

PUSHING LITHOGRAPHY

TO ENABLE ULTIMATE NANO-ELECTRONICS

LUC VAN DEN HOVE

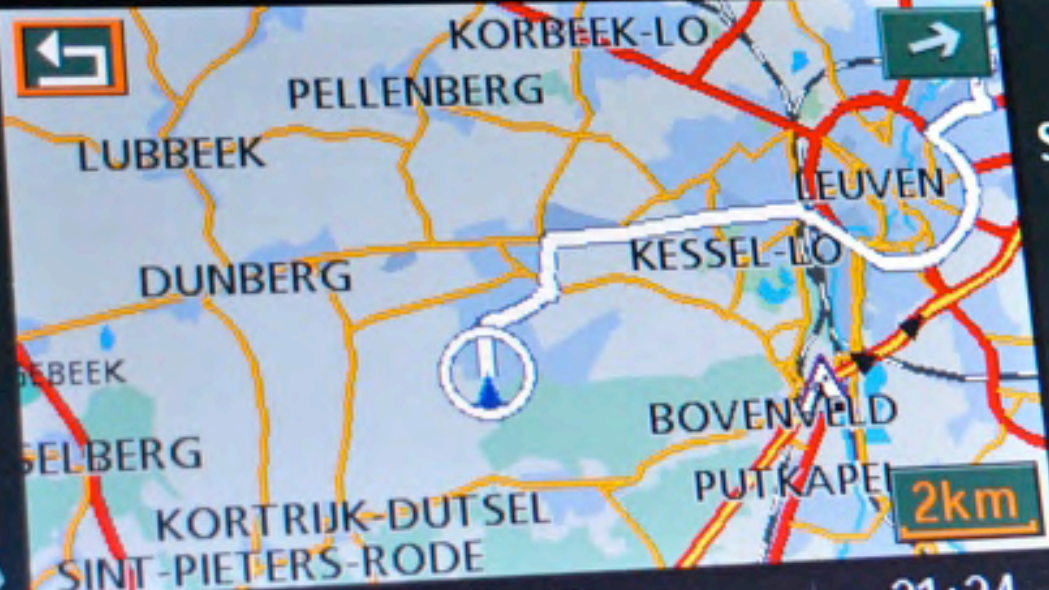
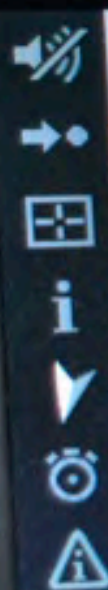
President & CEO imec



OUTLINE

- ▶ Industry drivers
- ▶ Roadmap extension
- ▶ Lithography options
- ▶ Innovation through global collaboration





