APPLICATION NOTE

Spotting shorts: how to use RCI to find low resistance defects in metal-insulator-metal capacitors

INTRODUCTION

Shorts, or low ohmic defects, are a common type of defect in Integrated Circuits (IC). Localizing shorts can be a tricky challenge, as there is little resistance contrast between the defect and the surrounding structures.

Here, we show how Resistive Contrast Imaging (RCI), if done with the right hardware, is an effective technique to highlight shorts within the oxide of Metal-Insulator-Metal (MIM) capacitors.

SETUP

RCI can be used to find low ohmic defects when the setup is capable of pre-amplification of the signal. Thanks to that, noise is reduced, improving the signal-to-noise ratio and overall sensitivity of the setup.

The setup used in this experiment:

- Tescan CLARA SEM.
- IMINA Technologies SA Nanoprobing platform with two miBots™.
- EFA system by point electronic GmbH with in-situ current pre-amplifiers for each probe.
- A GV10x from IBSS is used to run an in-situ plasma cleaning cycle prior to the experiment.

We analyzed MIM capacitors with two different types of shorts. The LOW probe was connected to the bottom plate of each MIM capacitor while the HIGH probe was connected to the high plate.

DEVICE 1

Figure 1 shows an SEM image of the MIM capacitor with a short defect between its two plates. The image was acquired at 13kV with a beam current of 300pA.

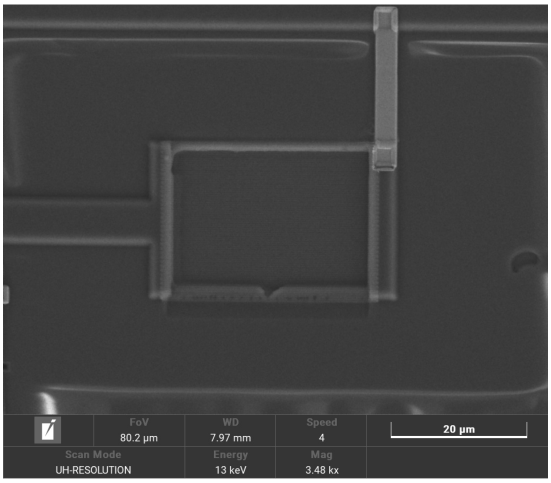

Figure 1. *SEM view of the Device 1: a MIM capacitor with a short between the plates.*

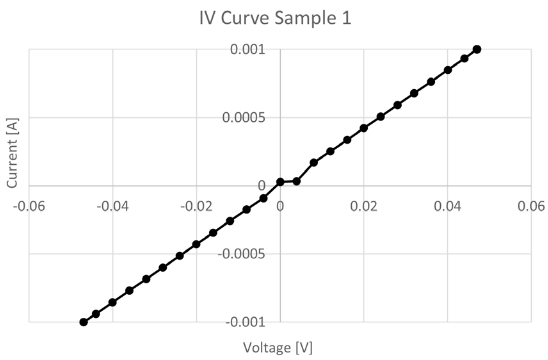

Figure 2. *IV curve between the plates of the first MIM capacitor.*

We land our probes on each electrode of the capacitor and record an IV curve. The defect has a resistive behavior with a calculated resistance of 47Ω. Since the device in question is a capacitor, we expect resistance between the plates to be in the GΩ range. Therefore, resistance of less than 100Ω can be considered a short and not a leakage.

We acquired the RCI image at the same acceleration voltage (13kV) but with an increased beam current (10nA). To maximize the contrast, we set a low scanning speed aiming the image acquisition time of a couple of minutes.

The acquired RCI image was colored in red and overlaid with the SEM image. The result is presented in Figure 3. A bright red spot of about 1.5µm in size indicated the location of the defect.

The high contrast obtained on a defect that has such low resistivity is only possible thanks to the in-situ current pre-amplifiers.

To obtain more accurate position of the defect, we increased the acceleration voltage to 15kV. The RCI contrast got higher, as shown in the zoomed-in RCI image acquired at the location of the defect (Figure 4). We adjusted brightness contrast and gain of the amplifier to improve the signal, and it was possible to highlight a spot of about 500nm. Such defect localization accuracy is sufficient to prepare a TEM lamella and identify the cause of the failure.

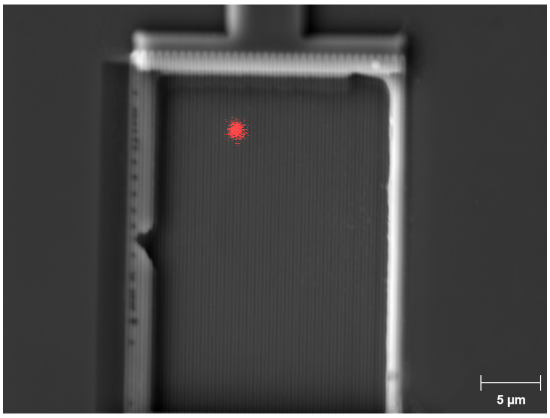

Figure 3. *High-contrast RCI signal indicates the location of the short between two MIM capacitor plates.*

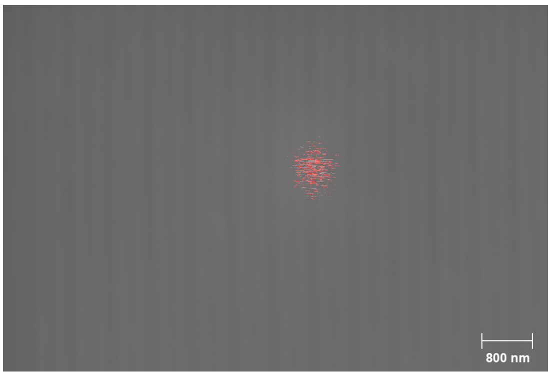

Figure 4. *Zoom-in of the defect site with increased ROI contrast to localize the defect more precisely.*

Tip: imaging with such conditions is possible only if the sample is not charging, as otherwise the image will drift, leaving a smeared-out effect on the image.

