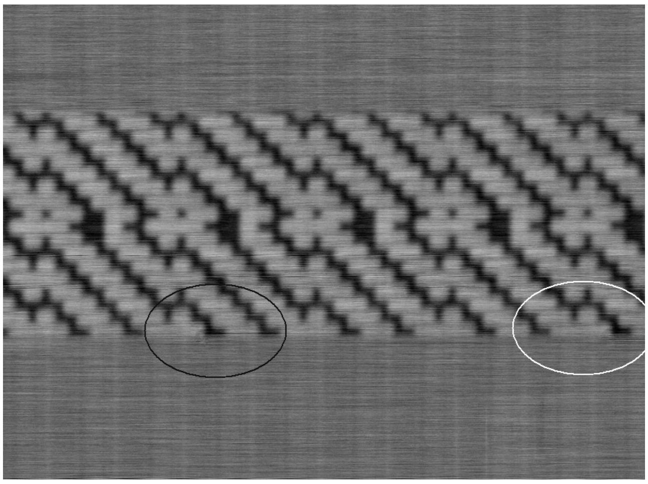


Figure5: Leakage current in nA range observed on capacitor test structures.

Figure6: Simplified schematic of measurement setup.



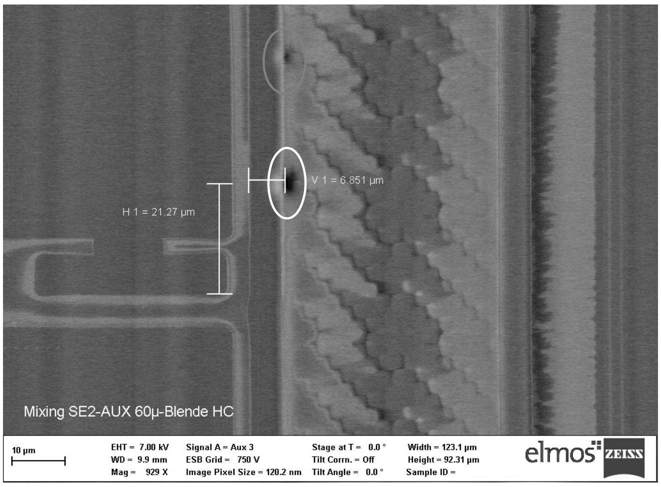
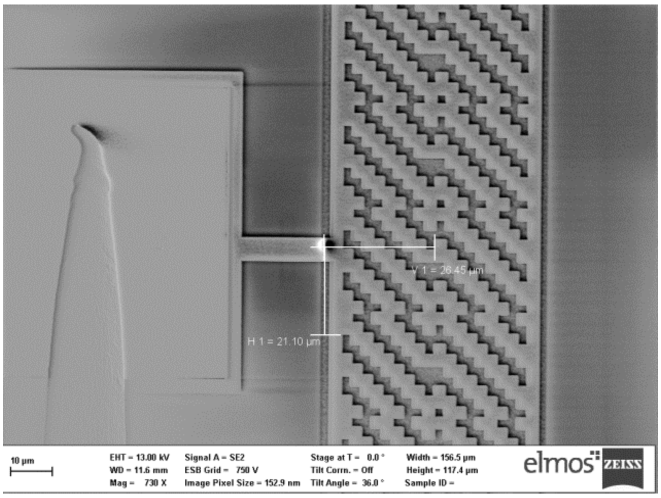


Figure7: First attempts yielded only very diffuse signals at the capacitor edges.

Figure8: Change of scanning direction showed massive increase in EBAC signal quality.



