SAND2017-10654C

Sandia National Laboratories

A Quantitative Method for Measuring Remaining Silicon Thickness During XeF_2 FIB Trenching for Backside Circuit Operations

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Outline

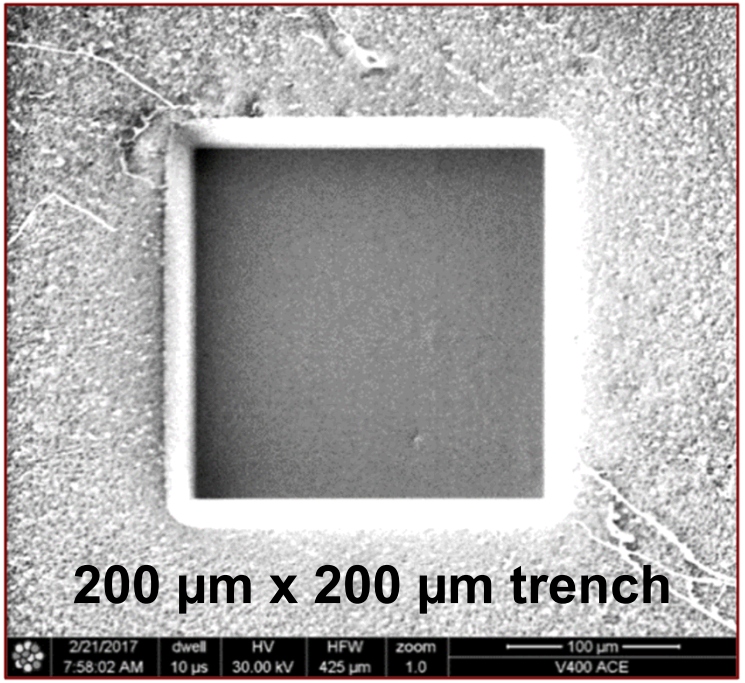
- Introduction
- Conventional Measurement Technique
- New Measurement Technique
- Results
- Conclusions
- Questions

Introduction

- Backside circuit edit (CE) is a critical requirement for the FA toolkit.
- Accurate measurements of remaining silicon thickness (RST) during backside Si trenching is critical.
- RST measurements using IR camera and artifact focal plane distance measurement technique is highly subjective and unreliable.
- Development of a VMT technique has enabled more reliable RST in-situ measurements.

Introduction: Process Sequence

- Si die is either pre-thinned or mechanically thinned to ~100 µm RST.
- Trenches are formed from the backside of a Si die in a backside FIB using XeF_2.
- For backside CE, the goal is an RST of 10 µm or less.

