COLLEGES OF NANOSCALE SCIENCE AND ENGINEERING
SUNY POLYTECHNIC INSTITUTE

300mm and 450mm Standard Calibration Wafers

Rand Cottle

CNSE - G450C

Outline

- Who are we
- Objective – need
- Scope –Applications
  - Metrology Calibration and Matching
  - Process Optimization and Monitoring
- Roadmap
  - Phase 0 – eBeam Prototyping
  - Phase 1 – 300mm
  - Phase 2 – 450mm
- Work to date
  - Designing Test structures
  - Initial Prototyping
  - Evaluation of data
  - Optimization for 300 and 450mm Manufacturability.

Who are we?

For Release: Immediate - March 5, 2015
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ISRAELI CONSORTIUM TO SIGN $2.9M AGREEMENT WITH SUNY POLY CNSE TO DEVELOP CRITICAL TOOLS FOR INDUSTRY TRANSITION TO 450MM TECHNOLOGY

Partnership to Develop Standard Calibration Wafers Will Support More Than 100 Jobs in New York and Israel with $50M Market Potential

Albany, NY - Supporting Governor Andrew M. Cuomo's vision for New York State's continued leadership in the global high-tech economy, SUNY Polytechnic Institute's Colleges of Nanoscale Science and Engineering (SUNY Poly CNSE) and Israel's Metro450 consortium today jointly announced plans to develop and produce Standard Calibration Wafers (SCW) for use with 300mm and 450mm metrology and process tools. The initiative will generate $2.9 million in investment and support more than 100 jobs in New York and Israel.

Today's announcement is an outgrowth of the partnership announced by Governor Cuomo on March 20, 2013 between SUNY Poly CNSE and the Israeli Office of the Chief Scientist (OCS) America's division in MATIMOP. Under the framework of this partnership, both sides are committed to generate advances in nanotechnology and expand joint research, development and business opportunities. The SCW project includes a $1.6 million commitment from Metro450 and $1.3 million in products, services and tool time from SUNY Poly CNSE.

Establishing industry benchmarks for efficacy is a vital component in the transition from 300mm to 450mm wafer technology. Without standardization, manufacturers would develop their own calibration techniques, yielding extended lead times, additional development costs, and unpredictable results. The SUNY Poly CNSE-Metro450 partnership will develop and produce the worldwide standard for semiconductor tool calibration and matching. Successful completion will enable an estimated $50 million market potential for both the 300mm and 450mm development community.

"Today's announcement is a testament to New York's global leadership in nanotechnology research and development, as envisioned by Governor Andrew Cuomo, and sets the stage for additional economic and employment opportunities for both New York and Israel," said Paul Farrar, General Manager of Global 450mm Consortium (G450C) and SUNY Poly CNSE Vice President for Manufacturing Innovation. "The international expertise represented by the SUNY Poly CNSE-Metro450 partnership will enable further advances and marks another milestone in the transition to 450mm technology."

"We are pleased to witness the success of this unique collaboration with SUNY Poly CNSE – a world renowned research center in the field of nanotechnology – in accelerating innovation and in enabling companies in New York and Israel to commercialize technological solutions in the global market," said Avi Hasson, Chief Scientist of the Ministry of Economy of the State of Israel. "We are looking forward to furthering this partnership as a catalyst for economic growth in both regions."

"Israel is a world leader in semiconductor metrology and inspection and our collaboration with SUNY Poly CNSE, one of the leading R&D facilities in the world, will generate significant advances in 450mm technology and provide positive economic impacts in both New York and Israel," said Menachem Shoval, Chair of Israel's Metro450 Consortium. "We are thrilled to see the continued growth of its collaboration with SUNY Poly CNSE and the State of New York, and we extend our gratitude to Governor Cuomo and SUNY Poly President Dr. Alain Kaloyeros, Chief Scientist Avi Hasson and Dan Vilenski – who is leading the Israeli National Nanotechnology Initiative (INNI), for their continued support and partnership."

Metro450 is an Israeli consortium, operating under the MAGNET program of OCS, which aims to encourage metrology technology development in Israel while preparing for the industry transition to 450mm wafer technology. Five companies including Applied Materials Israel (AMIL), Nova, Jordan Valley, Nanomotion and Intel Israel have joined together to bring forward the most advanced developments in silicon wafer metrology. Metro450 also includes 19 researchers from 4 universities: Technion, Haifa University, BGU and TAU- conducting dozens of projects in support of the consortium.