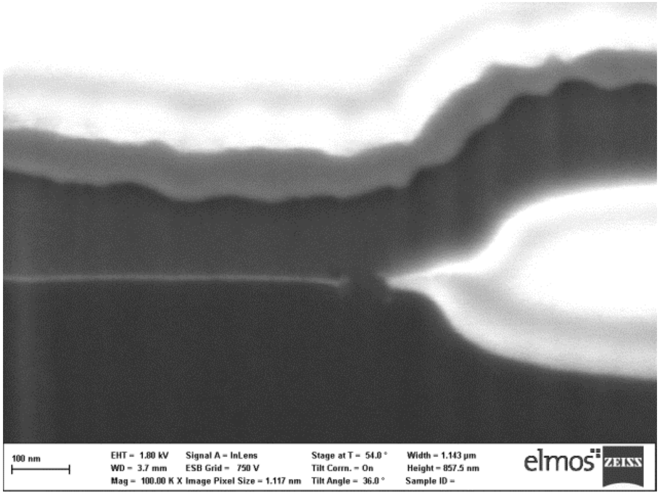


Figure9: Overlay image (EBAC + SE2) after parameter optimization (Amplifier+SEM) in another area of the capacitor test structure.

Figure10: FIB (Focused Ion Beam) cross section image of the localized failure site.

3 Detecting shorts and opens in metallization networks

Another typical task of daily failure analysis is the localization of shorts between internal asic signals or the localization of open/high resistive vias within a metallization network or within specific test structures (e.g. via chains).

Figure 11 shows the EBIC image in DC mode of a device after connecting one internal signal line to the EBIC amplifier with a probe tip on metal4 layer. Depending on the used acceleration voltage the whole routing down to metal1 layer of this signal can be highlighted in the EBIC image.
Afterwards the sample was modified via FIB (Focused Ion Beam) so that the signal was shorted to another internal signal line by depositing a platinum bridge. The corresponding EBIC image of the modified sample can be seen in figure12.
To check the sensitivity of the EBIC signal on the resistance between the two shorted signals the deposited platinum bridge was milled down till only a surface connection was left. This way the resistance of the original short was increased to approximately 24kOhms. In the EBIC image taken afterwards still both now high ohmic shunted signals and the location of the shunt are highlighted.

A useful advantage of EBIC compared to other methods (e.g. OBIRCH) is that only one of the shorted signals needs to be known as only one probe tip was needed for the tests performed.
For OBIRCH localization both shorted signals need to be known and contacted with a probe tip or on external pins for precise failure site localization.
Therefore often a lot of additional time consuming probe station measurements are needed when only using OBIRCH analysis.

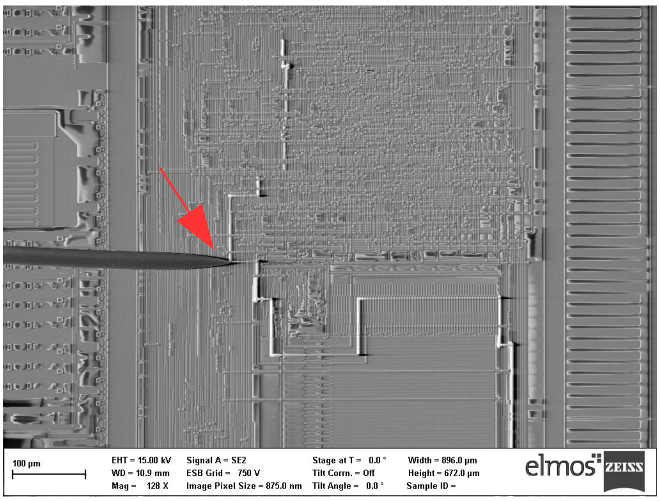


Figure11: Signal line routed on several metallization layers connected to EBIC amplifier via probe tip (red mark).

Figure12: Same signal line from figure11 shorted to a neighboring signal line. Area of the short and shorted signal are easily visible in the EBIC image (red marks).