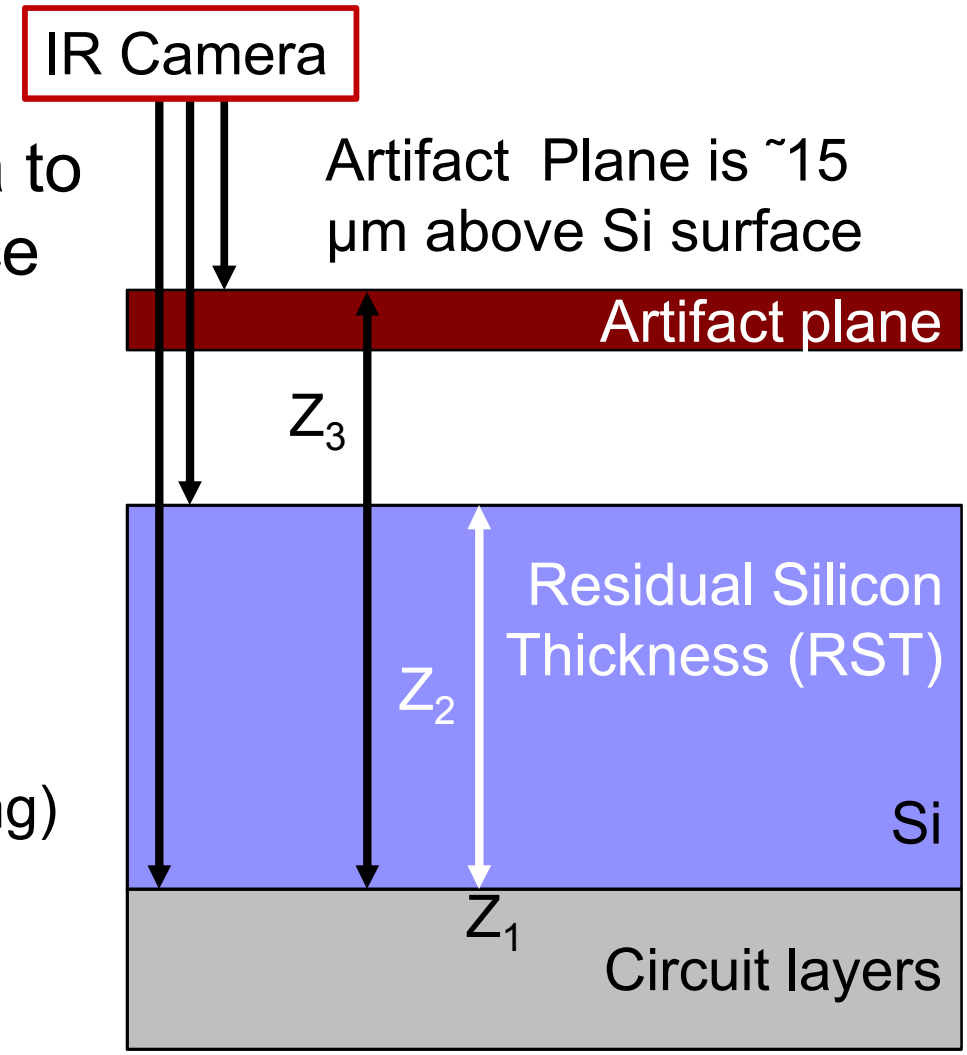


Conventional Si Measurement Technique

FIB backside Si trenching currently uses an IR camera to measure the vertical distance between focal planes

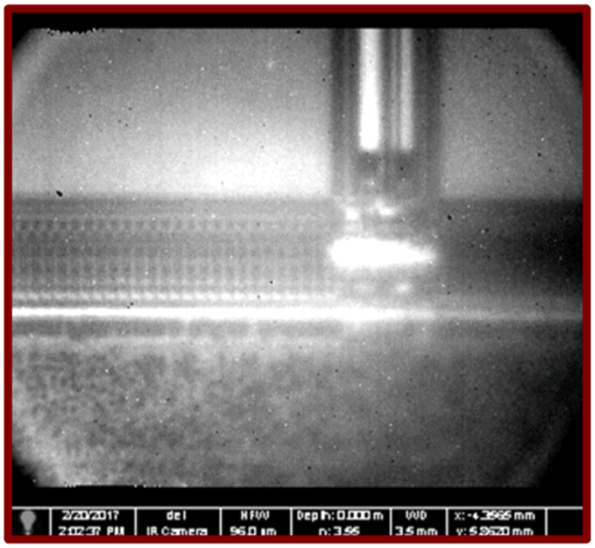
Discernable surface features:

- Pre Processing
  - Circuit layers
  - Silicon surface
  - Artifact plane
- Processing (XeF_2 Trenching)
  - Circuit layers
  - Artifact plane

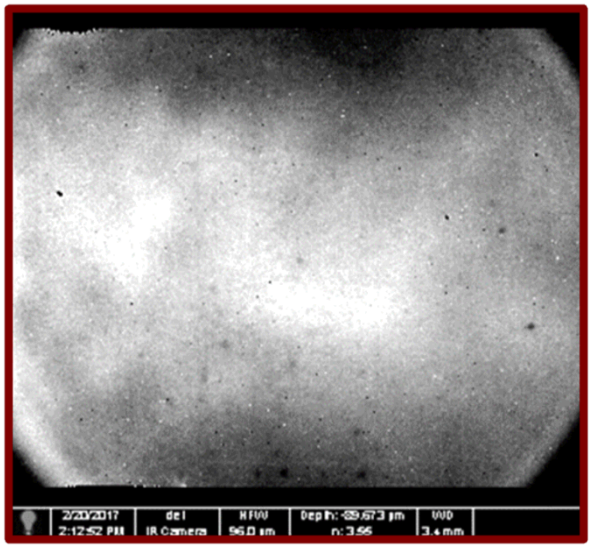


Conventional Si Measurement IR Camera Images

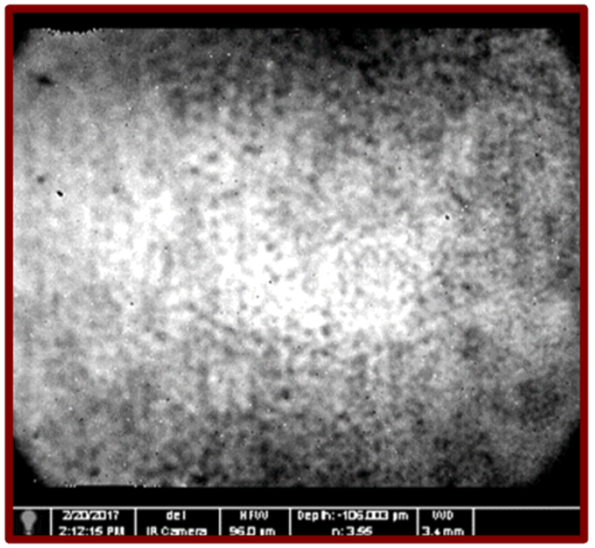
Circuitry In Focus → Si Surface in Focus → Artifact Plane