The goal of the Magnet program, operated by Israel's Ministry of Economy's office of chief scientist (OCS) is to provide a competitive position for Israel's industry with regard to state of the art technologies. It is chartered to initiate, guide and sponsor dedicated consortia, based on collaboration between Israeli industrial companies and academic institutes.

Metro450 consortium members, consisting of key IDM, equipment makers, and academia, will work with SUNY Poly CNSE to enable and validate the most advanced metrology tool calibration targets. Metrology is the science of measurement and, in the semiconductor field, refers to how devices are gauged for efficacy. For the successful industry transition 300mm to 450mm technology, standard efficacy levels must be established for better semiconductor metrology and inline process control.

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About SUNY POLY. SUNY Polytechnic Institute. SUNY Polytechnic Institute (SUNY Poly) is New York's globally recognized, high-tech educational ecosystem, formed from the merger of the SUNY College of Nanoscale Science and Engineering and SUNY Institute of Technology. SUNY Poly offers undergraduate and graduate degrees in the emerging disciplines of nanoscience and nanoengineering, as well as cutting-edge nanobioscience and nanoeconomics programs at its Albany campus, and degrees in technology, professional studies, and the arts and sciences at its Utica/Rome campus. As the world's most advanced, university-driven research enterprise, SUNY Poly boasts more than $20 billion in high-tech investments, over 300 corporate partners, and maintains a statewide footprint. The 1.3 million-square-foot Albany NanoTech megaplex is home to more than 3,500 scientists, researchers, engineers, students, faculty, and staff, in addition to Tech Valley High School. The Utica/Rome campus offers a unique high-tech learning environment, providing academic programs in technology, including engineering, cybersecurity, computer science, and the engineering technologies; professional studies,

300mm and 450mm Standard Calibration Wafers - A Standard Tool for Semiconductor Metrology Calibration and Matching

– Metrology Calibration and Matching

Metrology tool companies, as well as Semiconductors manufacturers are sharing the same problem: Is 'my' Metrology tool calibrated? The tool manufacturer would like to know if the tool met the expected performances and is ready to be delivered; the IC manufacturers would like to ensure that a tool is ' back in spec', after PM. Both would like to compare tool-to-tool and even Fab-to-Fab performances.

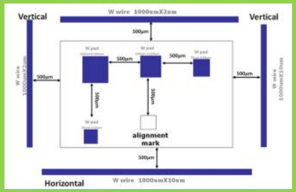
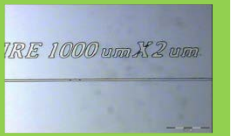
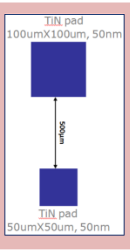
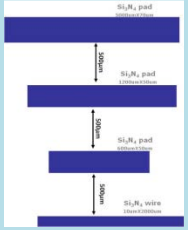
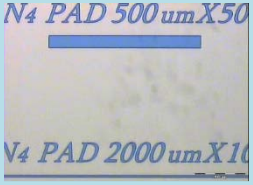
– Process Optimization and Monitoring

Evaluating and comparing manufacturing tool performances (Etchers, Scanners etc.) is complicated by convolving sources of metrology variation with process tool variations. By developing 'module monitors' with metrology tool companies and semiconductor manufacturers we can minimize and characterize metrology variance and avoid confounded results.

- Roadmap
  - Phase 0: eBeam Prototyping - Ongoing
    - Test structures pattern on 3” wafers by e-beam lithography
    - 3” wafers mounted on 300 and 450mm wafers for testing.
  - Phase 1: 300mm Q4 2014 to Q4 2015
    - Optomize test structures for manufacturability.
    - Develop integrated manufacturing flow at CNSE’s state of the art 300mm fabs.
  - Phase 2: 450mm 2016
    - Transfer 300mm manufacturing flow to G450C pilot line

Header TBD..................