STEENVELDSTRAAT

700m

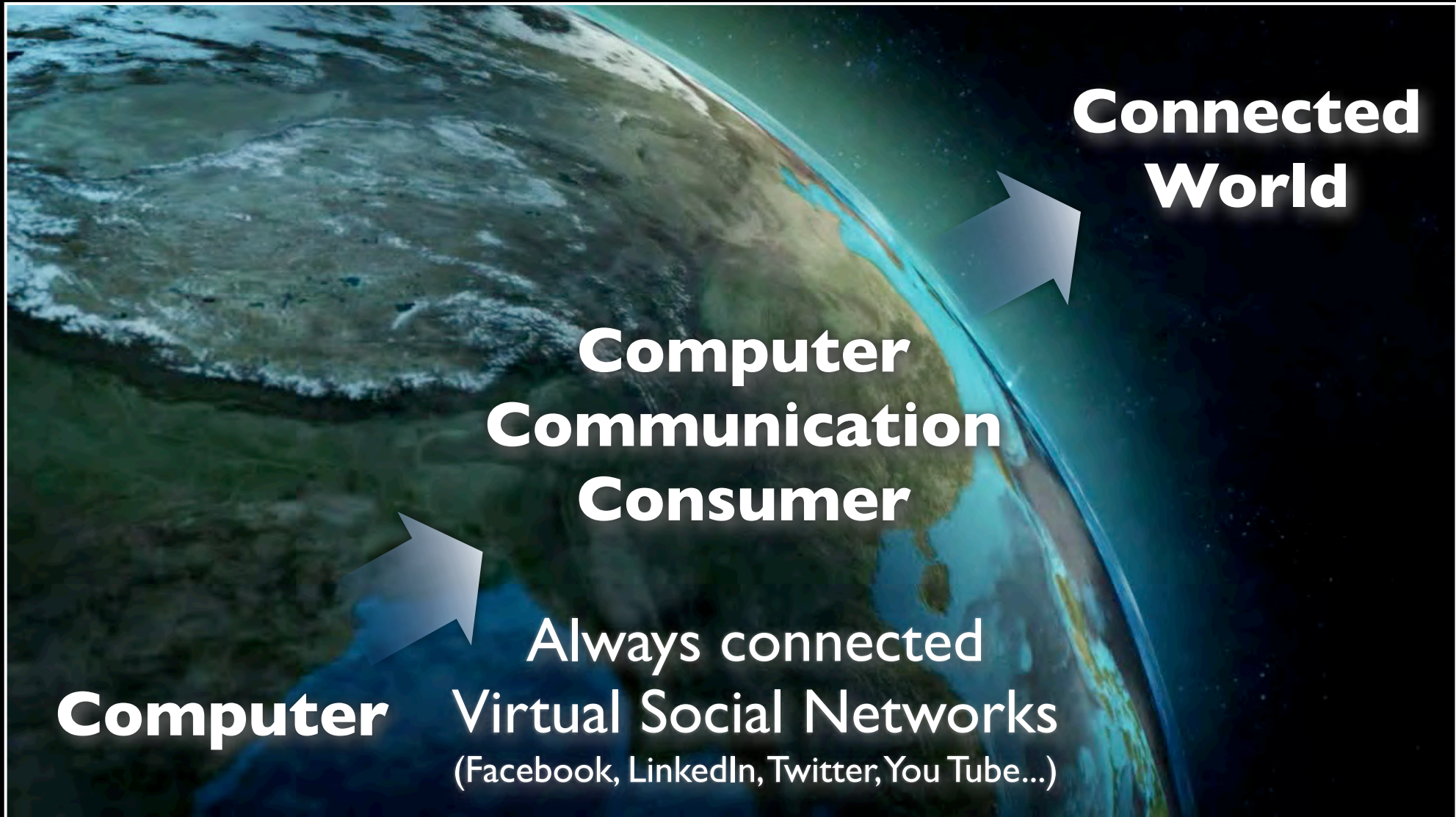
21:41 12 km

RADIO 1 TP TMC 21:24






Experience the world wherever you are



Experience the world wherever you are

**Ubiquitous Connectivity
Video + Ultimate Graphics
3D**

A 3D rendered office scene. In the foreground, a person with dark hair is sitting at a round, light-colored table, looking at a tablet device. On the table, there is a small blue cup on a saucer. In the background, another person with reddish hair is sitting at a desk, working on a computer. The office has large windows, wooden pillars, and a filing cabinet on the left.



Computing

Communication

Consumer



Computing

Communication

Consumer

**Lifestyle
Healthcare**

BUSY LIFESTYLE



1 billion overweight people
300 million of those are obese

AGING POPULATION

A blurred, long-exposure photograph of a crowd of people walking through a modern, brightly lit interior space, possibly a transit hub or office lobby. The image is dominated by a cool blue color palette. The people are out of focus, creating a sense of motion and a large, busy population. The background consists of large glass panels reflecting light, and the floor is highly reflective, mirroring the figures above.

600 million persons 60+
Expected to double by 2025

RISE IN CHRONIC DISEASES

A blurred, low-angle shot of a crowd of people walking in a modern, brightly lit interior space, possibly a transit hub or office lobby. The image is heavily blurred to convey a sense of motion and a large, diverse group of people. The color palette is dominated by cool blues and greys, with some warmer tones from clothing and lighting in the background.

600 million people worldwide
\$500 billion a year (US)
\$685 billion by 2020 (US)

MEDICINE GOES DIGITAL

PERSONALIZED - PREDICTIVE - PREVENTIVE



WEARABLE HEALTH AND COMFORT MONITORING

internet
doctor
hospital



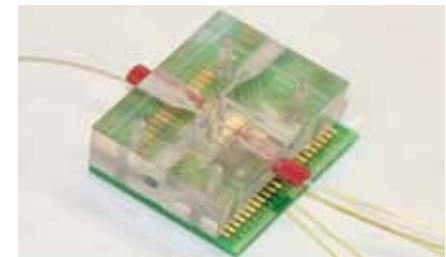
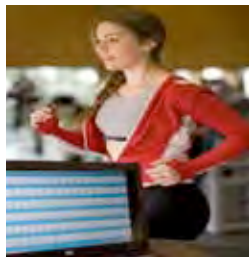
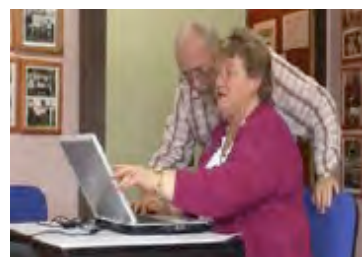
Anywhere, anytime
Connected health
Health and lifestyle