If the sample is charging, averaging about 20 fast scans will create a result similar to a single slow scan.

DEVICE 2

Electrical failure verification has identified a shorted capacitor. Subsequent OBIRCh and Thermal fault localization revealed an abnormal hot spot but did not suggest an ROI for further investigation, despite the crack observed on top of MIM capacitor.

So we proceeded to RCI with pre-amplified signal acquisition.

Figure 5 shows another area on this MIM capacitor containing a short between the electrodes. Due to the charging effect, we can only guess the exact limits of the bottom electrode under the top plate.

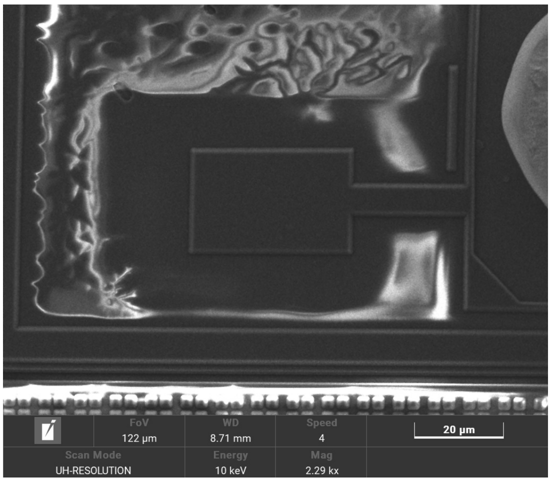

Figure 5. *SEM image of the Device 2: MIM capacitor containing a short between the plates. This sample is heavily charging.*

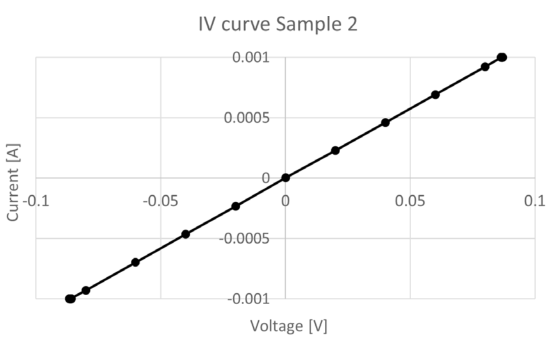

Figure 6. *IV curve between the MIM capacitor pads.*

We landed the probes and recorded an IV curve between the capacitor pads. The sample showed a resistive behavior with a resistance of 86Ω. This value is low enough to be considered a short.

Next, we acquired an RCI image with an acceleration voltage of 5kV and a beam current of 10nA.

The location of the defect is clearly visible as a large white dot in Figure 7. In this case it was not possible to narrow down the defect location to a smaller than 5-7µm.

Examination under the optical microscope confirmed that this part of the device contains a large crack, which most likely is the source of the short.

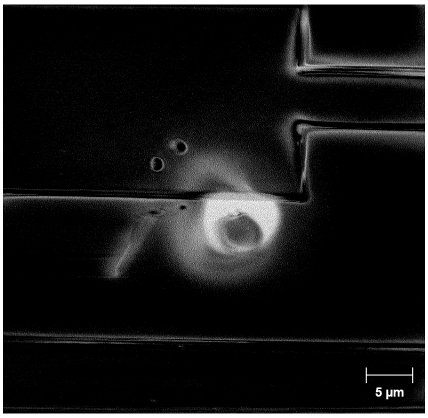

Figure 7. *RCI signal highlights the shorted area in the second MIM capacitor.*

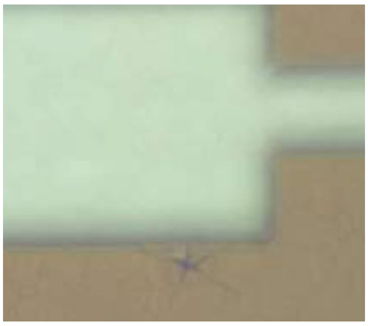

Figure 8. *Optical image of the shorted pad clearly shows a crack in the dielectric under the pad.*

CONCLUSIONS

In this application note, we demonstrate how to localize low ohmic defects, or shorts, in MIM capacitors using RCI. We have showed how we localized two defects of different nature to provide more insight about the technique.

Most other failure analysis methods fail to localize low ohmic resistance defects between two parallel plates. While OBIRCh could potentially find a failure spot with a few microns precision, RCI contrast enhanced by pre-amplifiers yields unparalleled localization precision of 500 nm for such fails, so it is much easier to prepare a lamella for further investingation with TEM.

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