JVS - Standard Calibration Features

<table>
<tr><th>Target type</th><th>Target usage</th><th>Target design</th></tr>
<tr><td>W Pads, 200x200um, 250nm</td><td>"XRF Module Calibration & Setup the Thickness Standards
Tool Calibration & Tool-2-Tool Matching"</td><td rowspan="3">
W targets
Done</td></tr>
<tr><td>W Pads, 100x100um, 250nm</td><td>"Stage Axes Mapping
Tool-2-Tool Matching"</td></tr>
<tr><td>W Wires, 1000x2um, 250nm</td><td>XRR Axes Offset Calibration
Tool Calibration</td></tr>
<tr><td>TiN Pads, 50x50um, 500nm</td><td rowspan="2">XRF Module Calibration & Setup the Thickness Standards
Tool Calibration & Tool-2-Tool Matching</td><td rowspan="2">
Done</td></tr>
<tr><td>TiN Pads, 100x100um, 500nm</td></tr>
<tr><td>Si3N4 Wires, 2000x10um, 50nm</td><td rowspan="3">XRR Axes Offset Calibration
Tool Calibration & Tool-2-Tool Matching</td><td rowspan="3">
Si3N4 targets
Done</td></tr>
<tr><td>Si3N4 Pads, 500x50um, 50nm</td></tr>
<tr><td>Si3N4 Pads, 1200x50um, 50nm</td></tr>
<tr><td>SnAg Bumps:
• Diameter variation :10um, 15um, 20um, 50um, 80um
• Height variation:5um, 7.5um, 10um, 25um, 40um
• 2 bump array types: dense and isolated</td><td>?</td><td>On going</td></tr>
<tr><td>Siege target :
Pattered structure and pads with known %Ge</td><td>?</td><td>On going</td></tr>
</table>

Nova - Standard Calibration Features

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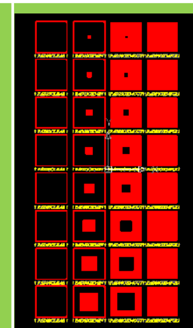
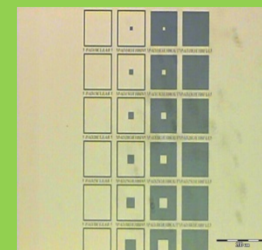
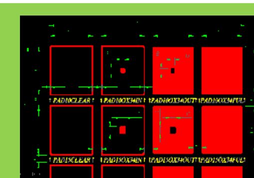
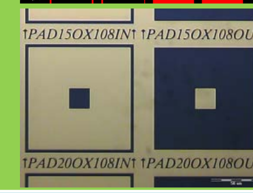
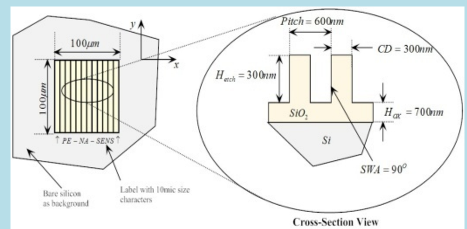
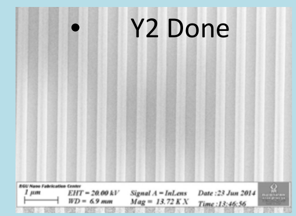
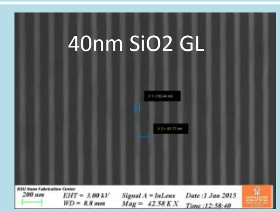
Target type	Target usage	Target design
Set of varying pads embedded inside a large pad	Check sensitivity to XY static stage position	 • Y2 Done   
Thin oxide target-34nm		
Thin oxide target-45nm		
Thin oxide target-54nm		
Thin oxide target-108nm		
Partially etched Oxide grating lines	Check sensitivity to stage static tilt	  • Y2 Done
Set of 9 targets with varying thickness of SiO2 on Si	?	Table A below • Y3 Done
Set of 6 targets with varying thickness of SiO2 on Si3N4 on Si	?	Table B below
20nm and 40nm Oxide grating line targets	?	 