Z_1 position = zero

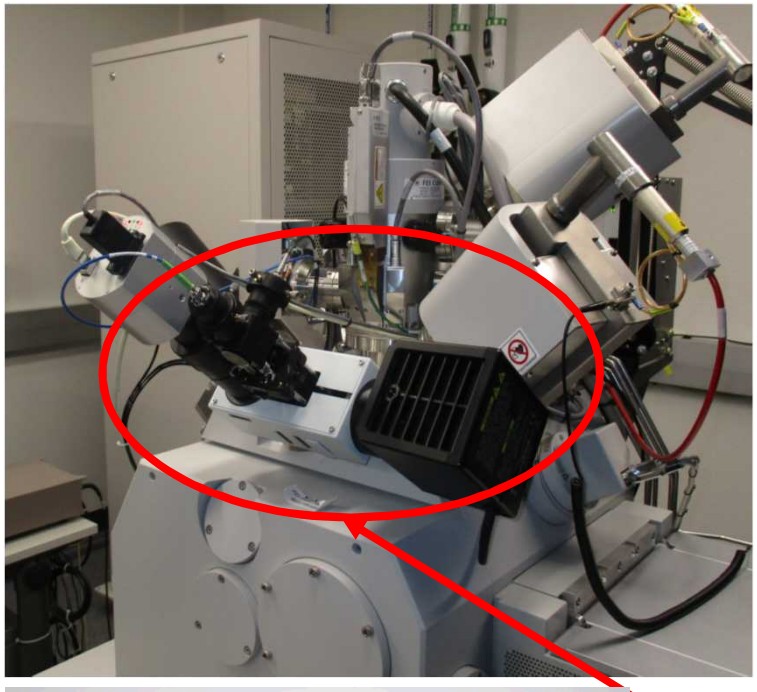


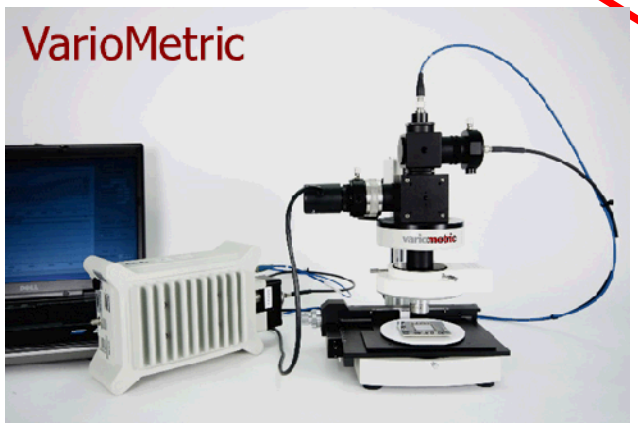
Z_2 position = Si thickness

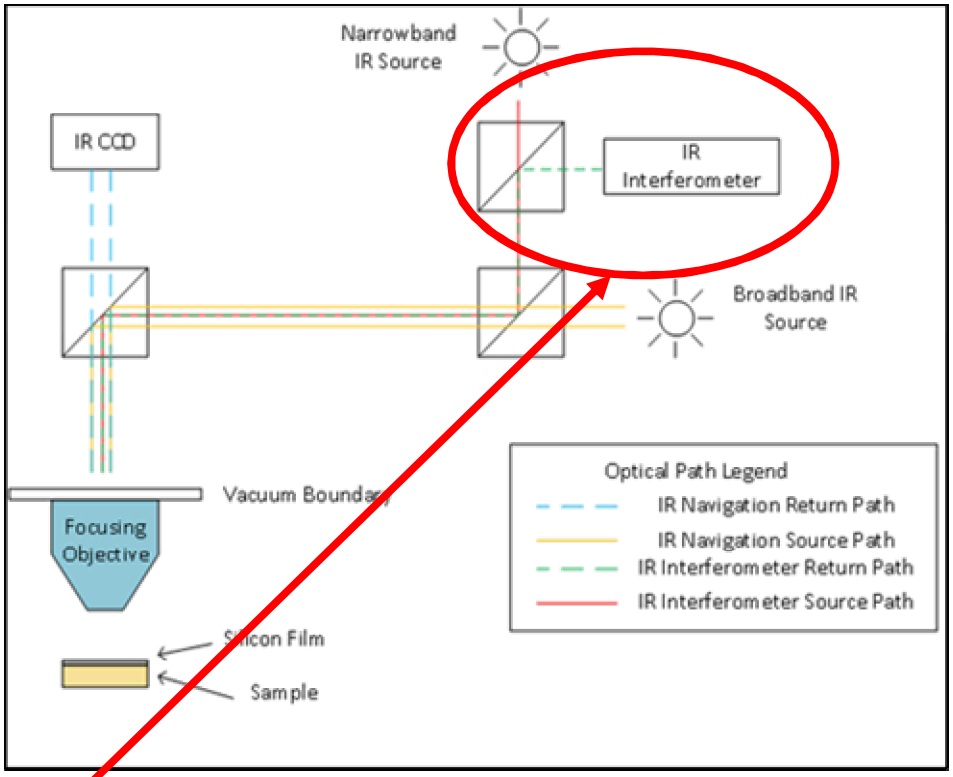


Z_3 position = Si thickness + 15 µm

Integrated VMT Interferometer



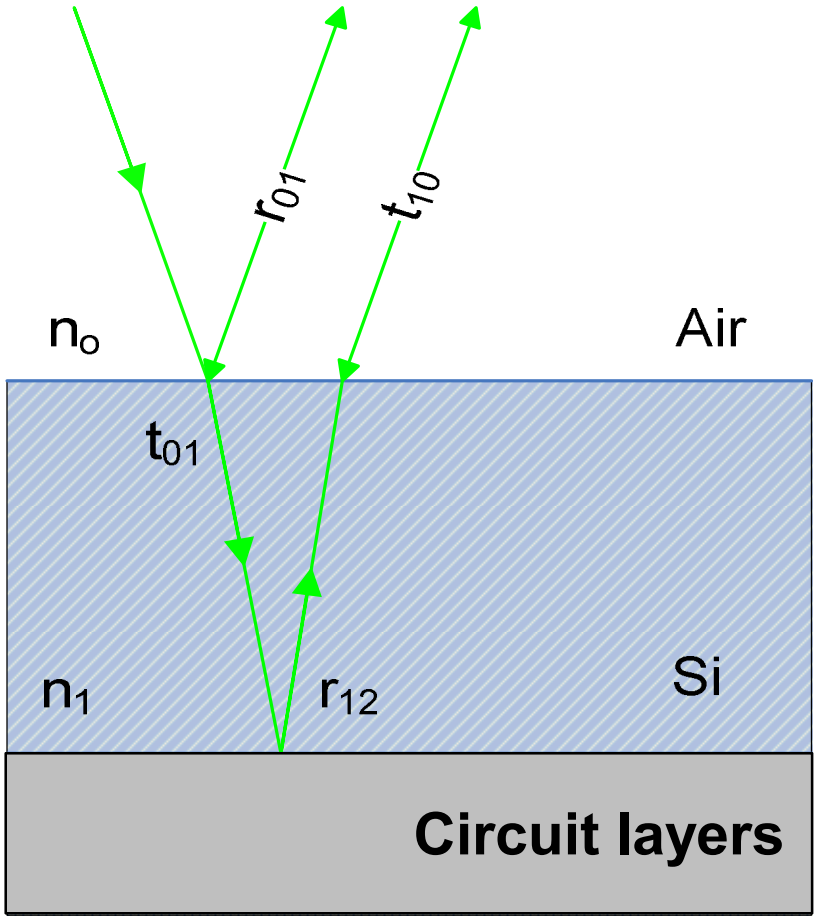