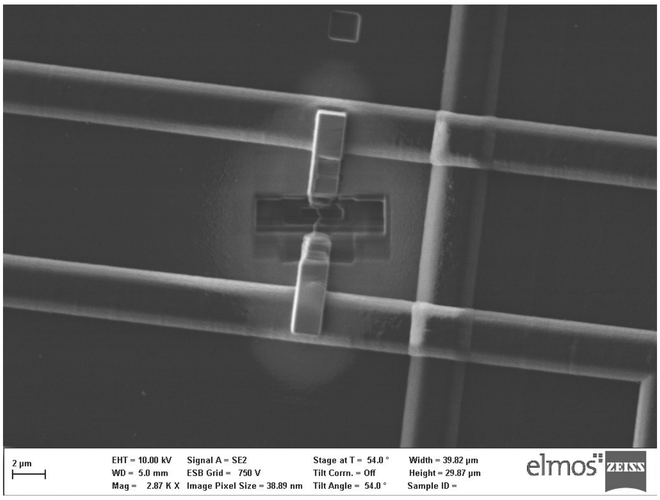


Figure13: FIB bridge milled down till it got high ohmic (approx. 24kOhms).

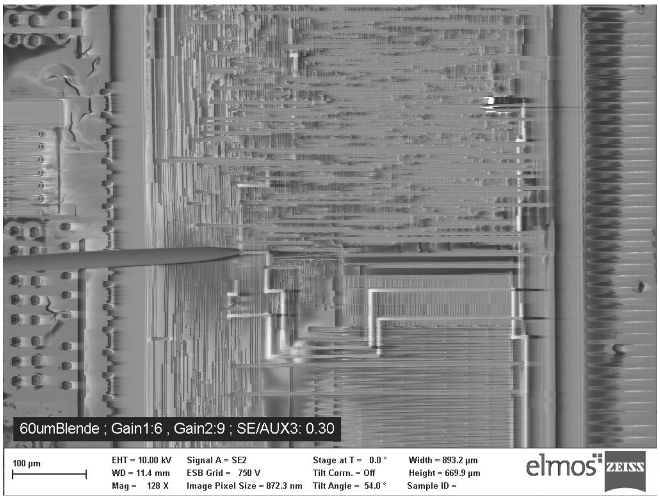


Figure14: Shunted signal and area of the high ohmic shunt are still visible.

The localization of high resistive vias within a metallization network or via chain test structure can be performed in the same way.
As an example figures 15+16 show a high resistive via chain test structure. With EBIC/RCI analysis the failure site could be traced back to a single high ohmic via within the whole chain consisting of 1 million vias.

Comparable methods like voltage contrast imaging can only be used on fully open vias, whereas EBIC/RCI also works on high ohmic connections due to its higher sensitivity.

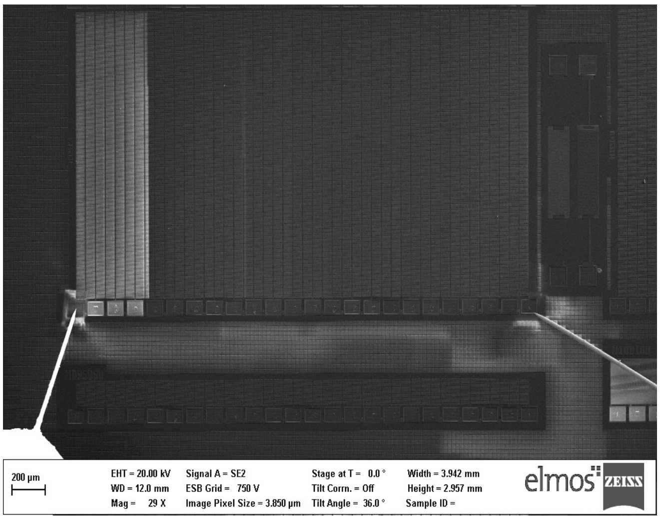


Figure15: Via chain with over 1.000.000 vias contacted with 2 probe tips.

