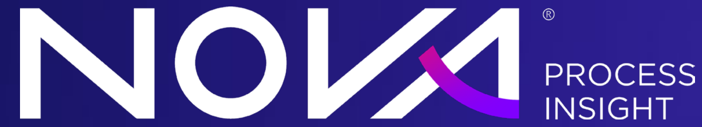

Unique Technology for Exponential Growth

Dr. Shay Wolfling, CTO

September 2022

Dr. Shay Wolfling

Chief Technology Officer

- Joined Nova as CTO in 2011.
- R&D manager at KLA-Tencor-Belgium, leading multidisciplinary metrology & inspection projects.
- Founder and VP R&D of Nano-Or-Technologies, a start-up company with a proprietary 3D optical technology, acquired in 2005.
- PhD in physics from the Hebrew University.

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Outline

Technology Trends

Key Challenges

Unique Solutions

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Technology Trends

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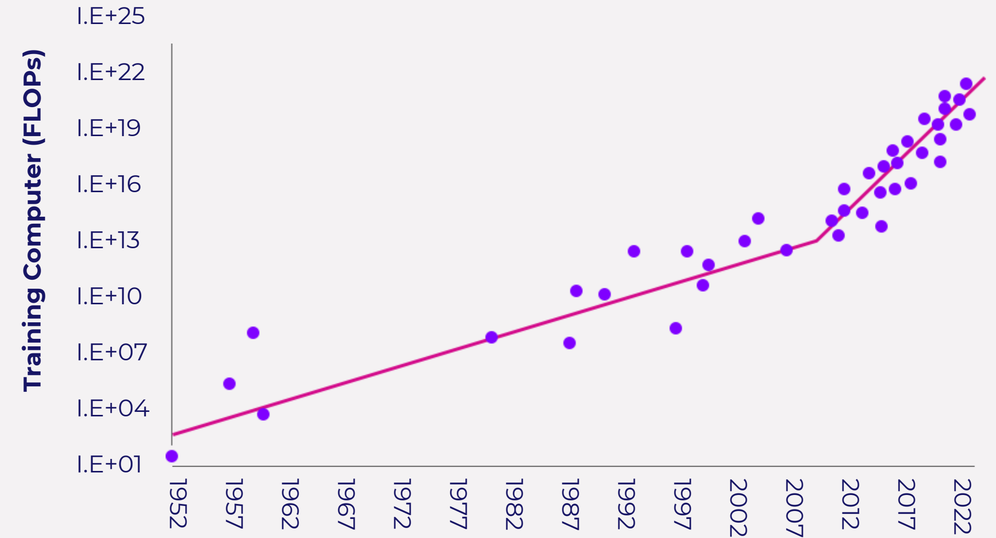
Key Trends

Exponential growth in data generation

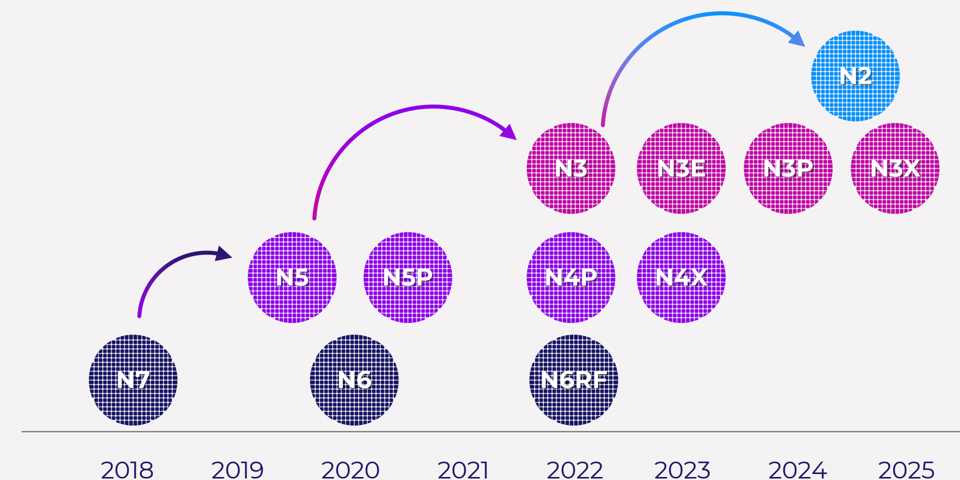
- Higher performance IoT Edge Computing with less power and space
- Compute needs for AI expanding – decision intelligence, generative AI & constant optimization
- Data Fabric - breaking data silos



Source: Imec

There is more than a single track forward

- Increasing Diversity of development tracks (Both leading & trailing)
- FinFET variants, Nanosheets, SOI, New materials, Analog, In-memory computation and more
- Chiplets and Advanced Packaging
- System integration (Device-Technology Co-Optimization)



Source: TSMC

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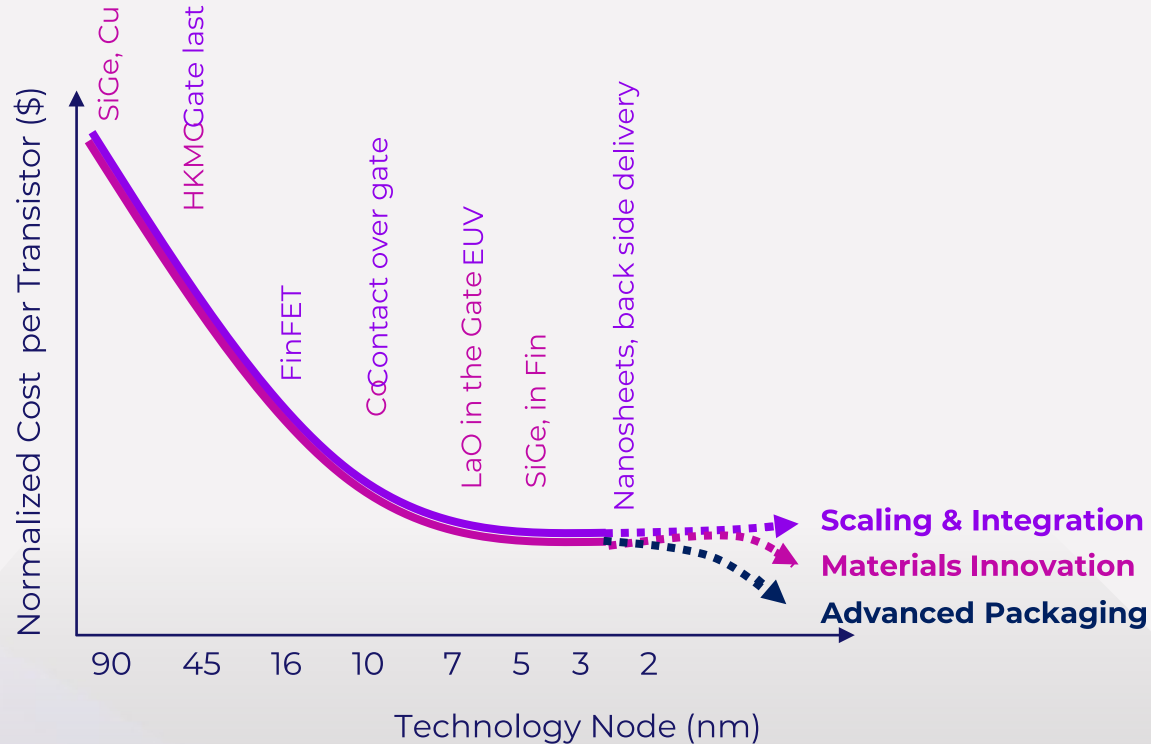
Traditional Scaling Gets a Boost



- Linear scaling is only part of the way forward
- More than Moore is essential:
  - New integrations
  - Novel materials
  - True 3D – device and system

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Solutions & Technology Inflections