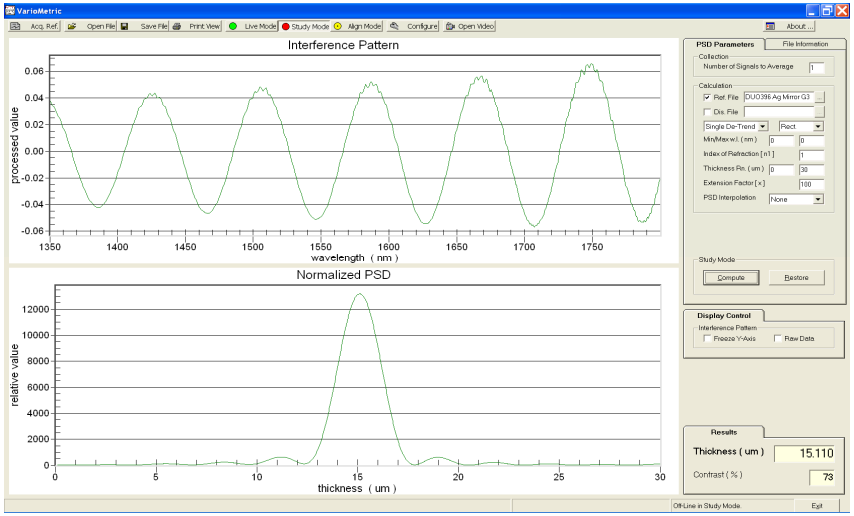
Modification

Integrated VMT Interferometer

Laser Reflectance Spectroscopy



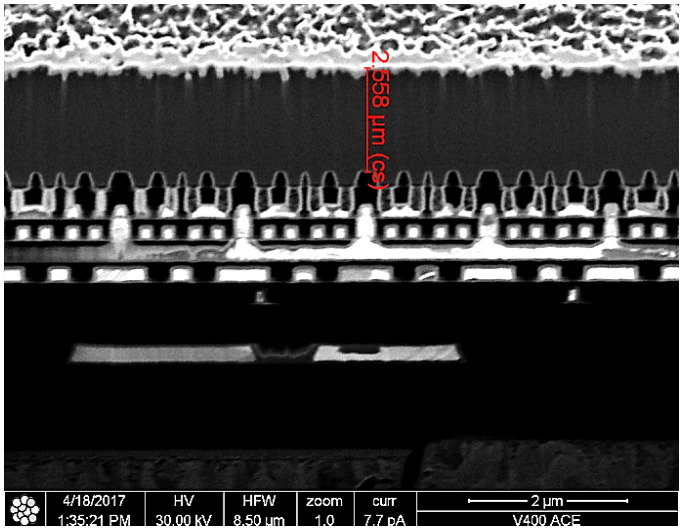
Modification allows accurate, quantitative RST measurement at the processed FIB trench floor.