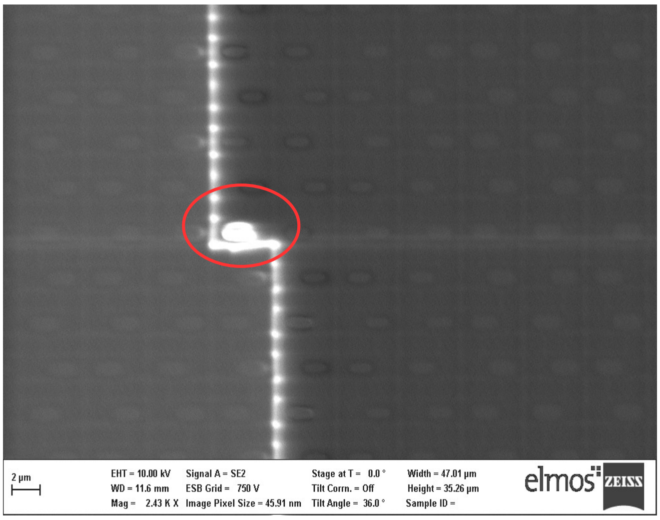


Figure16: Single high ohmic via highlighted in the EBIC/RCI image.

4 EBIC imaging of pn junctions (dopant contrast)

For EBIC imaging of dopant areas e.g. within bipolar structures or diodes the DC mode of the EBIC/RCI amplifier was used. By varying the acceleration voltage the dopant regions in different depths in the substrate can be visualized (see figures 19-21).

For best resolution the investigated device was delayered down to contact level. Two probe tips were used for EBIC image acquisition.
This way misaligned dopant regions causing leakage currents could be detected in the past in cases where OBIRCH and photon emission analysis did not yield any results (see figures 22-24).

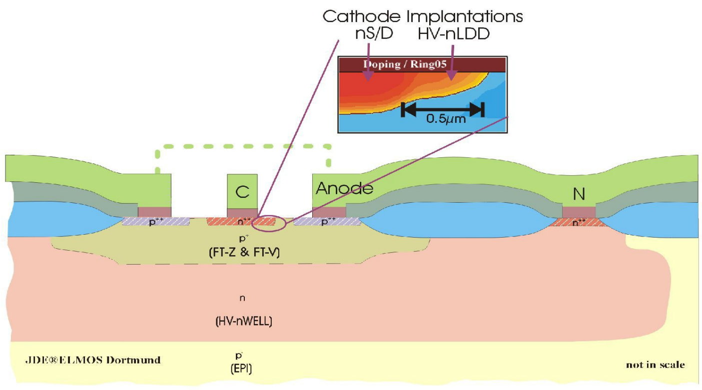


Figure17: Cross section with the different dopant regions in the investigated bipolar structure.

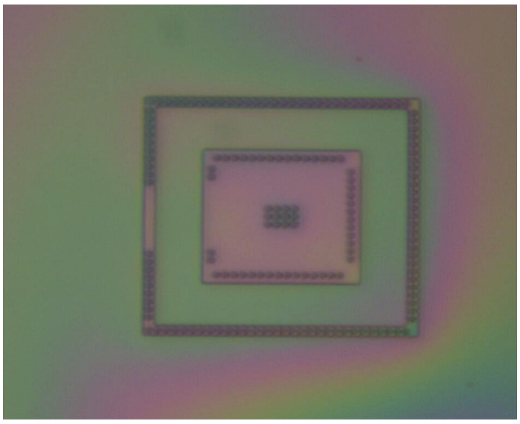


Figure18: Light microscope overview image of the parallel polished specimen down to contact level.