	Inflections	Key value
Patterning	High NA EUV, Additive patterning	Density
Logic transistor	**New architectures –** Nanosheet, Forksheet, Complementary FET	Performance, Density, Power & Cost
Interconnect	Buried Power Rail, **new materials**, selective process	Performance, Power
3D NAND	**Multi-Decks**, Logic over / under memory, Increasing bits per cell	Performance, Density, Power & Cost
DRAM	EUV adoption, **3D DRAM**	Performance, Density, Power & Cost
Packaging	**Heterogenous integration**, System level optimization	Performance, Density, Power & Cost

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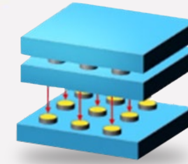
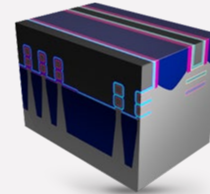
Dimensional & Material Implications

Advanced Packaging



NOVA PROCESS INSIGHT
ancosys®

New Materials



NOVA PROCESS INSIGHT
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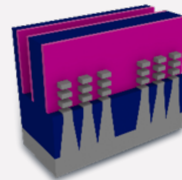
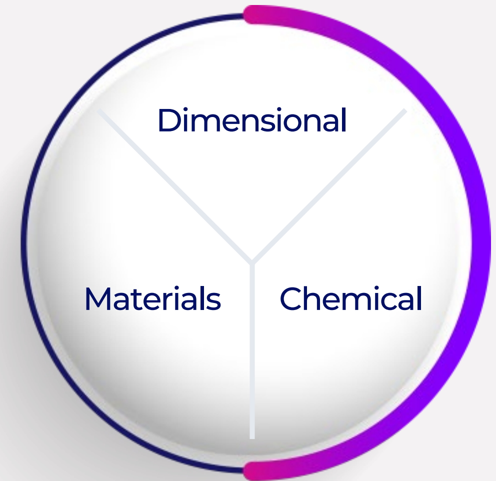
Vertical Integration

NOVA PROCESS INSIGHT

Device Scaling



NOVA PROCESS INSIGHT



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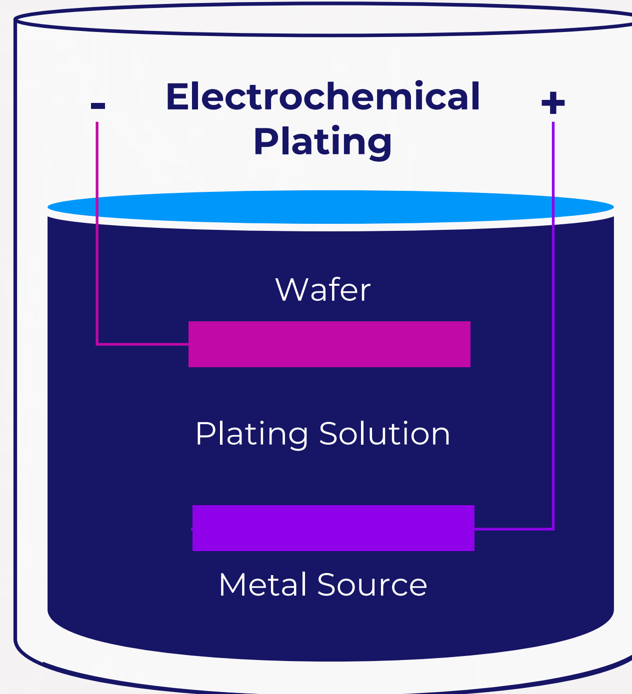
Chemical Metrology

Measure Chemical Solutions

Rather than on Wafer

Plating Bath
Clean & Etch Composition



Main components:

Acids, bases, organics

Secondary components:

Contaminants, breakdown products, leftovers

Markets

- Front End Damascene
- Advanced Packaging

Benefits

- Optimizing wet processes
- Higher yield & Reduced excursion
- Chemical waste reduction

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Key Challenges

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Memory – 3D NAND Process Challenges

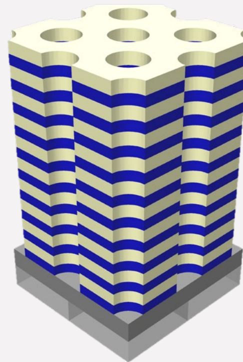
Dimensional

1. Full profile – per deck and in total
2. Logic under Memory cell
3. Bottom parameters
4. Tiers and liner thickness
5. Tilt and Overlay between decks

Material

6. Dielectric composition & thickness control
7. Channel Poly Si crystallinity & grain size
8. Channel sidewall
9. Chemical residues
10. Stress management

Single Deck

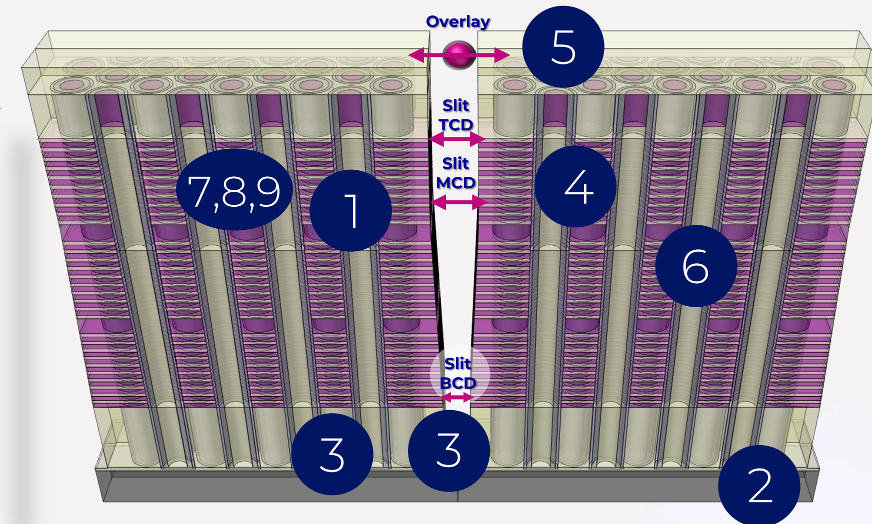


Triple Deck

> 400 Tiers

> 20um thickness

Logic under Memory



From Single Deck to Multi Deck

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Memory – 3D DRAM Process Challenges