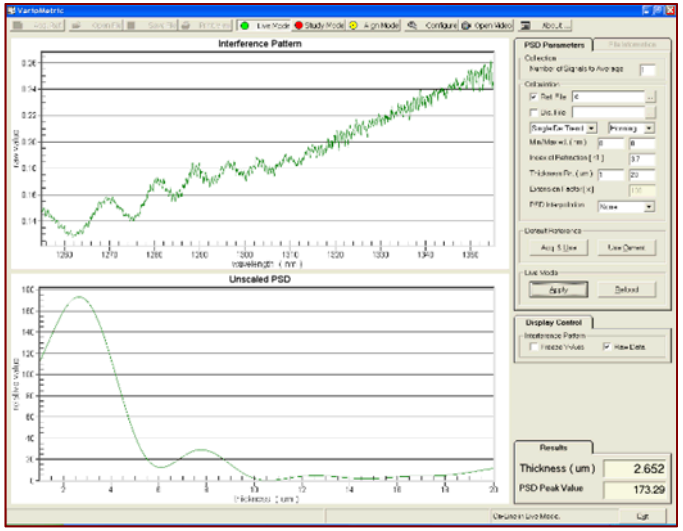
Introduction - Conventional - New - Results - Conclusions

FIB Trenching Silicon Measurement Results

The FIB trenching results using the VMT interferometer has demonstrated a highly accurate quantitative measurement of the RST obtained in-situ.



SEM cross-section
2.55 µm

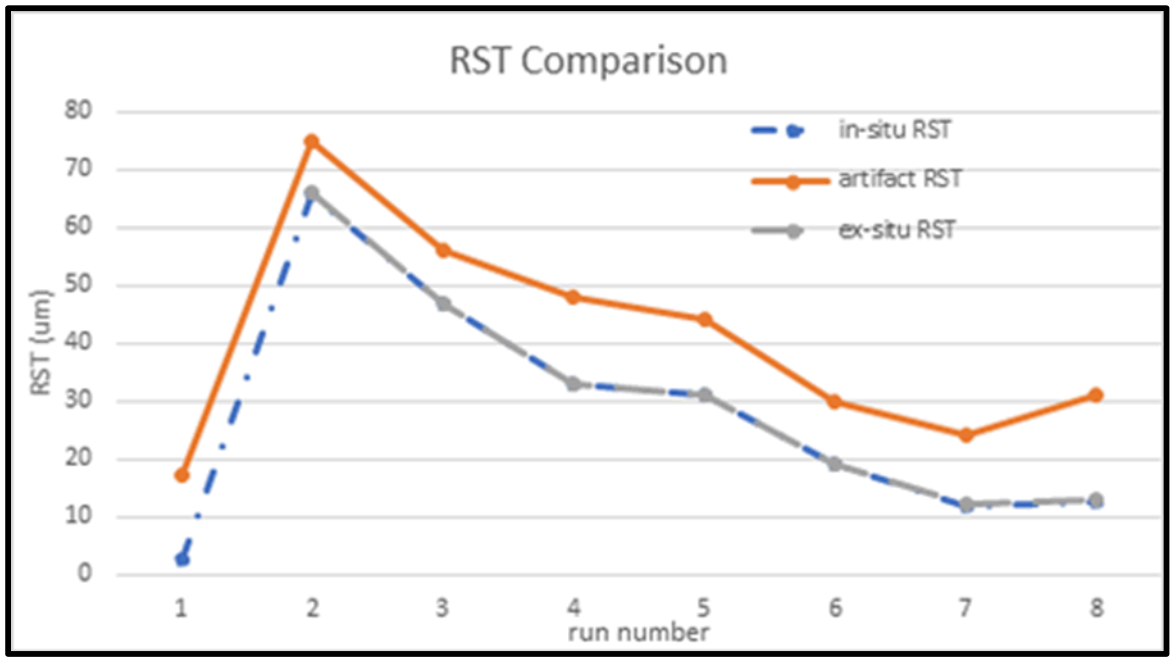


VMT measurement software
2.65 µm

Introduction - Conventional - New - Results - Conclusions

RST VMT vs. IR measurements

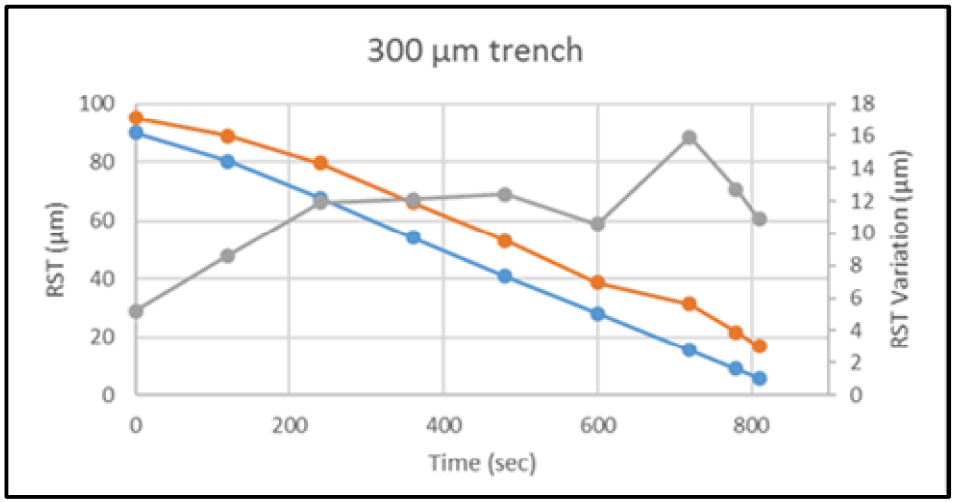
Compare RST in-situ and ex-situ VMT measurements to artifact focal-plane distance methods for measuring RST for 8 different samples.