WEARABLE HEALTH AND COMFORT MONITORING

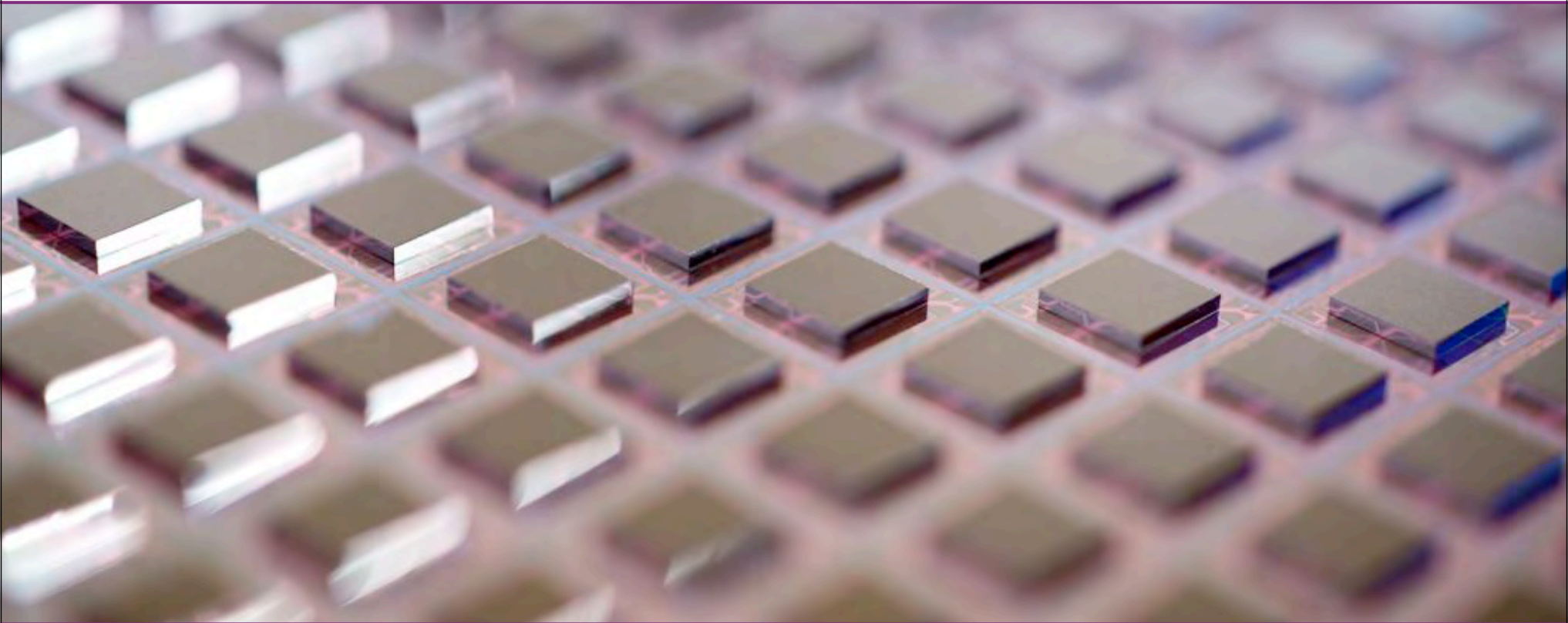


ECG NECKLACE FOR AMBULATORY APPLICATIONS

WEARABLE HEALTH AND COMFORT MONITORING

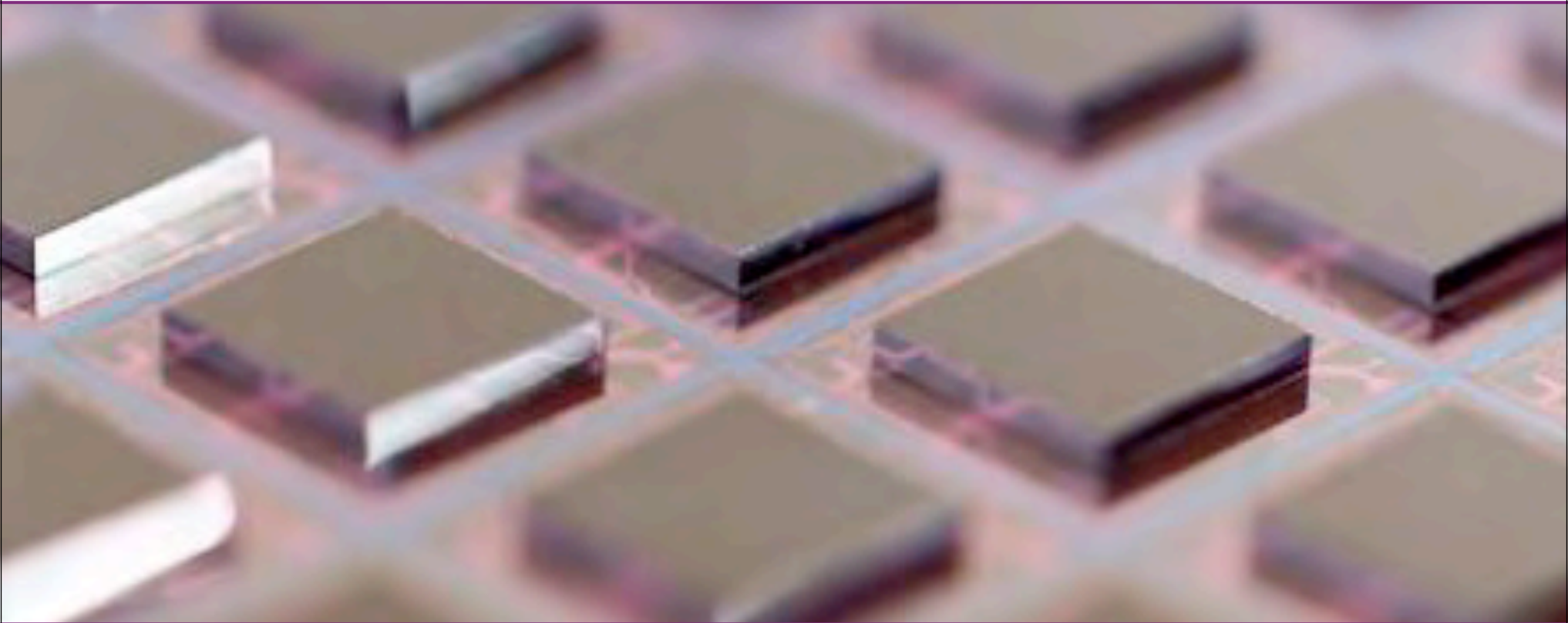


BOOSTING CHIP PERFORMANCE AND SYSTEM FUNCTIONALITY



TERAFLOP
TERABIT
MORE FUNCTIONALITY

BOOSTING CHIP PERFORMANCE AND SYSTEM FUNCTIONALITY



TERAFLOP
TERABIT
MORE FUNCTIONALITY

RELENTLESS SCALING

1965

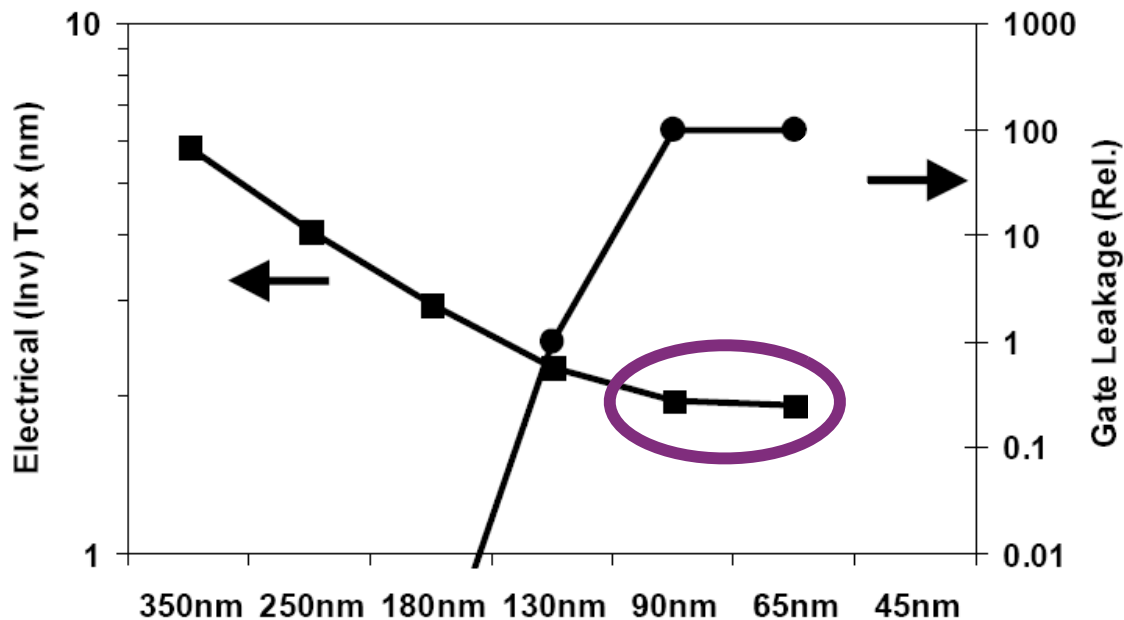
2002-2003
~ 90 nm

Lithography Enabled Scaling

STOP

Geometric
(Dennard's Law)

Scale: t_{ox} , L_g , x_j , ...