Dimensional

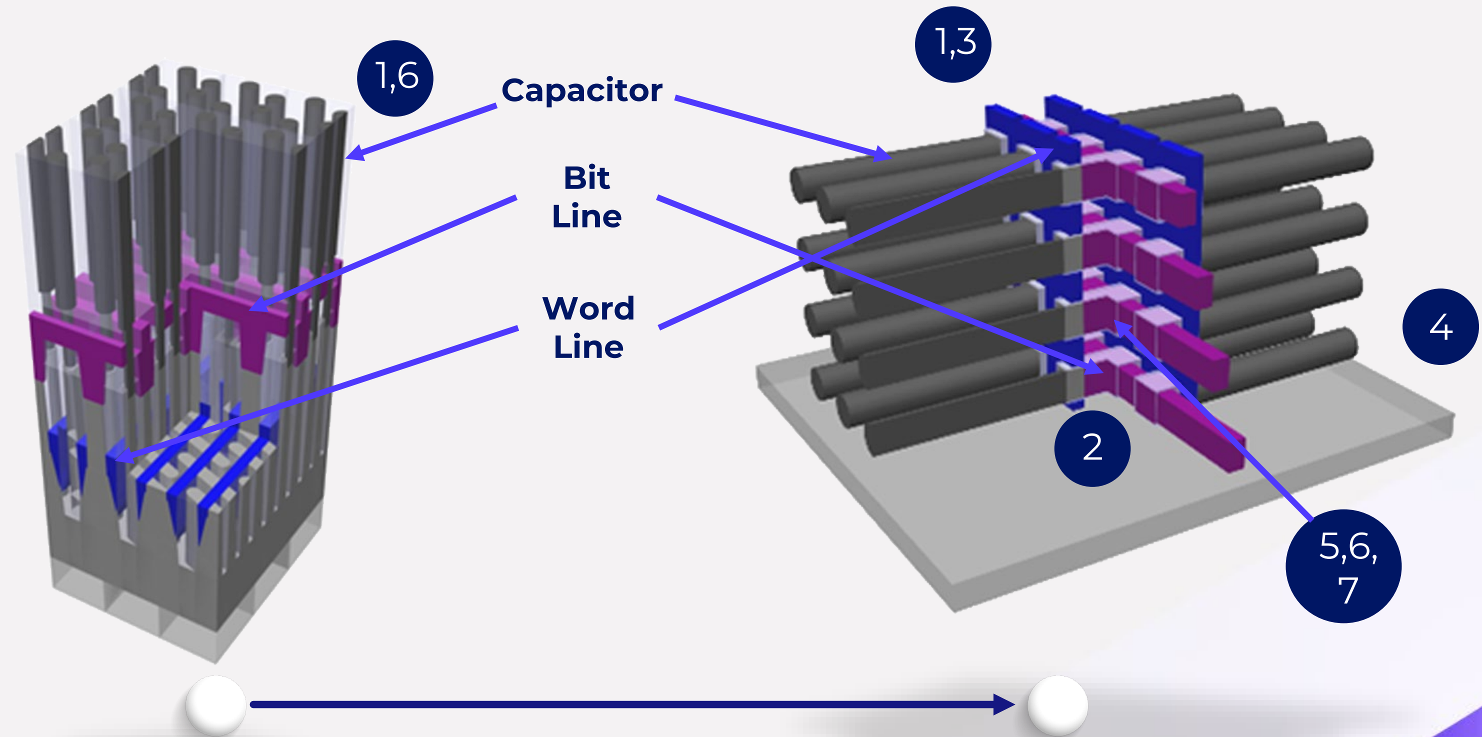
1. High-Aspect Ratio capacitor holes & supporters
2. Bottom gate parameters
3. Tight contact holes
4. Lateral selective etches for thinner capacitors

Material

5. Dielectric composition & thickness control
6. Higher dielectric constants
7. Material residues

2D DRAM
2D scaling is not enough

Move to 3D DRAM-
Same path as NAND



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Logic Architecture - Process Challenges

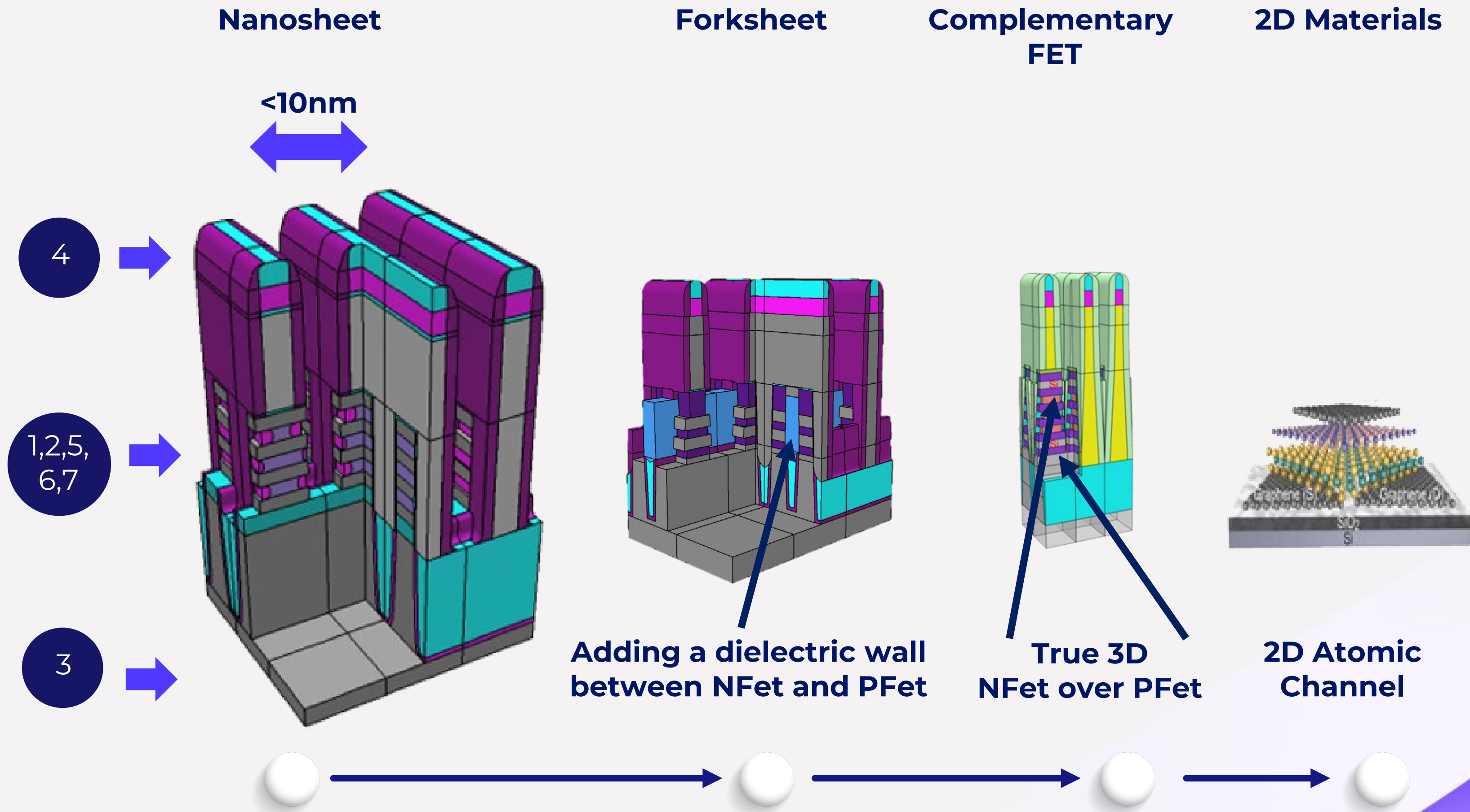
Dimensional

1. Multiple nanosheets – shapes, spacing & thickness
2. Thin deposition surrounding nanosheets
3. Buried structures
4. Local topography variations

Material

5. Si / SiGe uniformity
6. SiGe residues
7. Stress & strain on multiple nanosheets
8. Doping control

Clear Architecture Evolution – Increased Complexity



Source: Nova, American Chemical Society

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Interconnect - Process Challenges