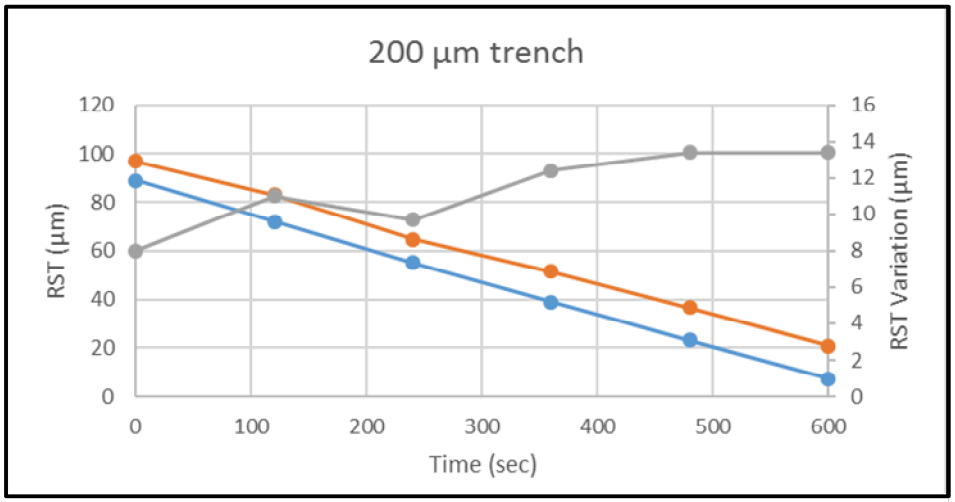
Run #	In-situ VMT	Ex-situ VMT	artifact
1	2.6		17
2	66	66	75
3	47	47	56
4	33	33	48
5	31	31	44
6	19	19	30
7	12	12	24
8	12	13	31

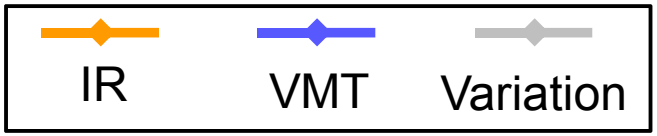
RST VMT vs. IR measurements

300 µm x 300 µm trench



200 µm x 200 µm trench

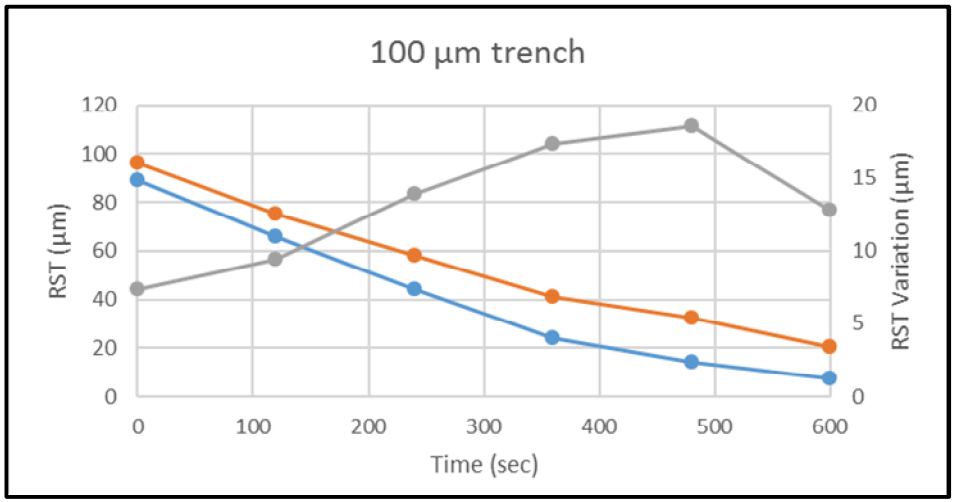




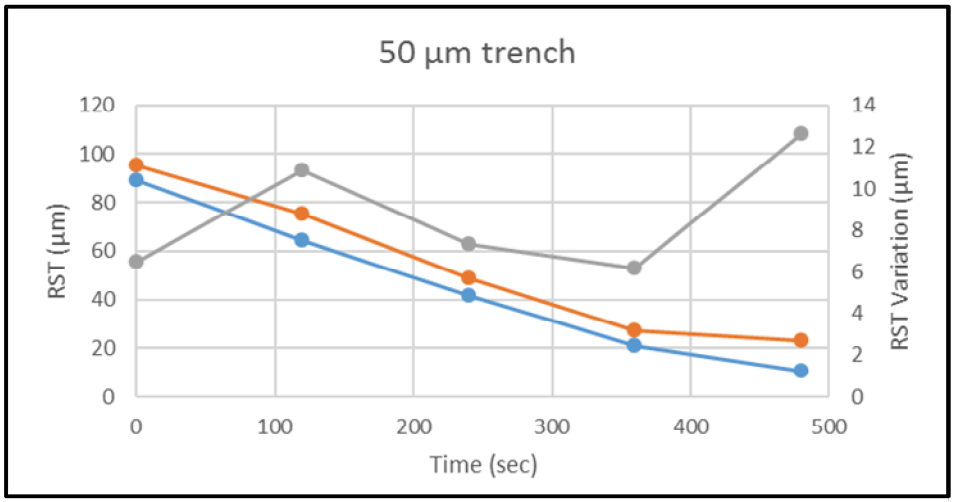
FIB trenching results using the VMT interferometer have demonstrated highly accurate, in-situ RST measurements.