Table A

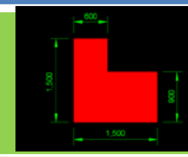
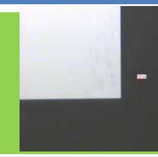
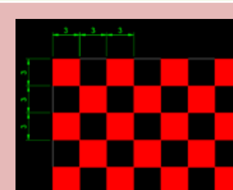
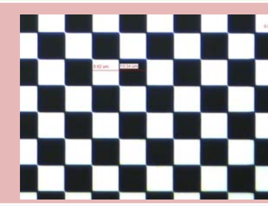
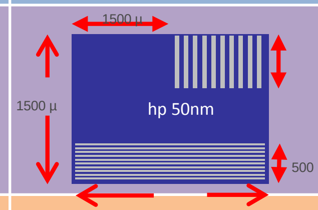
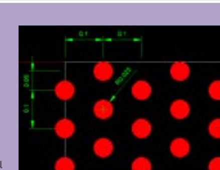
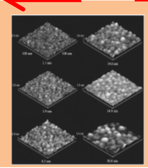
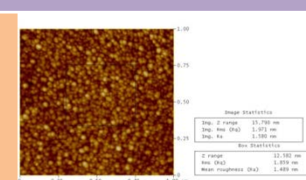
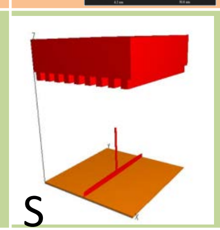
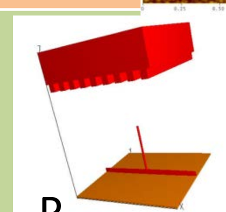
S/N	Oxide on Silicon
	Oxide Thickness, nm
1	6.1
2	16.0
3	20.2
4	40.4
5	53.0
6	99.7
7	198.5
8	487.6
9	948.8

Table B

Sample	Nitride (Å)	Sputter thickness(Å)
1	1000	234
2	1000	394
3	1000	494
4	1000	646
5	1000	804
6	1000	1116

Header TBD....................

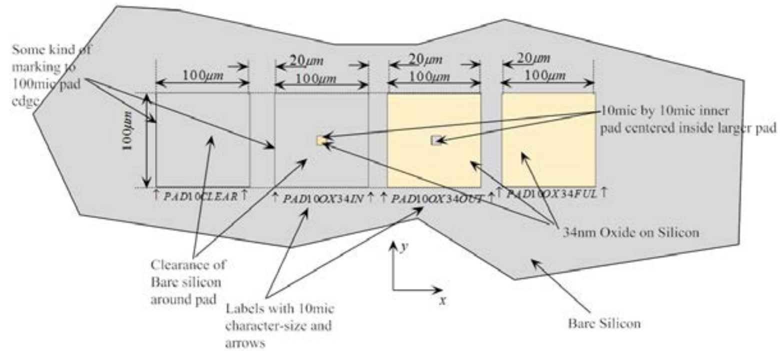
AMIL - Standard Calibration Features

Target type	Target usage	Target design/Results
H&V line edge target V1	BF Spot size & shading	  • Done
Checkerboard Targets Target 1 -Checkerboard 3um Target 2 - Checkerboard 6um Target 3 - Checkerboard 10um	Focus & MTF uniformity	  • Done
HRC target	Null, BF spot, BF shading, focus & MTF	 • Ongoing
H&V line edge target V2 & Ghost measure target	GF spot size & Ghost measure	  • On hold
Gain & Shading target	Gain & Shading calibration	  • Done
Polarization targets	Polarization reflection/transmission	  • Target simulation has been completed • Target fabrication is ongoing