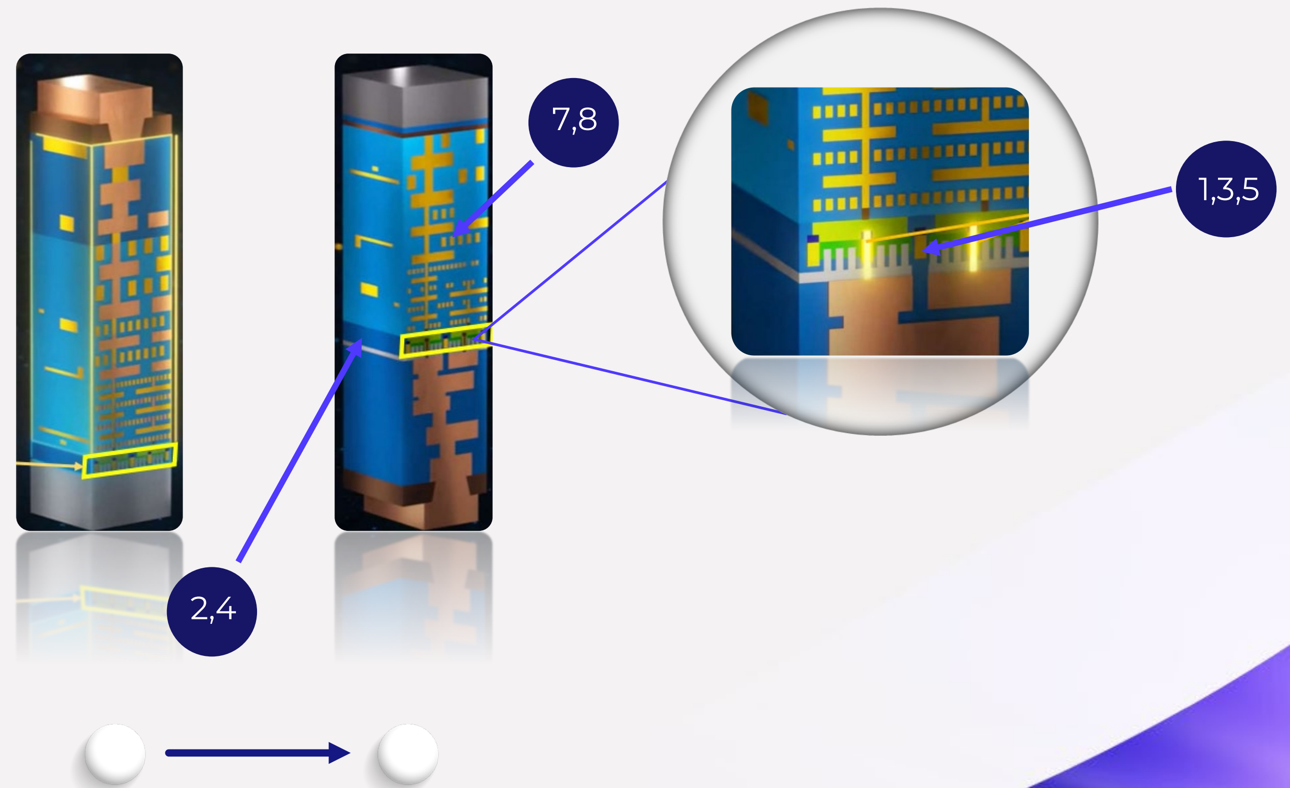
Dimensional

1. HAR Cu nano-TSV profile control
2. Topography for Wafer-to-Wafer bonding
3. Voids & Delamination
4. Surface roughness

Material

5. Via Pitch and CD too narrow for plated copper
6. Cobalt etch - Single damascene
7. Cu fill - Buried Power Rails
8. Cu, Ru & Co interconnects plating

New Architecture
Backside Power Delivery Network & Hybrid-Bonding with Nano-TSVs



Source: Intel

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Packaging Process Challenges

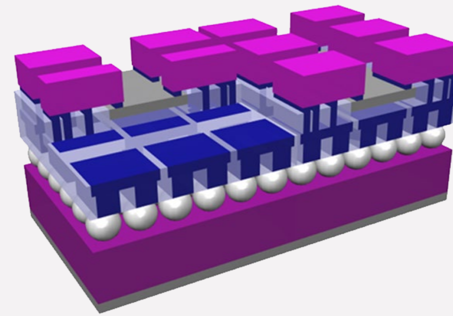
Dimensional

- The move from 2.5D to 3D - Topography & Profile
- High aspect ratio structures
- Buried structures
- Local topography variations

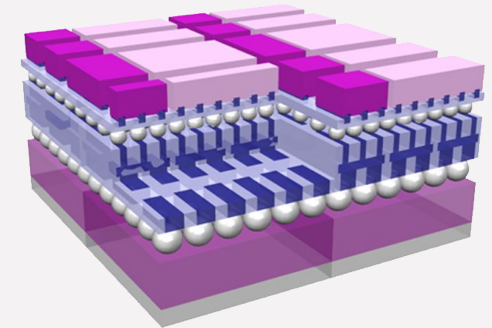
Material

- Optimal plating
- Highly saturated copper bath management
- By-Products metrology
- Contaminants and photoresist leach control
- Dielectric composition & thickness control

Fan Out



3D-IC



True 3D architecture and tighter chemistry requirements

Enabling Chiplets

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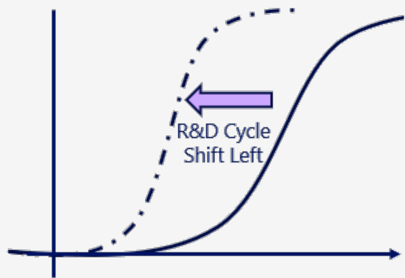
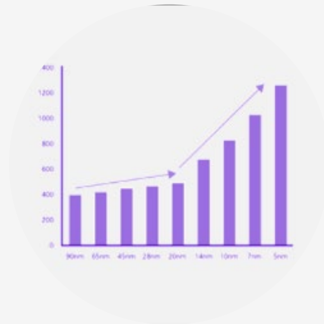
Metrology Challenges

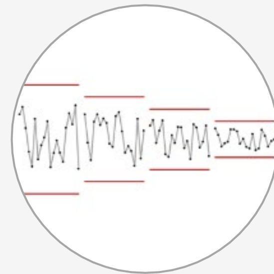
Process Complexity



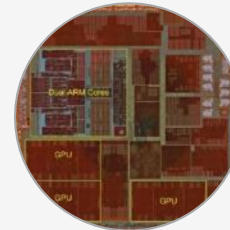
Shorter R&D cycles



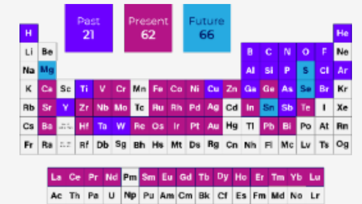
More steps & higher sampling



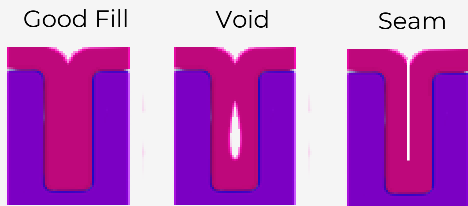
Tighter specs as design rule shrinks



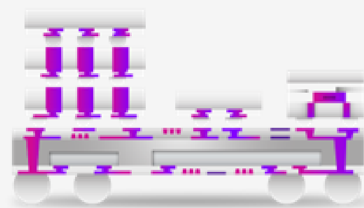
In-die & complex structures



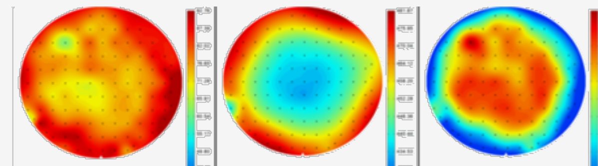
New materials



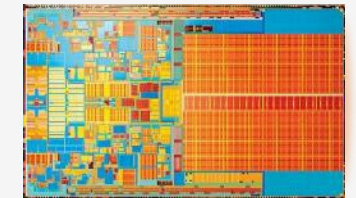
Chemical control to enable filling of HAR structures