RELENTLESS SCALING

1965

2002-2003
~ 90 nm



Lithography Enabled Scaling

Geometric
(Dennard's Law)

Scale: t_{ox} , L_g , x_j , ...

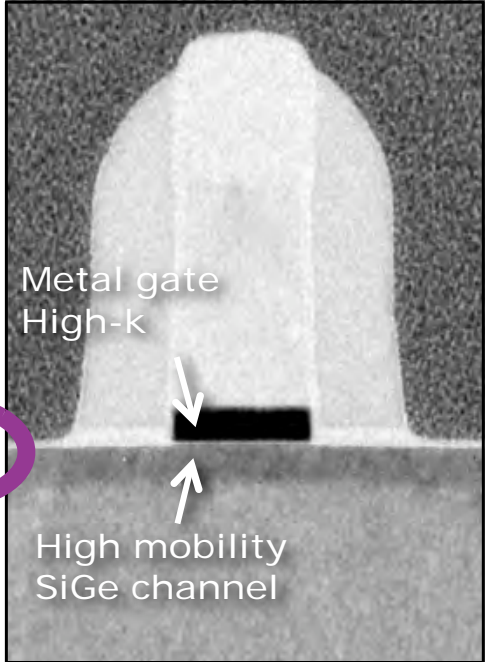
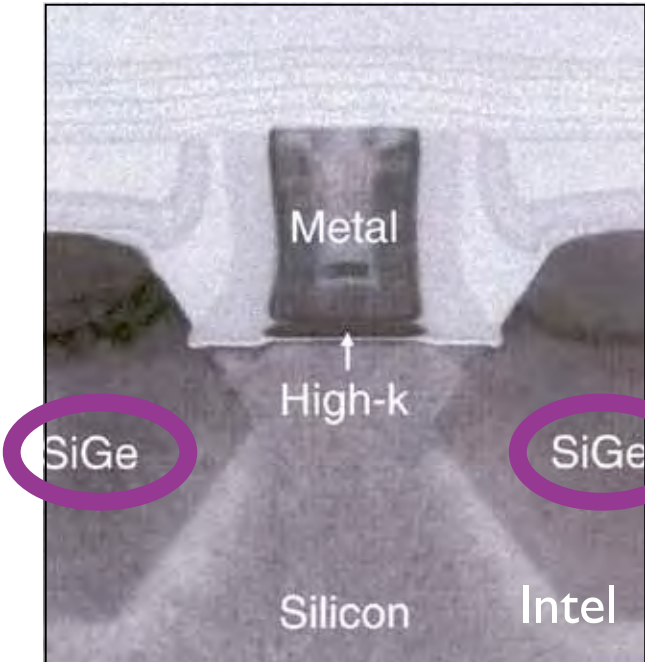


Materials Enabled Scaling

RELENTLESS SCALING

1965

2002-2003
~ 90 nm



RELENTLESS SCALING

1965

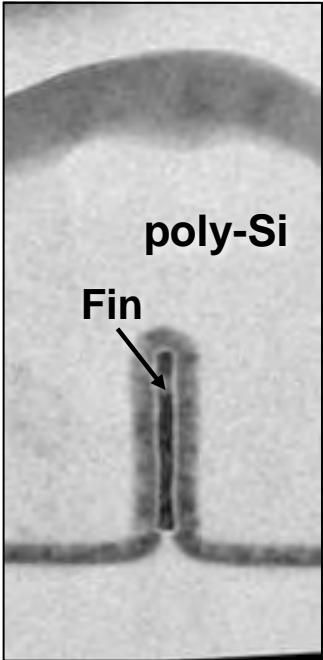
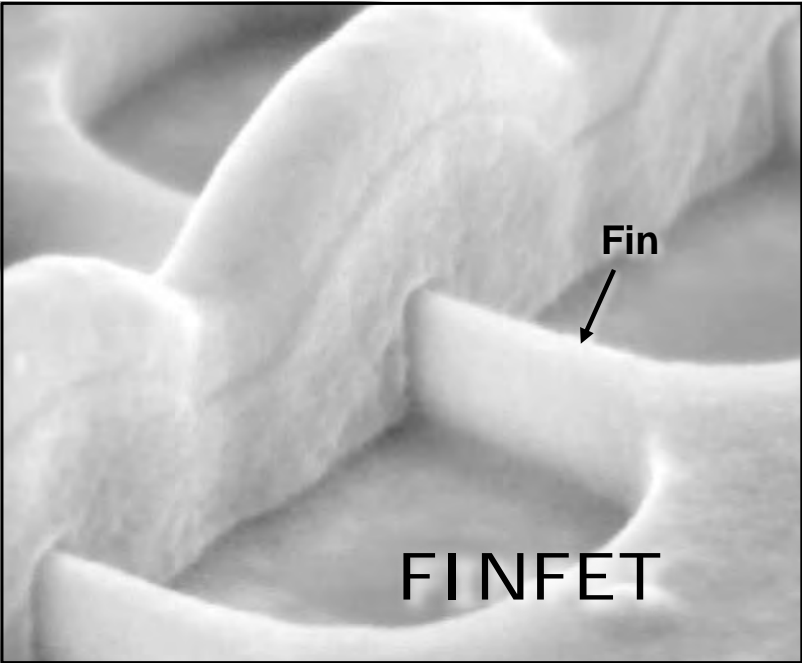
2002-2003
~ 90 nm