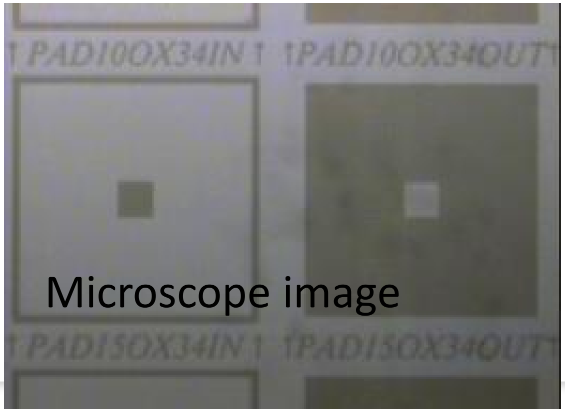
Target Production

partnering for process control

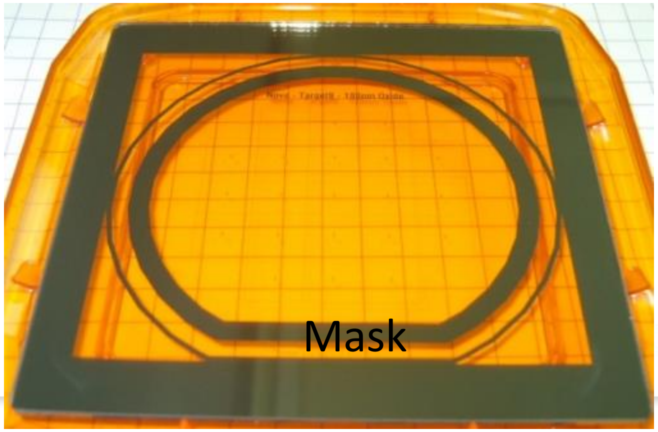
- Target was designed by Nova so it enables extraction of **all** system-dependent coefficients **per** wavelength and **per** pad size (several sizes produced):



- Prototype (3” glued onto 12” wafer) was then produced by the Nano-Fabrication Center at Ben-Gurion University of the Negev, Israel via Metro450 consortium.



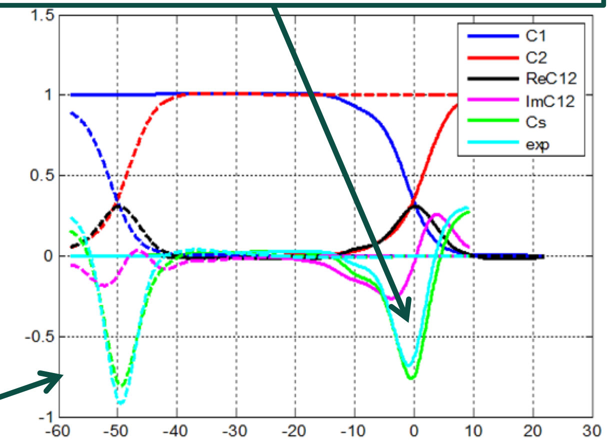
Microscope image

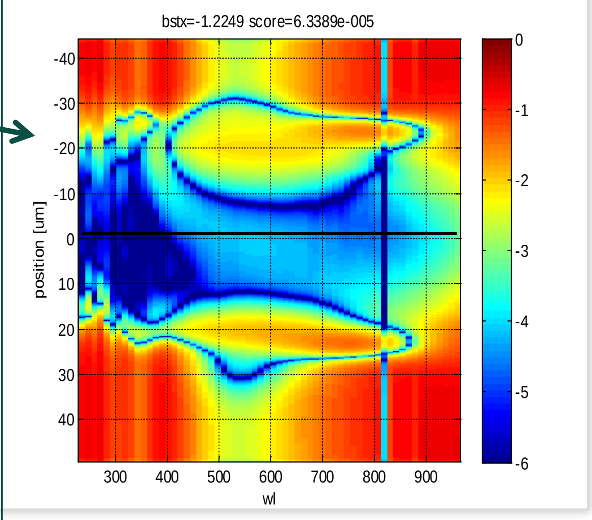

Mask

Target Initial Tests Results

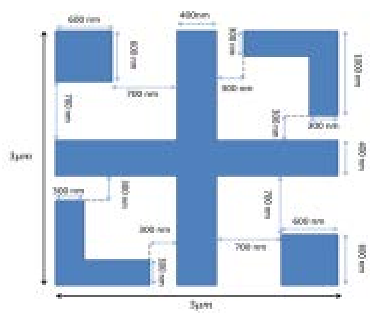
- **The prototype target was measured w/ nova tool.**
- **Sensitivity of procedure to identify signal variations as spot scans pad lateral matches theoretical design, thus:**
  - Validating targets quality.
  - Validating the generic methodology proposed in Metro450-Y1 for target design.
  - In the upper picture: Signal versus scan along pad (for one wavelength) showing Capability of ~10nm accuracy in determining pad X-edge using optical means.
  - In the lower picture: Same scan but now with additional wavelength axis added gives ability to accurately determine optical chromatic aberrations.
- **Overall: Target Enables quantitative assessment of how signal is contaminated by spot spill-over → Target purpose achieved.**

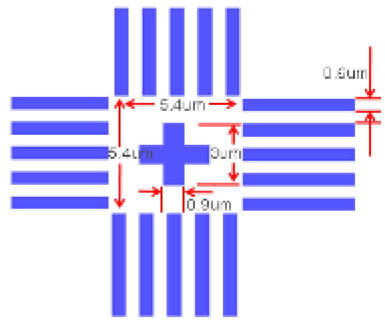
Green (model) vs. Cyan (meas.) are one of the system-only-coefficients whose determination is required by the target. Their match corroborate both model and target design.