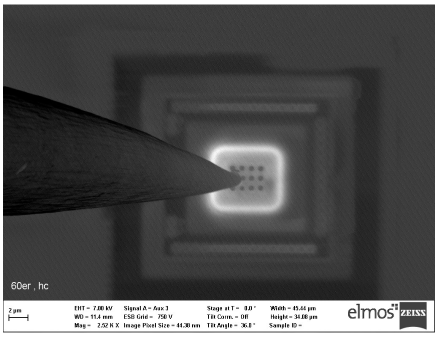


Figure19: EBIC image at 7kV

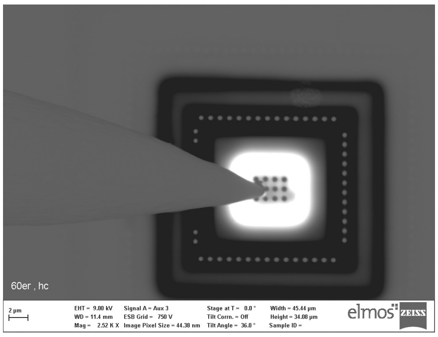


Figure20: EBIC image at 9kV

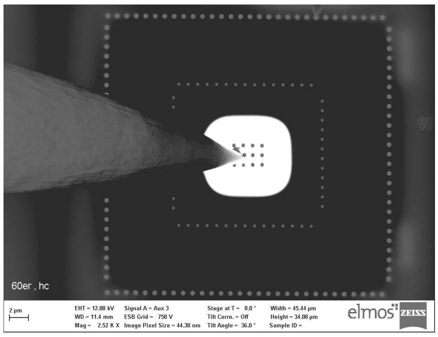


Figure21: EBIC image at 12KV

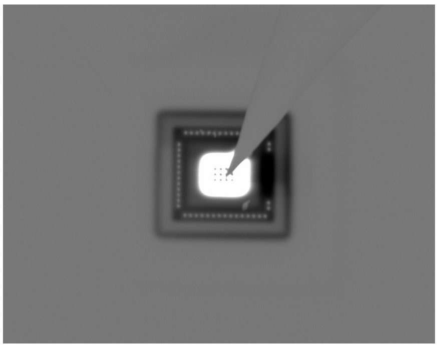


Figure22: Same EBIC analysis performed in the past on fail device at external lab. Image at 9kV acceleration voltage.

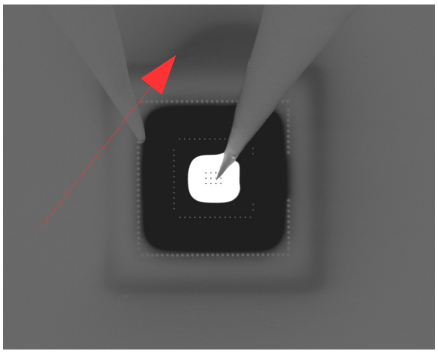


Figure23: EBIC analysis performed in the past at external lab. Fail device at 12kV acceleration voltage. Local deviation to a reference device visible.

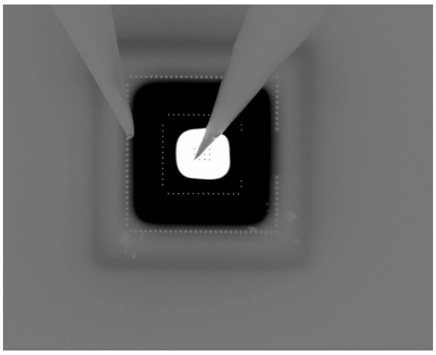


Figure24: Reference device at 12kV acceleration voltage.

Summarized evaluation results:

Within a short amount of time the evaluated Kleindiek EBIC/RCI system could be successfully implemented in the standard analysis flow at the Elmos semiconductor AG.

During evaluation phase this new analysis option helped in solving yield related internal issues as well as successful physical root cause analysis on external customer returns.

Besides the already mentioned advantages of the EBIC/RCI option in the examples above compared to currently used analysis methods (OBIRCH, photon emission, probe station measurements, voltage contrast ..), especially for upcoming process shrinks a SEM based localization method will become more and more important not only for specific problems, but also as a standard analysis tool.

Elmos would like to thank Kleindiek Nanotechnik GmbH for offering the possibility of evaluating the EBIC/RCI amplifier.