~ 15nm

Lithography Enabled Scaling

Materials Enabled Scaling

Strained Si
High-k
Metal Gate
Multi Gate



RELENTLESS SCALING

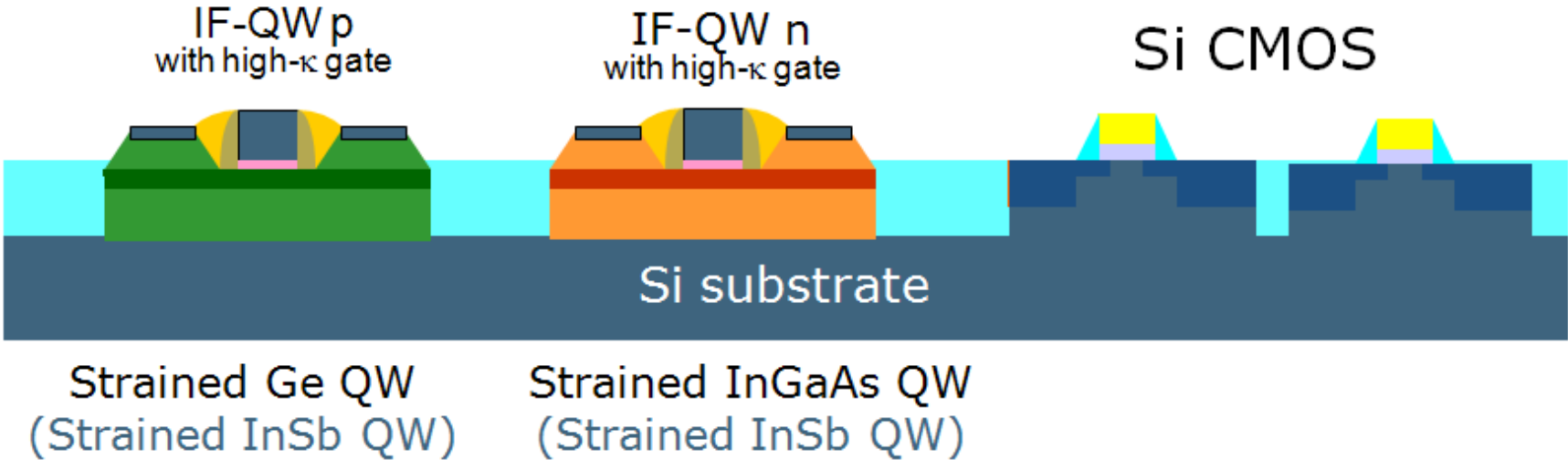
1965

2002-2003
~ 90 nm