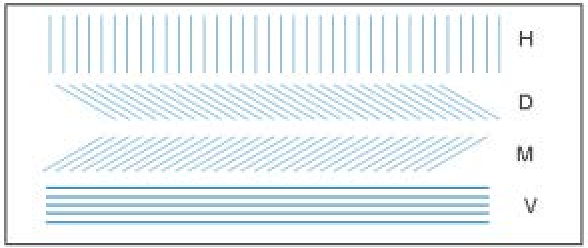


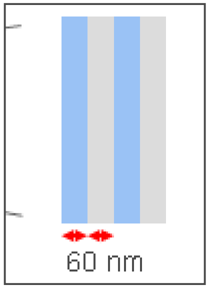


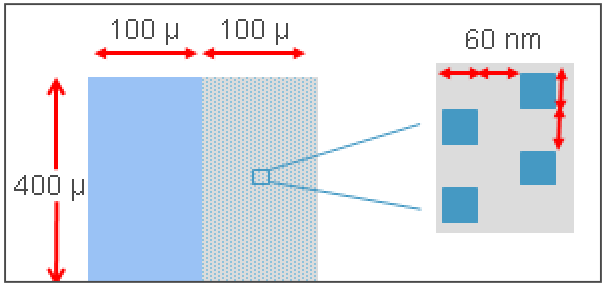
Different targets

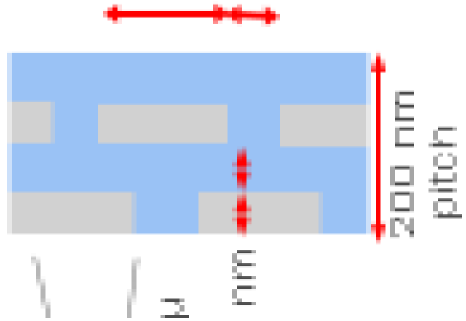


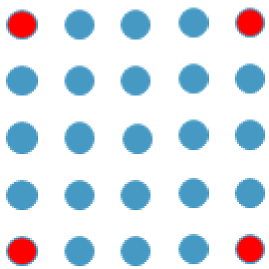


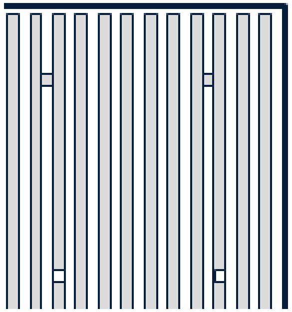


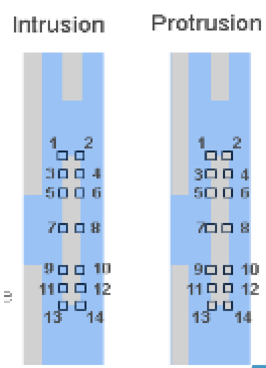






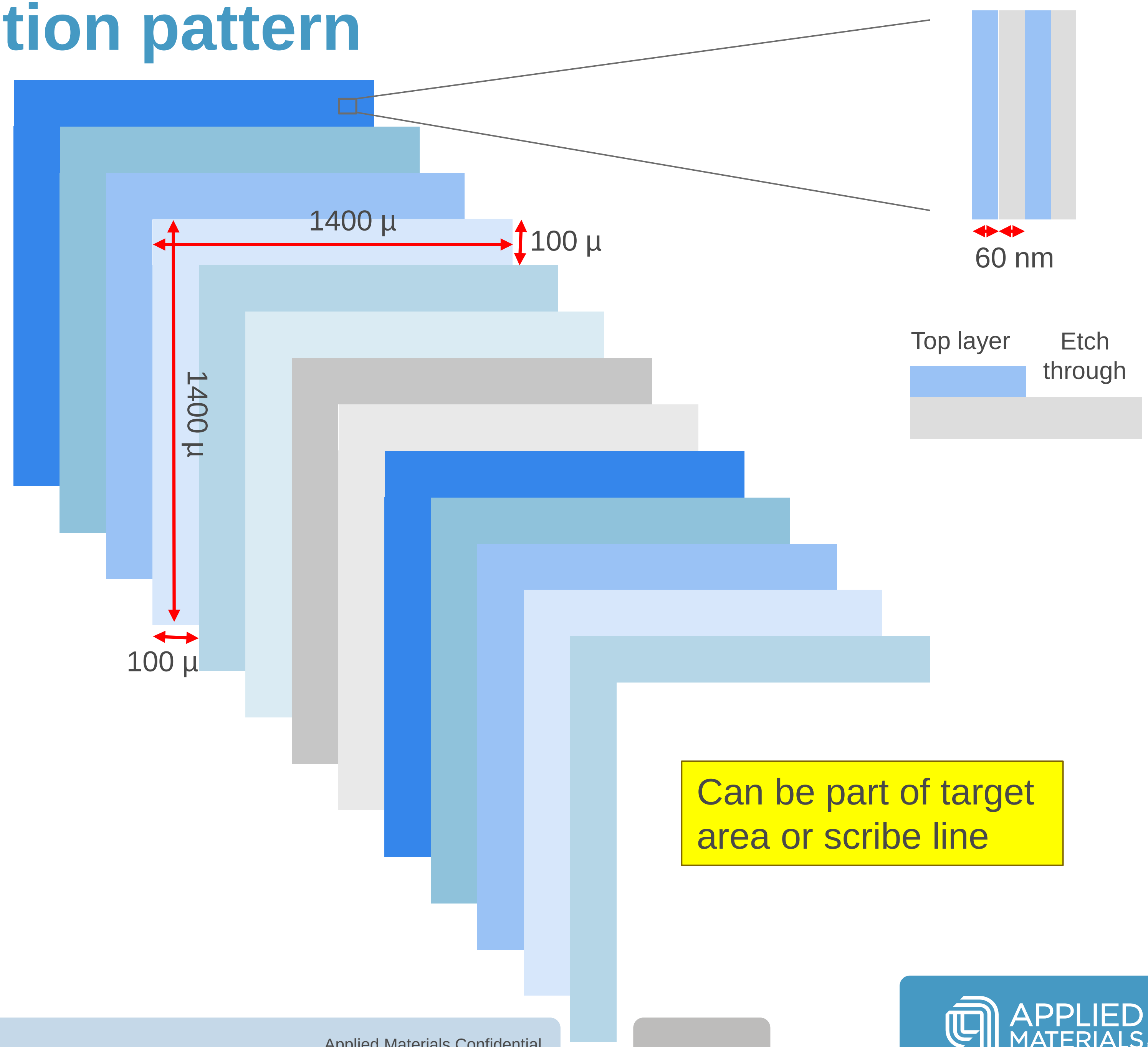






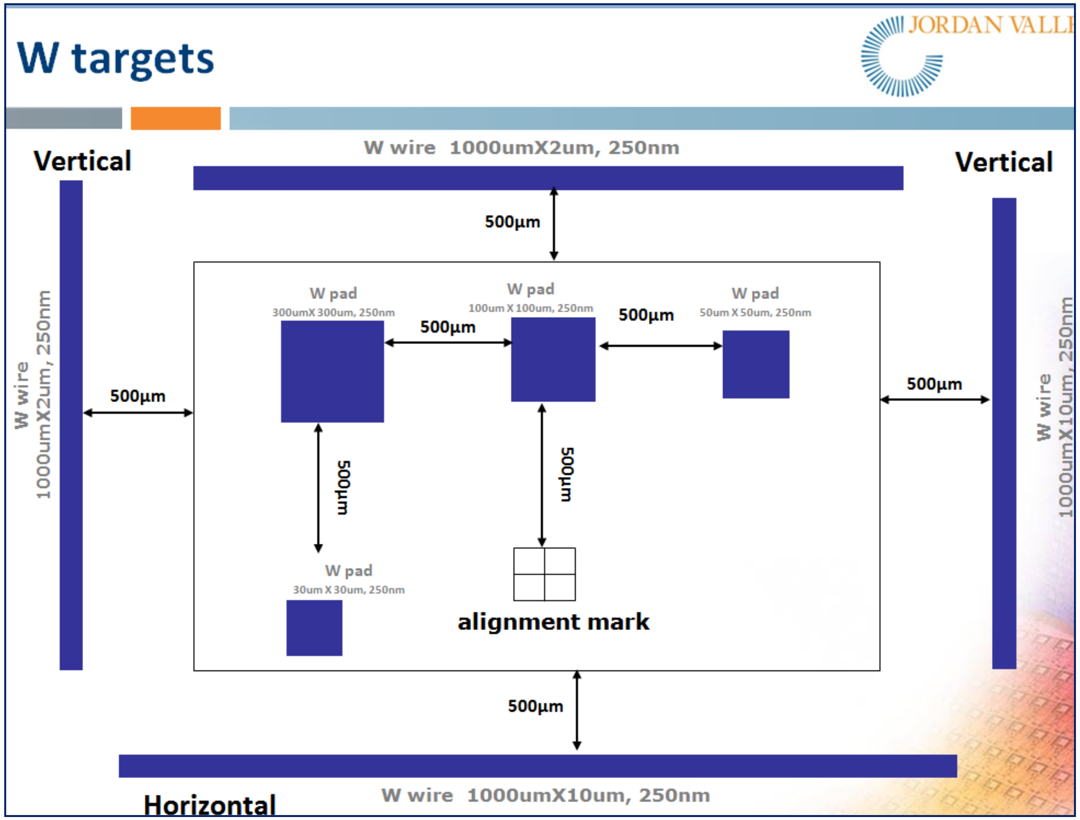
Resolution pattern