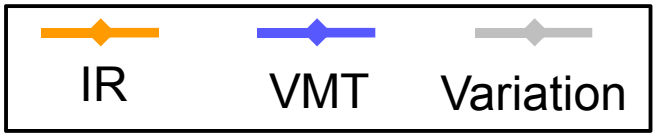
RST VMT vs. IR measurements

100 µm x 100 µm trench



50 µm x 50 µm trench





FIB trenching results using the VMT interferometer have demonstrated highly accurate, in-situ RST measurements.

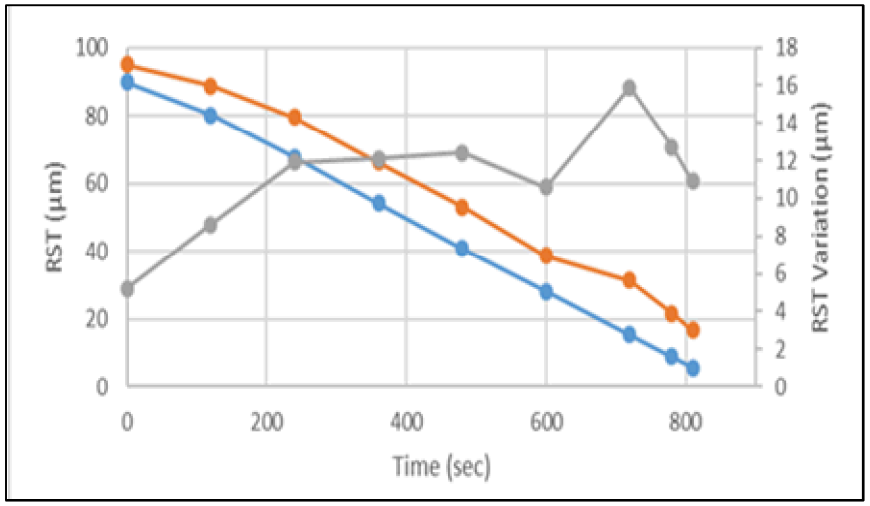
Introduction - Conventional - New - Results - Conclusions

Conclusions

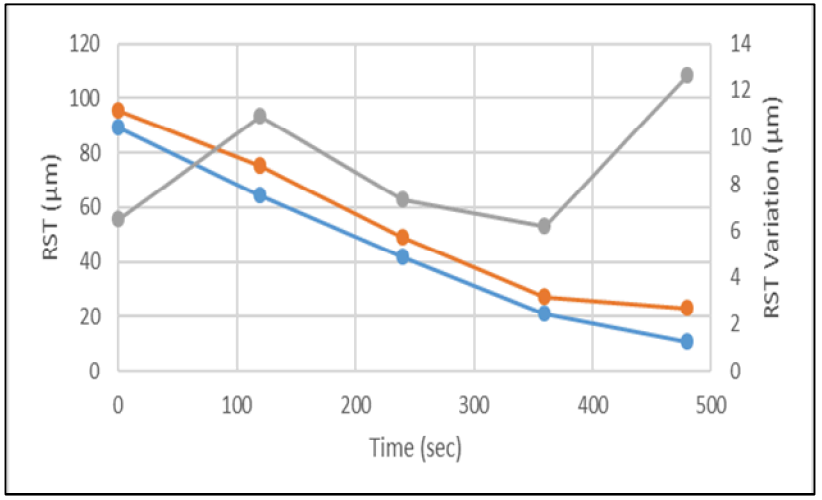
- Demonstrated a novel RST quantitative measurement technique with improved accuracy and precision for reliable backside circuit edits.
- Modifications to the illumination path of the NIR camera do not alter the IR navigation capabilities of the system.
- RST measurements are made at intermediate intervals to assure that critical endpoint such as n-wells, STI, or a buried oxide layers are not damaged.
- Improved RST reliability and throughput with in-situ measurements as opposed to subtractive methods such as tilting and measuring from the top surface to determine depth or using the subjective focal length of the NIR camera.