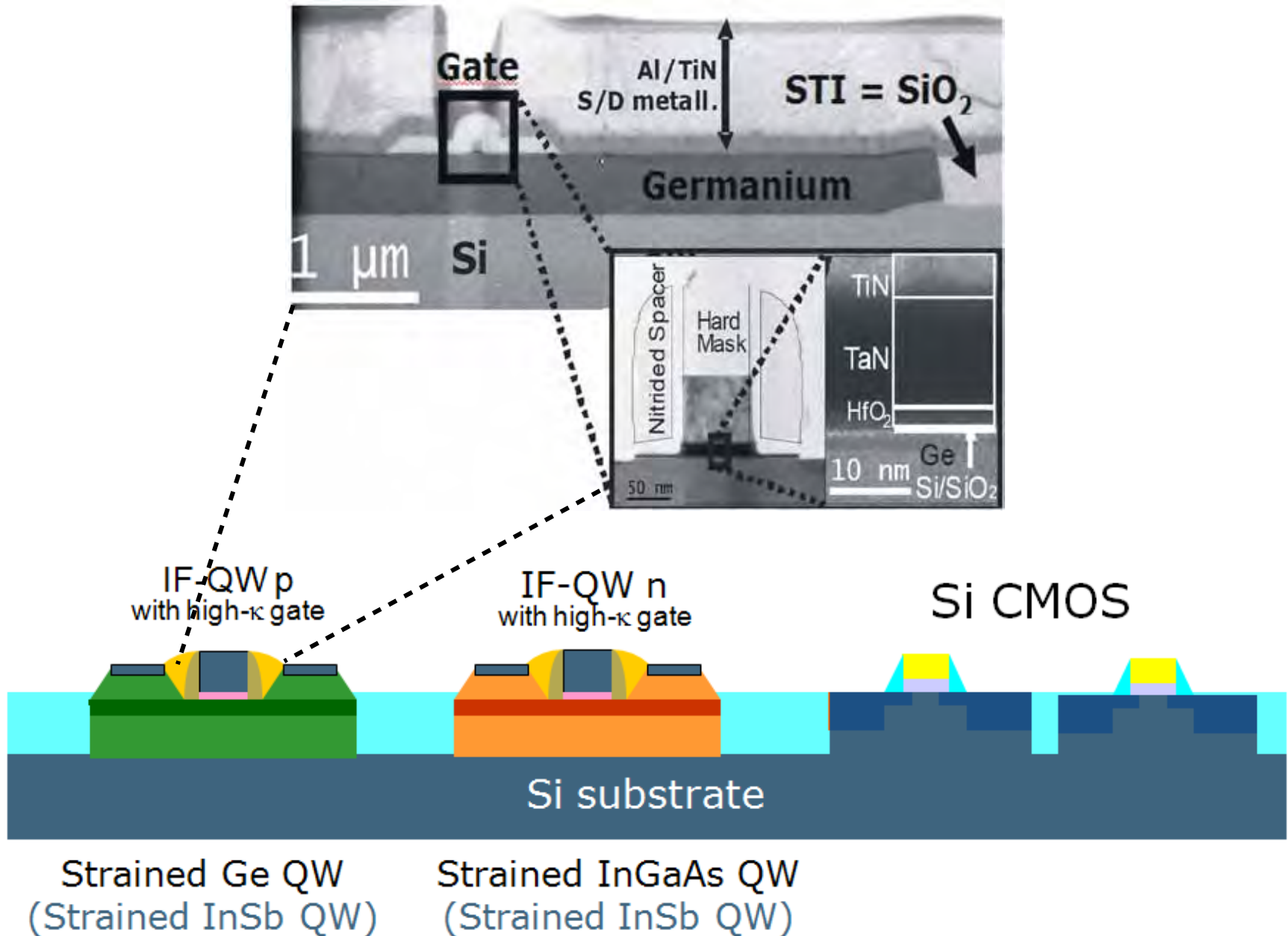
~ 15nm

Lithography Enabled Scaling

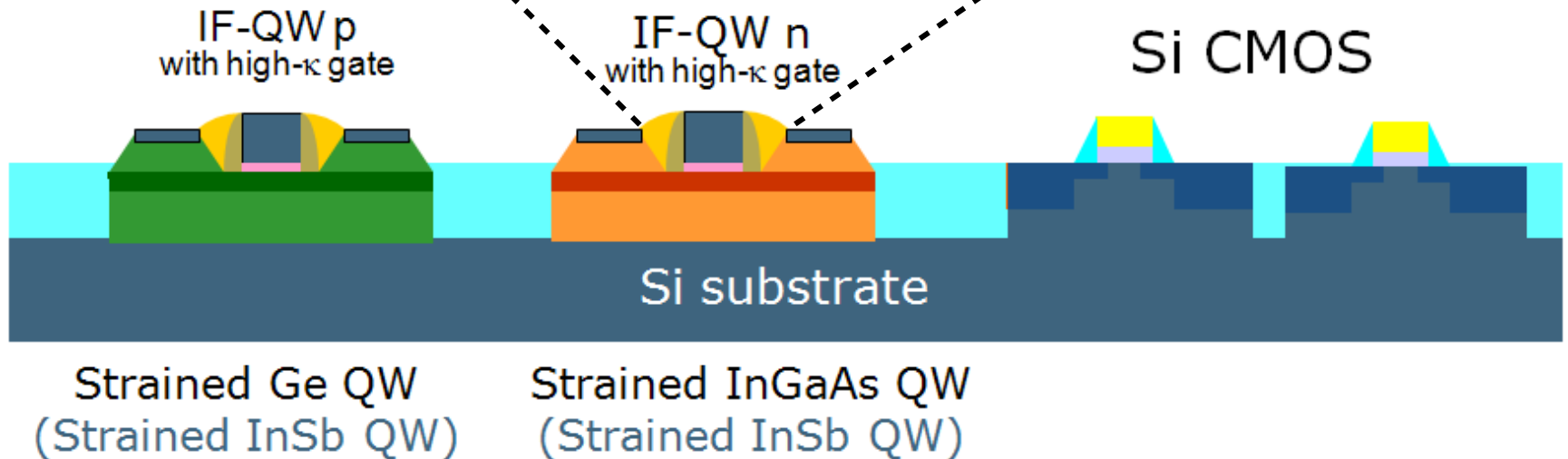
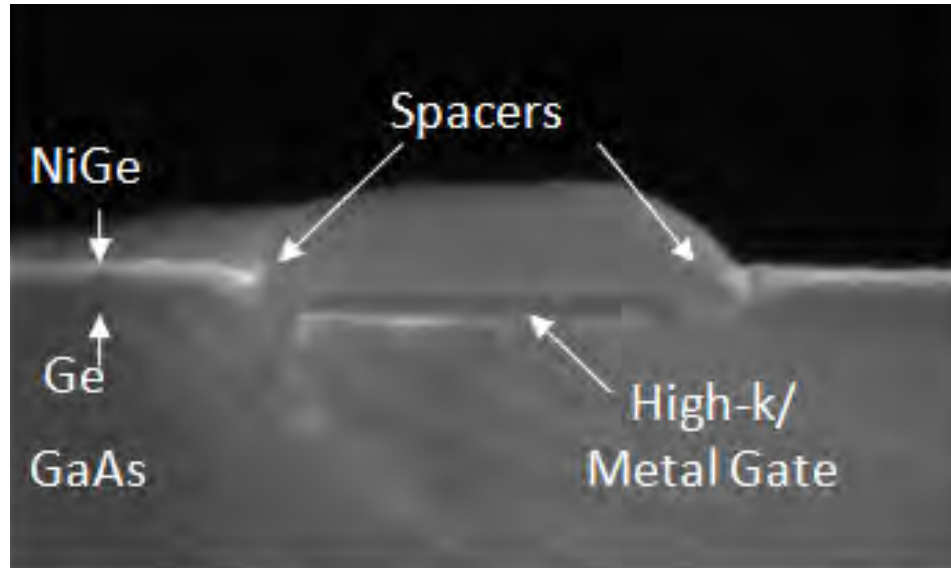
Materials Enabled Scaling