Topography & Profile 3D Packaging



Local variation is critical: local density, Z Profiling



Monitoring more parameters → broader metrology scope

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Nova Solutions

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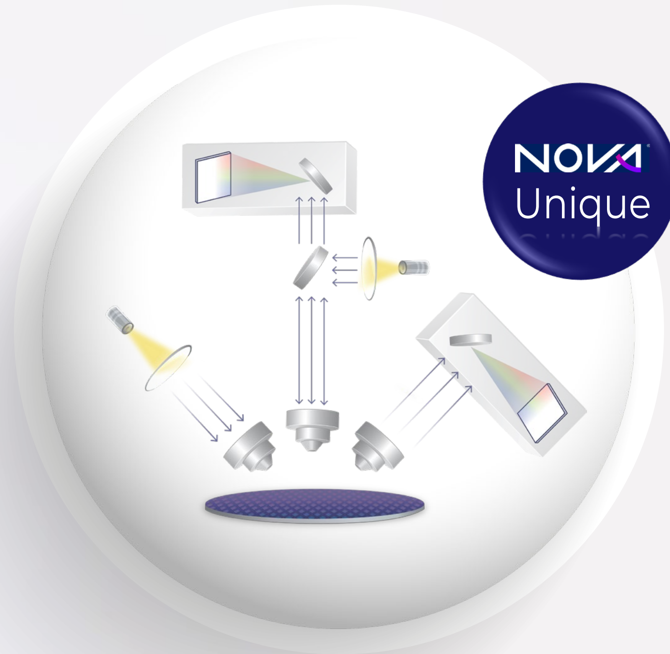
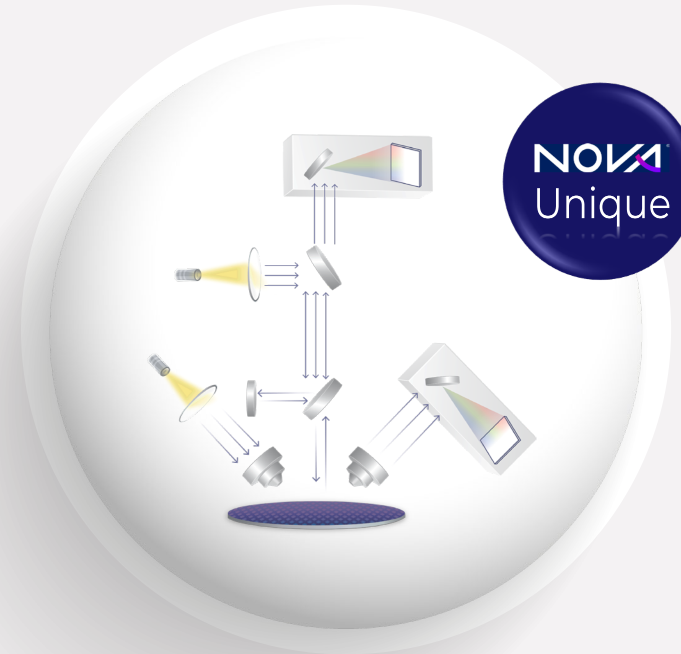
Dimensional Metrology

Multi-Channel Integrated Metrology
Combining Normal Incidence & Oblique



Stand Alone performance in IM
Extending Nova IM leadership

Spectral Interferometry
PRISM



An additional source of
information to SR and SE

Critical Dimensions

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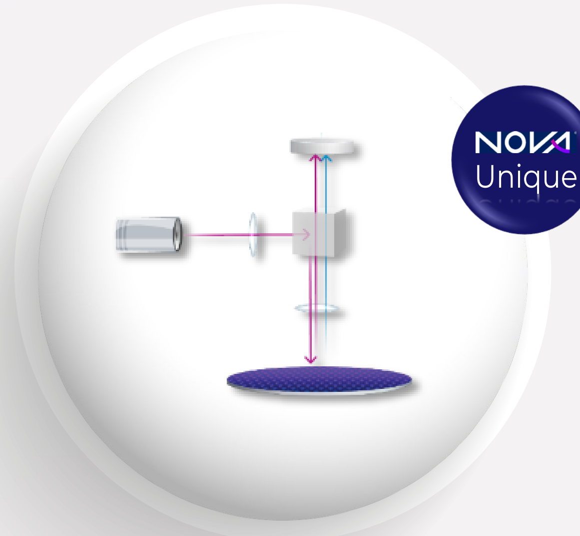
Materials Metrology

X-Ray: XPS and XRF
VERAFLEX

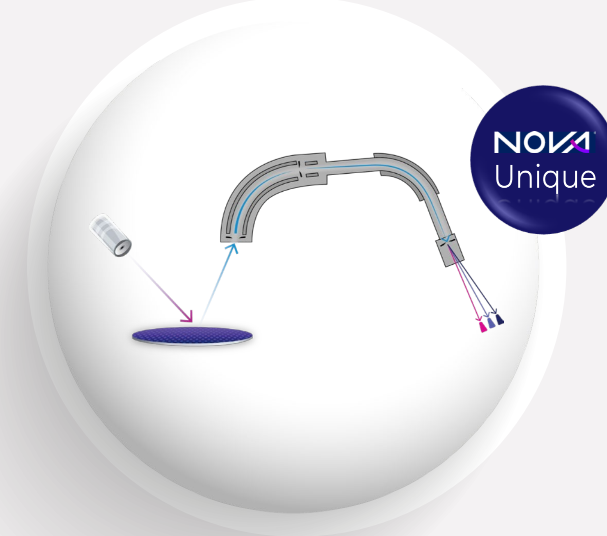
In-Line composition & thickness
Market leading technology
High volume manufacturing

In-line Raman
ELIPSON



In-Line stress, strain and crystallinity
Measuring material properties optically

In-line SIMS
METRION



In line full Composition profile
Bringing SIMS from Lab to Fab

Material Properties

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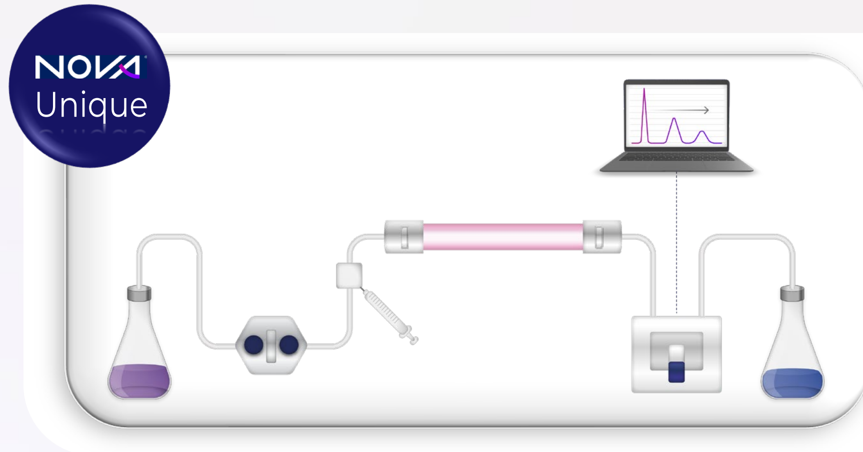
Chemical Metrology

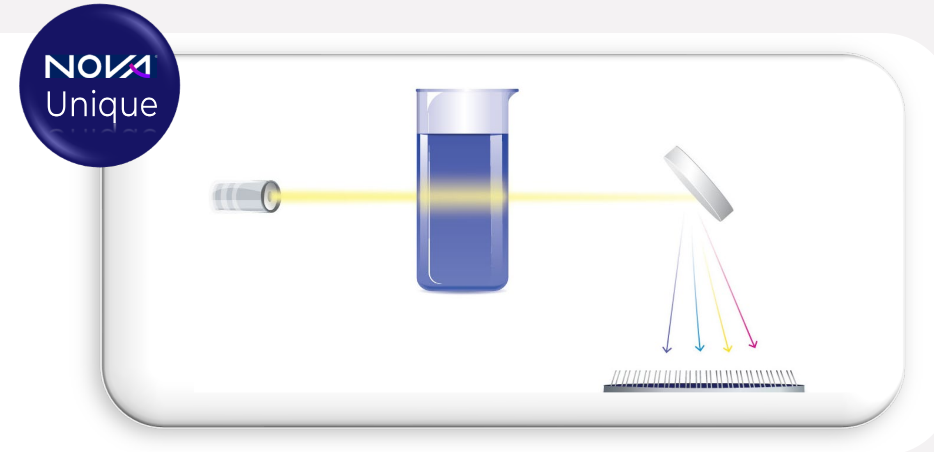
ancolyzer Product Family

High-Performance Liquid Chromatography



Automated separation technique whereby all components are separated before being measured

Optical Spectrophotometry



Quantitative analysis using optics to directly measure component concentration

Chemical Analysis & Replenishment

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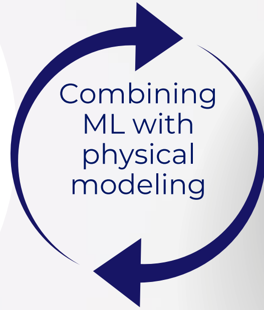
Software Solutions