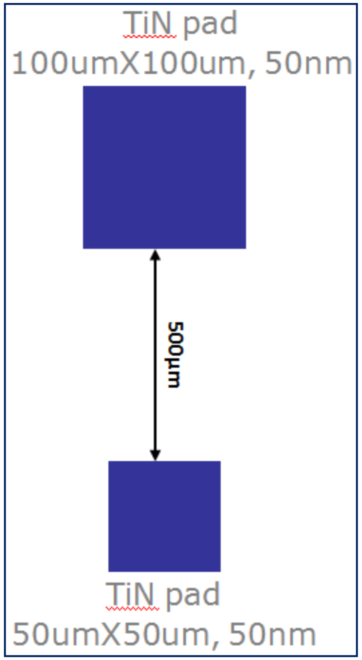
Line width [nm]
60
80
100
150
200
250
300
350
400
500
600
800
1000

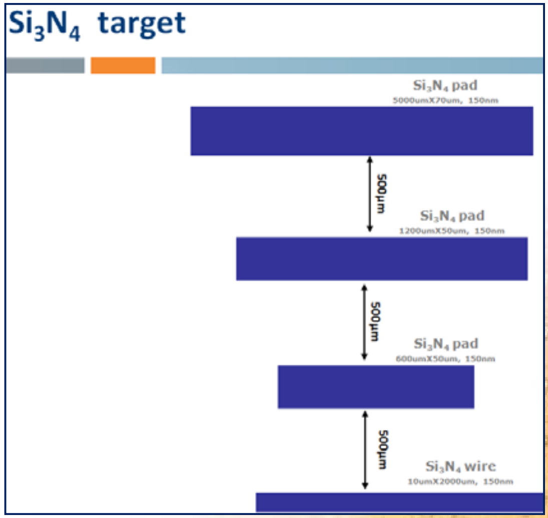


Can be part of target area or scribe line

WP4: Short Summary of Year 2
JV Targets







Optimization for 300 and 450mm Manufacturability

- Structures divided into two wafers: one FEOL and one BEOL.
- Metal subtractive etch process replaced with damascene.
- Structures being optimized to minimize CMP dishing.
- 300mm manufacturing flow being designed for maximum compatibility with 450mm pilot line. Only unit process common to both line will be used.

Summary

- Target design validation on 3" coupons wafers is mostly complete.
- Target optimization for compatibility with 300mm manufacturing flow is underway.
- 300mm process integration and prototyping to be done Q2-Q4 2015
- Transfer to G450C 450mm pilot to begin in 2016.