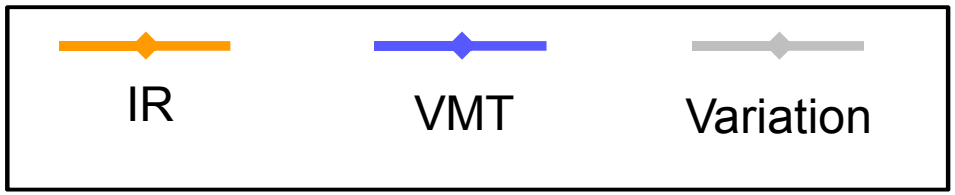
Remaining Silicon Thickness VMT vs. IR measurements

300 µm x 300 µm trench



50 µm x 50 µm trench



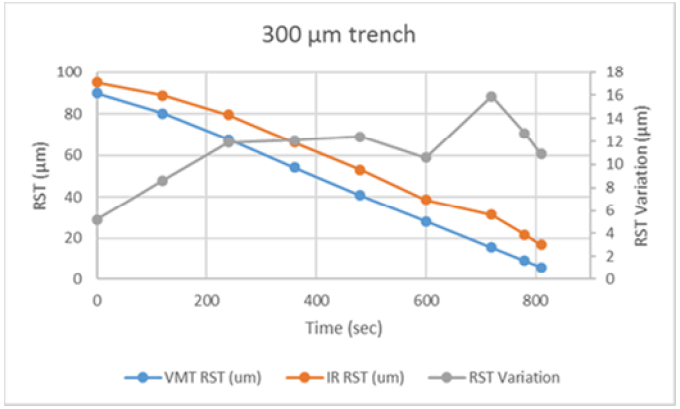


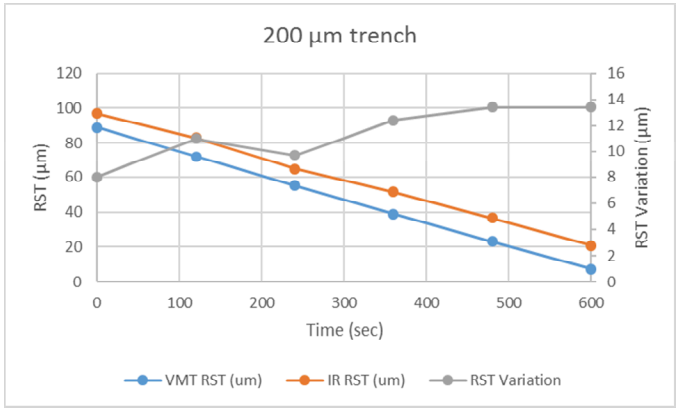
FIB trenching results using the VMT interferometer have demonstrated highly accurate, in-situ RST measurements.

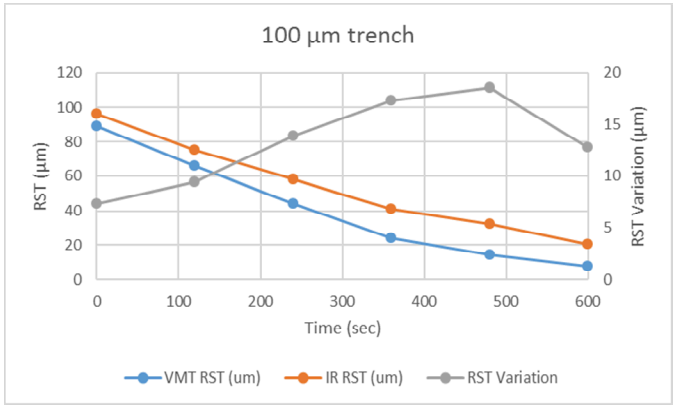
Conclusions

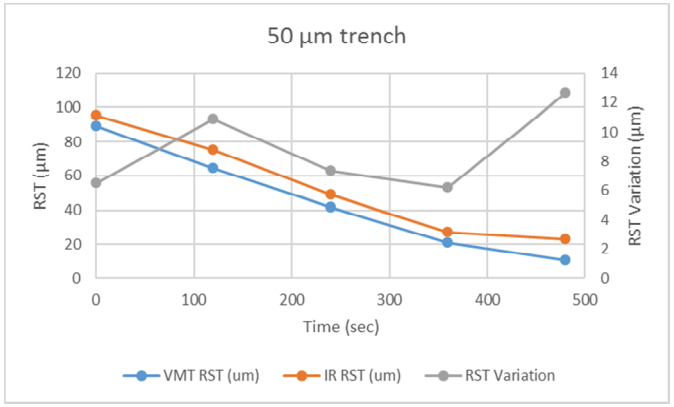
- We have constructed and demonstrated a novel method to measure the RST during the backside trenching process using XeF_2 to ensure sufficient accuracy and precision allowing much greater success with FIB integrated circuit edits.
- By modifying the illumination path of the NIR camera, we enable quantitative, accurate RST measurements of the silicon substrate while maintaining all previous IR navigation capabilities.
- The ability to make intermediate measurements of the RST also removes doubts that a critical endpoint such as n-wells, fringing, or a buried oxide layer is fast approaching or could have been missed.
- The interferometer value has much higher accuracy in its readings than using a subtractive method such as tilting and measuring from the top surface to determine depth, or using the focal length of the NIR camera to determine the RST

Silicon Thickness VMT vs. IR measurements









The FIB trenching results using the NIR interferometer has demonstrated a highly accurate quantitative measurement of the RST obtained in-situ.

FEI V400ACE FIB and Varioscale VMT

Backside trenching FIB

Silicon measuring interferometer (VMT)