Physical Modeling
Nova MARS



Machine Learning based Modeling
Nova FIT

Cloud-Based Fleet Management
Nova FM+

Inherently accurate sample description
Expanding beyond OCD

AI-enhanced Machine Learning
Dramatically reducing time to solution

Central management,
performance monitoring
and big data analytics

Across all Product Lines

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Solutions for Nanosheets

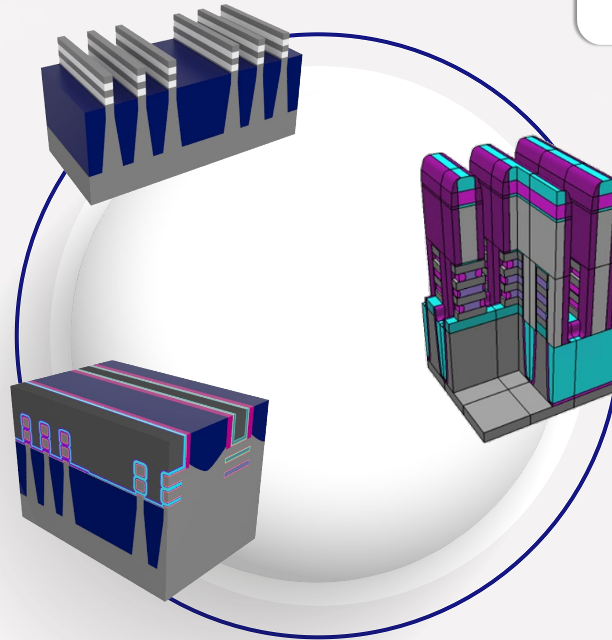
Unique Technologies to Answer Key Challenges

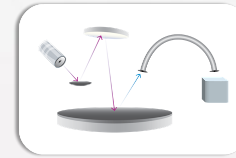
Fin Patterning

- XPS - Multiple nanosheets thickness
- SIMS - Multiple nanosheets full profile
- OCD - Multiple CDs along gate and fin HAR profile; Buried structures
- Raman - SiGe stress post Etch of nanosheets

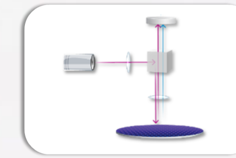
Gate Formation

- Raman - SiGe deposition uniformity
- XPS - LaO thickness
- SIMS - Doping control

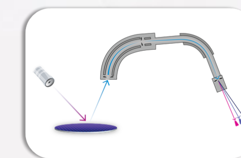




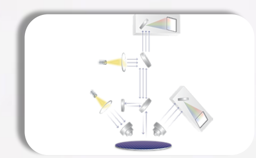
VERAFLEX: XPS/XRF



ELIPSON: Raman



METRION: SIMS



PRISM: OCD SI

Replacing Metal Gate

- Raman - Multiple nanosheets stress
- OCD - Individual nanosheet indentation and thickness
- OCD, Raman , XRF - SiGe residues
- XPS - High K thickness

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METRION – Inline SIMS

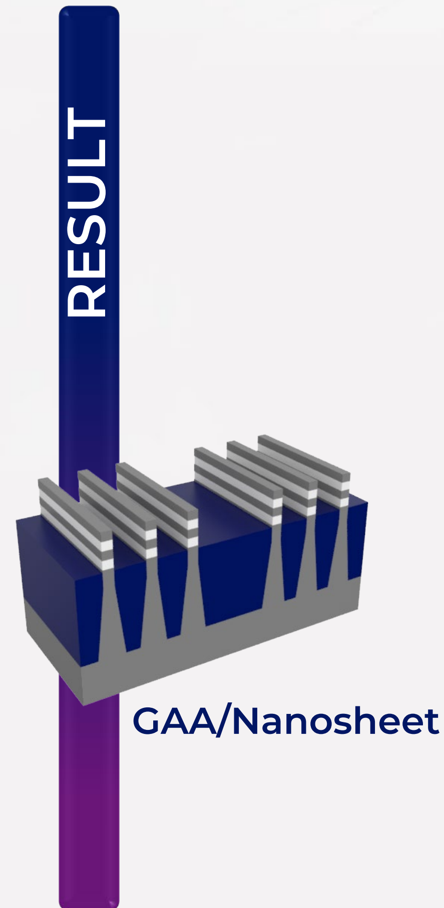
Nanosheet Use Case: SiGe Deposition

The **Challenge**

Variations in nanosheet SiGe growth affect etch selectivity and impact device performance

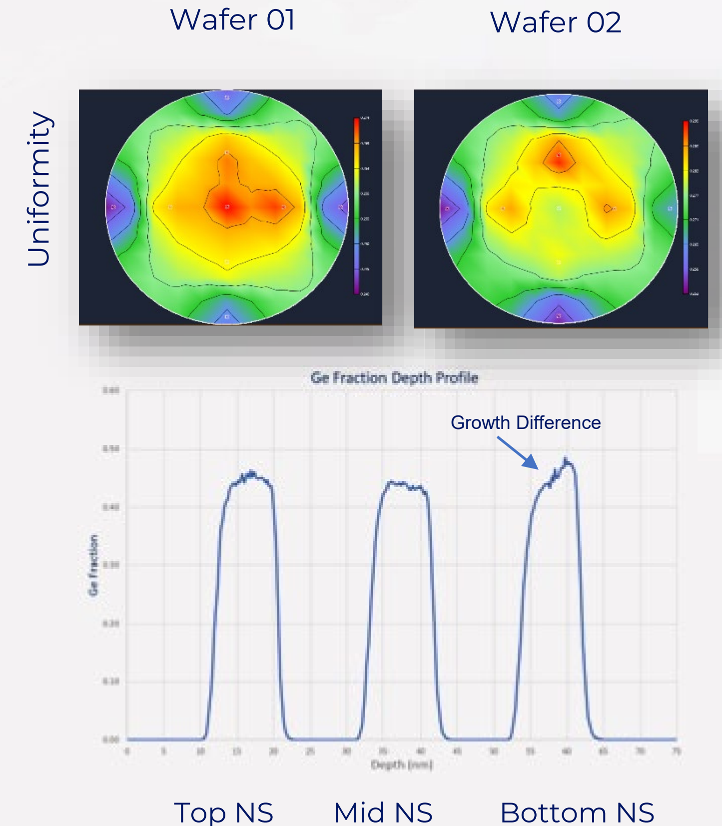
METRION Solution

In-line SIMS monitors Ge concentration to ensure uniform deposition on each individual nanosheet and across the wafer



In-Line Germanium Deposition Uniformity Across Wafer

SiGe Growth Uniformity Monitoring



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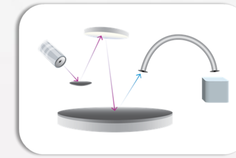
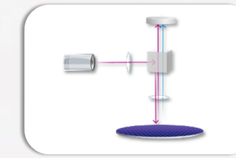
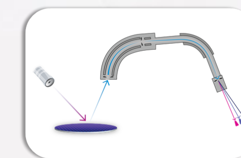
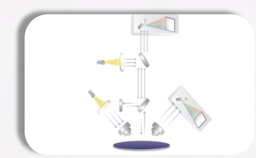
Solutions for Memory - 3D NAND