EXTREME HIGH MOBILITY CHANNELS



EXTREME HIGH MOBILITY CHANNELS



RELENTLESS SCALING



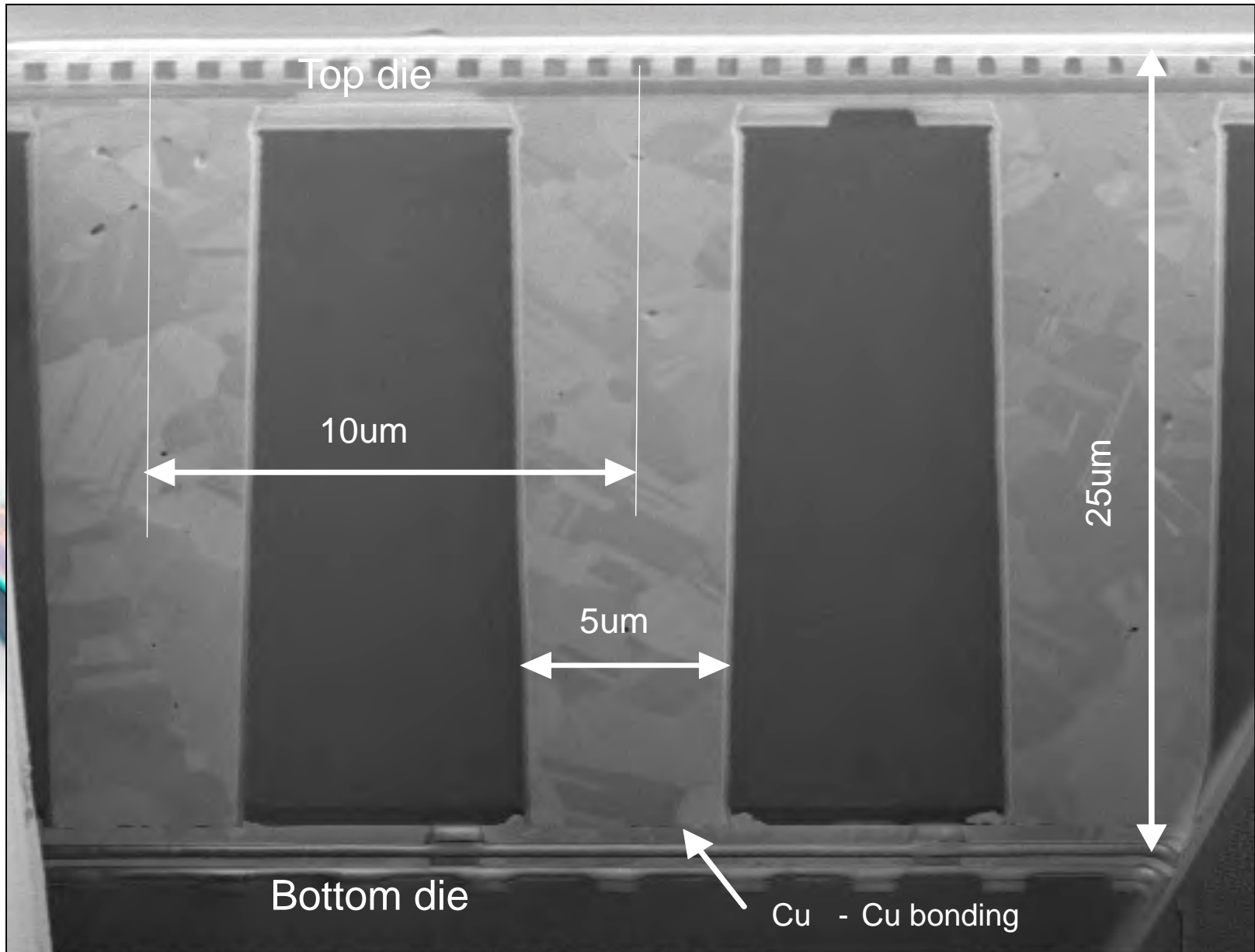
Lithography Enabled Scaling

Materials Enabled Scaling

3D Enabled Scaling

From Plane to Cube

3D STACKED ICs CONNECTED THROUGH TSVs



PERFORMANCE

MOBILE SYSTEMS

E.g., Netbooks

Cost, Power, Form factor,
Performance

REUSE

COMPUTE SYSTEMS

E.g., Routers, Servers

Performance, Power efficiency,
heat dissipation, Reliability

**3D Integration &
advanced packaging**

CONSUMER

E.g., micro-servers

Power, Cost, Performance,
Form factor, ...