Unique Technologies to Answer Key Challenges


VERAFLEX: XPS/XRF

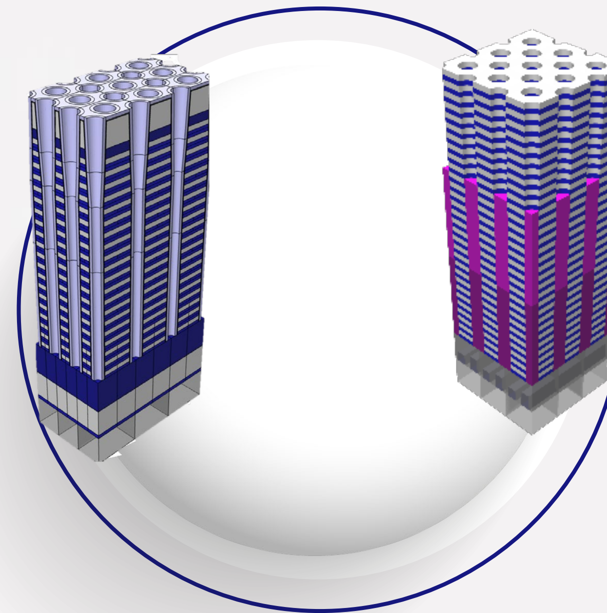

ELIPSON: Raman


METRION: SIMS


PRISM: OCD SI

Pillar Sidewall Liner Deposition

- XPS - Liner thickness
- SIMS – Contamination detection & Individual layer thickness
- OCD - Channel hole profile, bottom contact
- Nova FIT - Machine Learning for 3D complexity



Channel Hole Etch at Top Decks

- XPS - ONON thickness & composition
- Raman- Channel poly crystallinity & Grain size
- OCD - ONON & channel poly thickness

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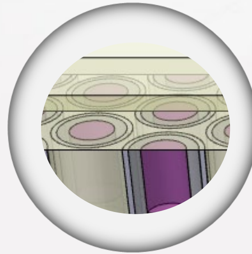
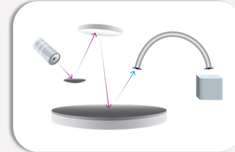
Zoom in- Solutions for 3D NAND

VERAFLEX: XPS/XRF

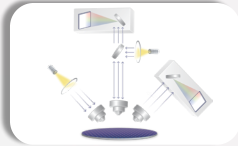
In-Die Measurement

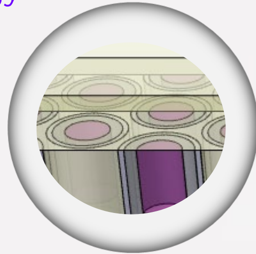




Integrated Metrology

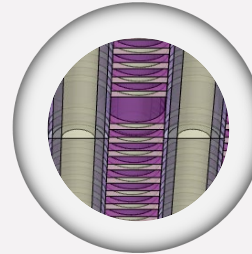
Top Oxide CMP

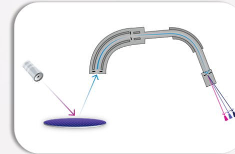




METRION: SIMS

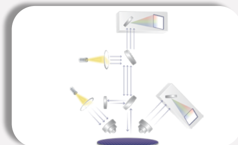
Word Line
Contamination Detection

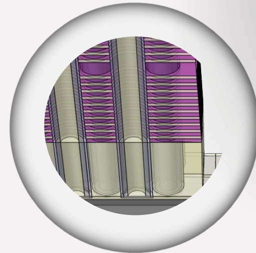




PRISM: OCD

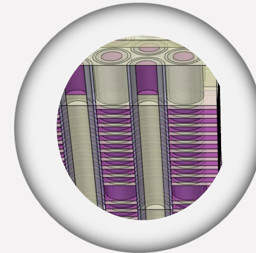
Channel Etch Profiling

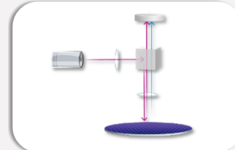




ELIPSON: Raman

Polysilicon on Sidewall





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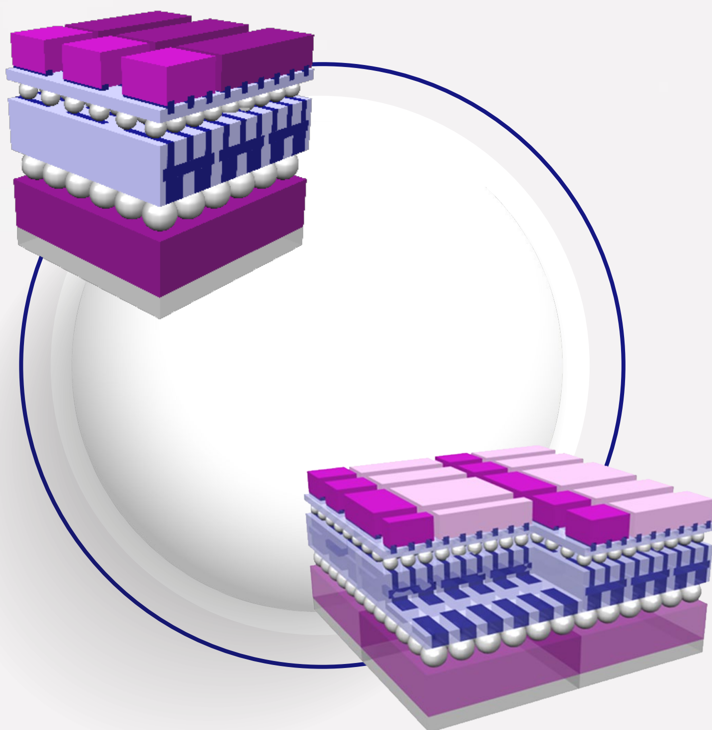
Solutions for Packaging

Unique Technologies to Answer Key Challenges

Dimensions

- RDL CD and thickness
- Multi-Layer dielectric thickness
- TSV CD and depth
- Topography



Materials

- Al bond pad monitoring
- 3D Interconnect: TSV, hybrid bonding – Cu2Cu
- High K composition & thickness
- Cobalt cap & liner monitoring

- Organic additive breakdown
- Additive by-product buildup
- Photoresist components leaching
- Bath cross-contamination
- Bath replenishment

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ancolyzer chemical metrology

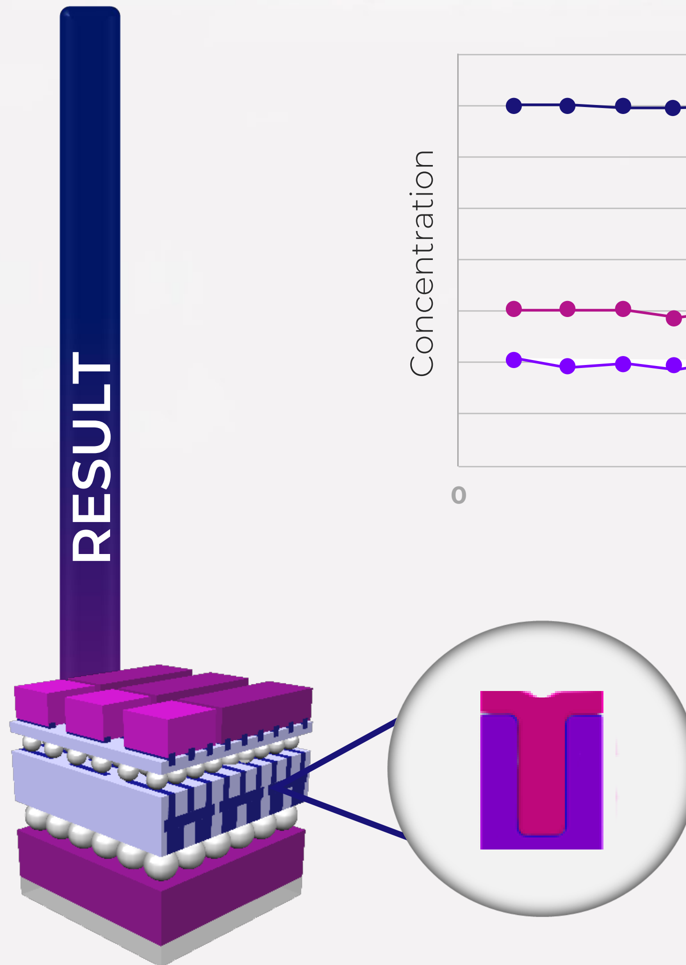
Packaging Use Case: High Aspect Ratio Plating

The **Challenge**

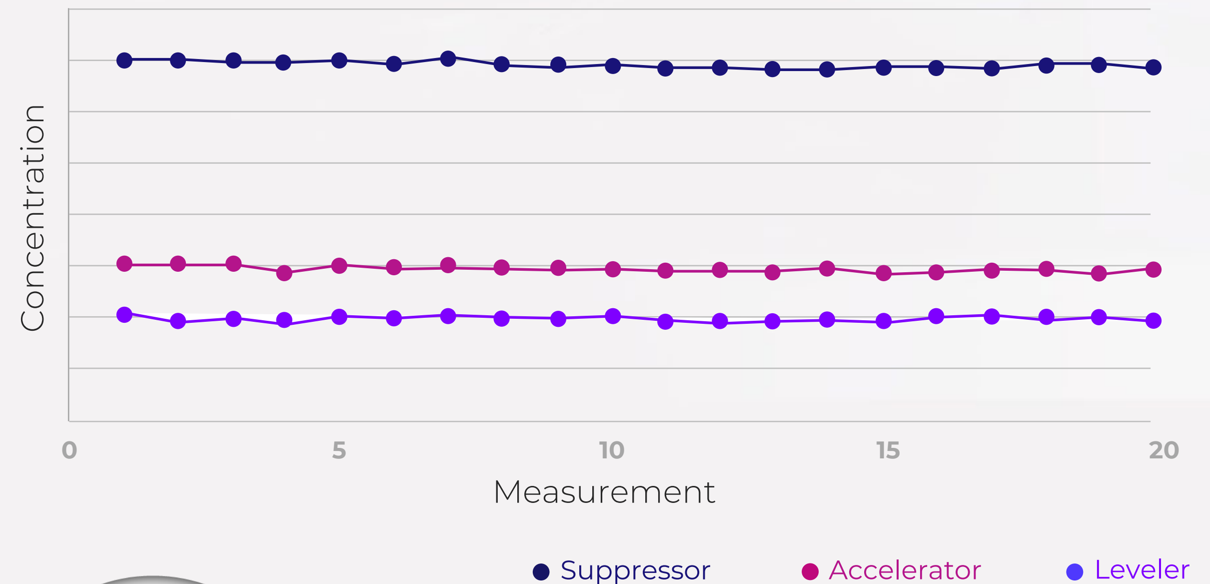
Electroplated Copper micron-size vias plating quality is strongly affected by the changes in the plating solution

ancolyzer Solution

Automated inline analysis of inorganics, organic additives, breakdown-products and contaminants



Excellent Control, Accuracy and Reproducibility



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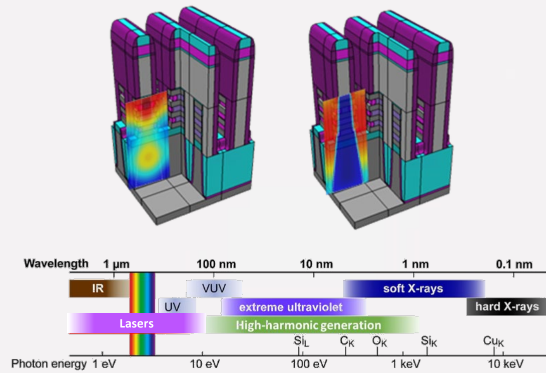
NOVA

INVESTOR DAY 2022

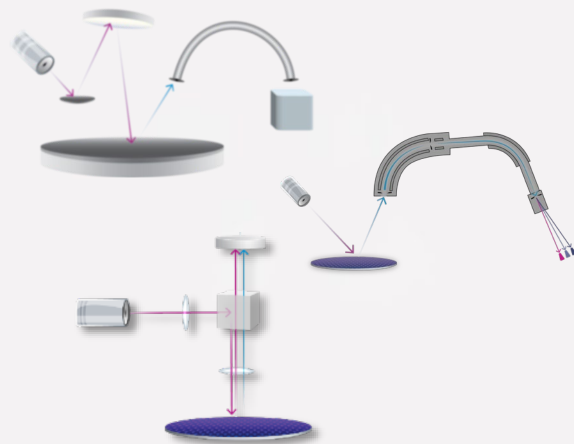
Nova Future Directions

Dimensional



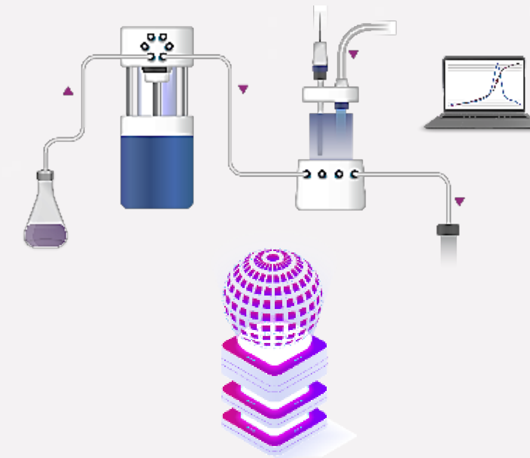
Different energy sources and extended wavelength range

Materials



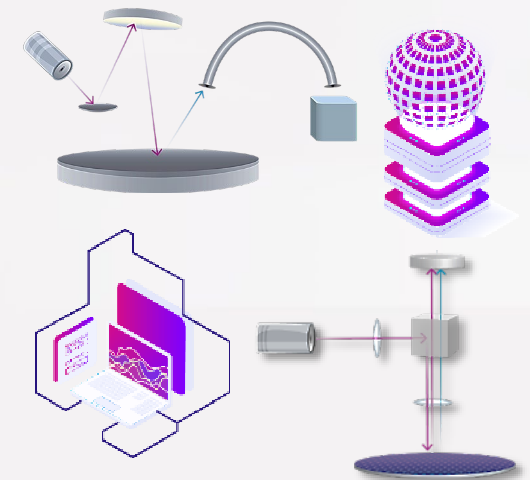
Additional material technologies from Lab to Fab

Chemical



Chemical metrology enhanced with Nova HW and algorithms core competency

Software and Algorithms



Physical and ML combined solutions enhancing materials metrology

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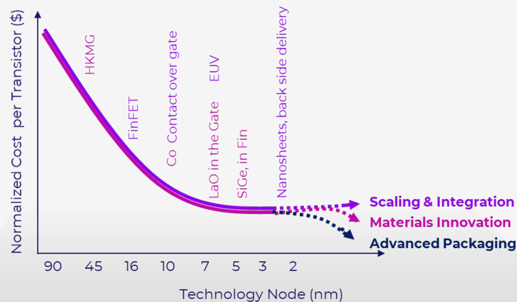
Summary

Trends

Exponential growth in data generation

More than a single track forward

More than Moore is essential



Challenges

Multiple technology inflections

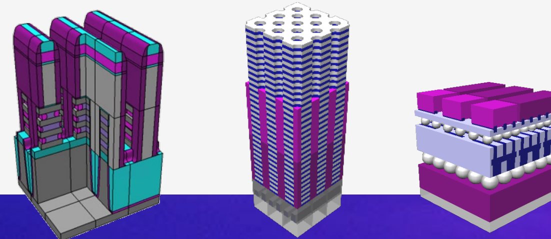
Logic- architecture evolution with increased complexity

3D NAND - multiple decks

DRAM - Going to 3D

Packaging- tighter process windows

Dimensional, Material and Chemical implications



Solutions

Unique technology solutions across all product lines

Enhanced by physical modeling and machine learning

Holistic technology portfolio for all device segments

Ongoing Innovation to Support Exponential Growth

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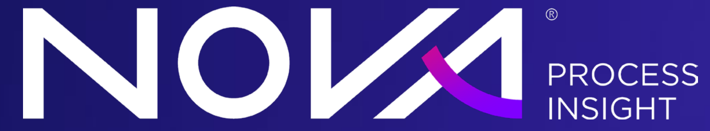

Thank You