MODULARITY

HEALTHCARE

E.g., sensor nodes

Form-factor, power,
bio-compatibility, reliability

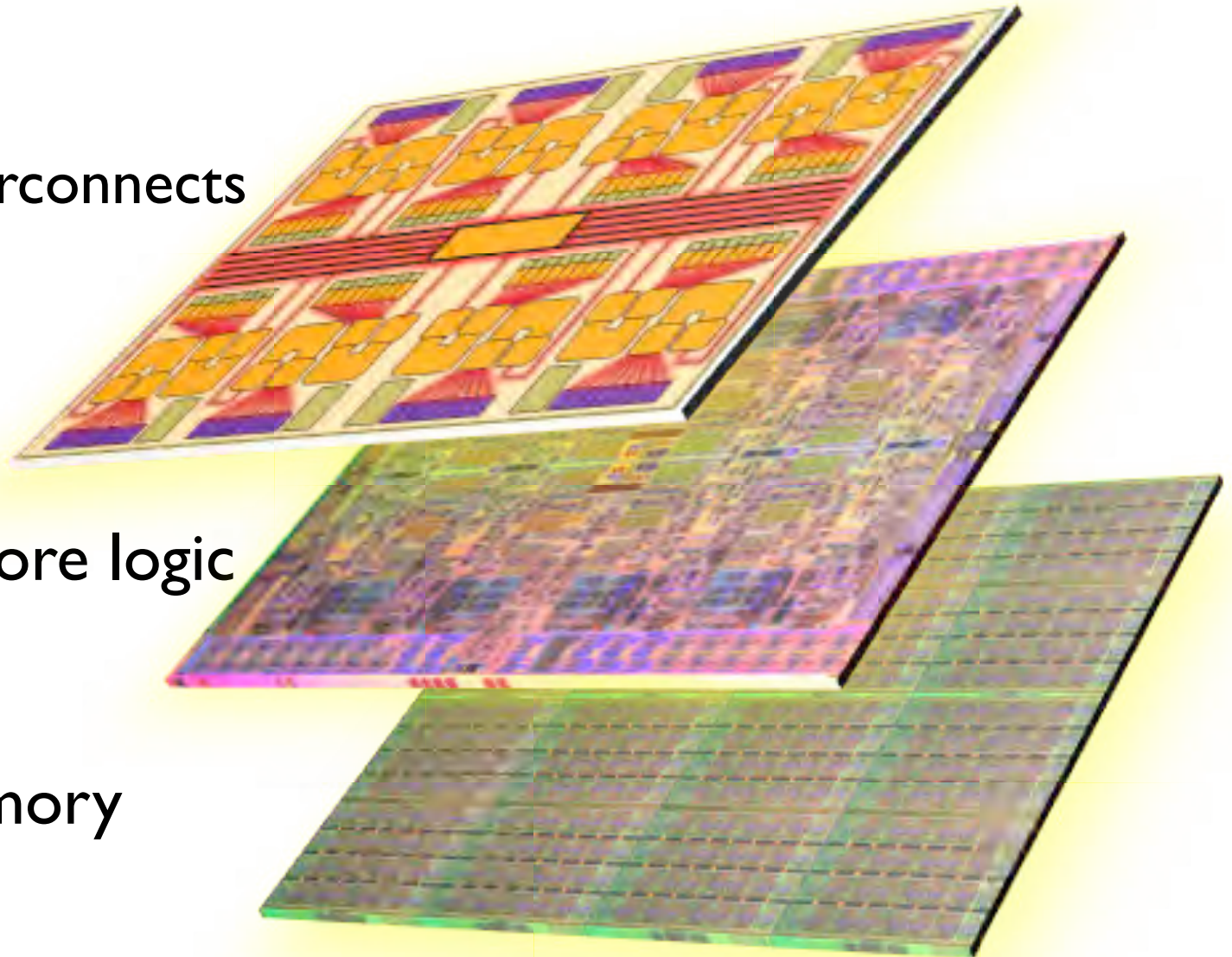
FORMFACTOR

3D STACKED ICs CONNECTED THROUGH TSVs

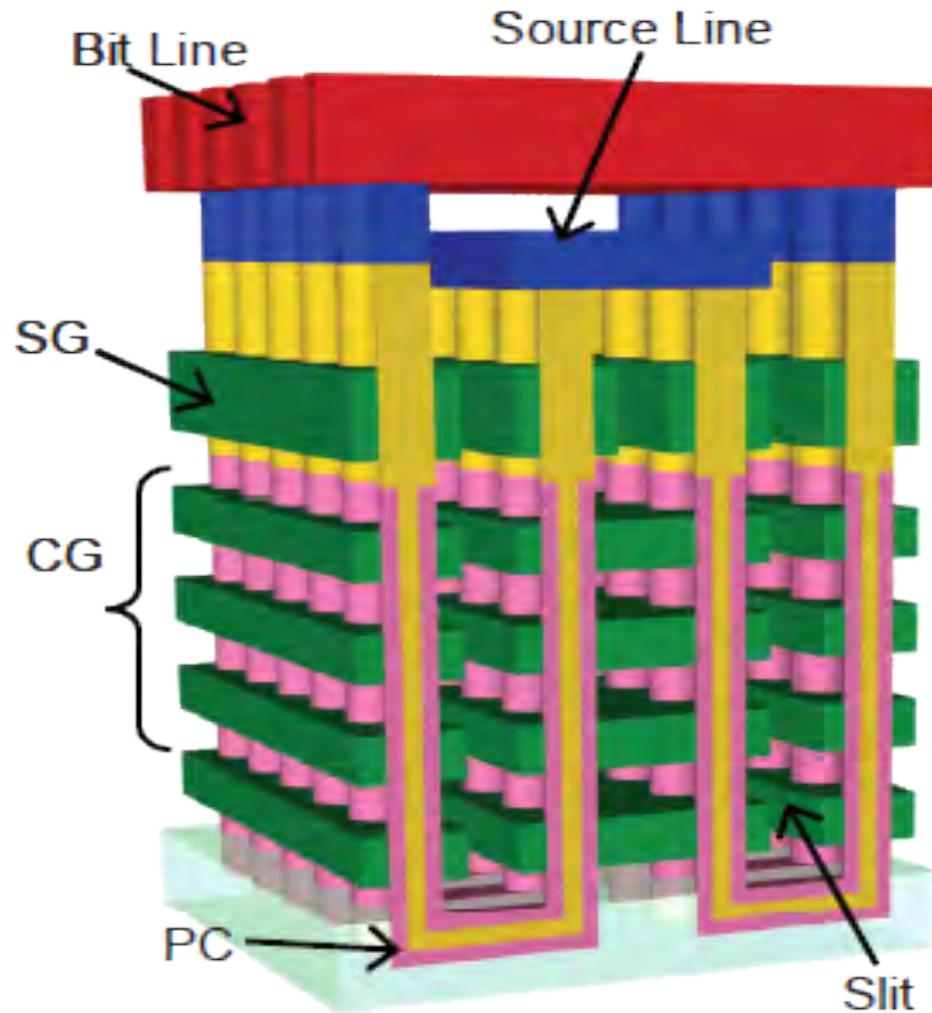
Optical interconnects
Photonics

Multi-core logic

Memory

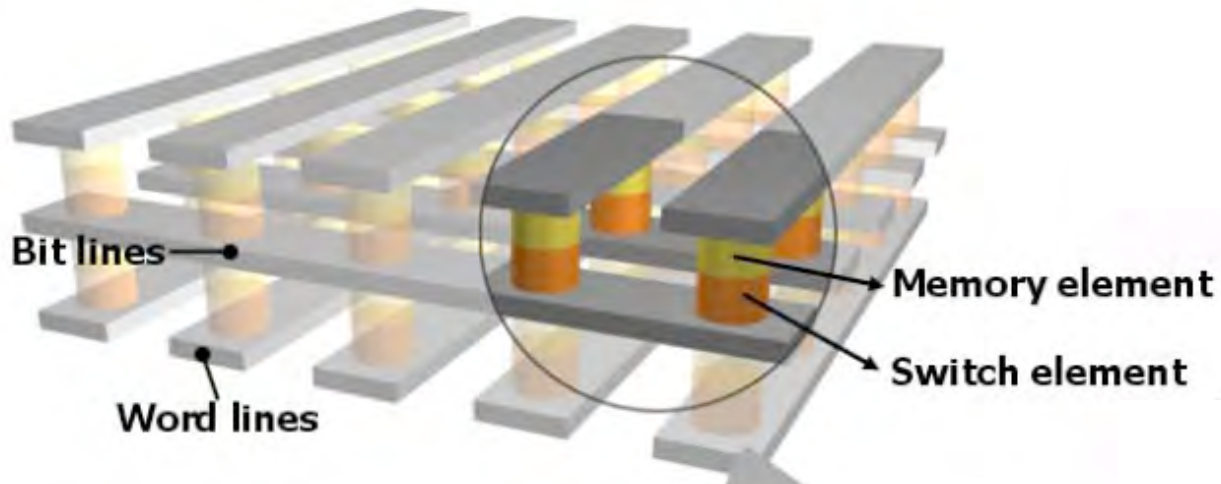


NEW MEMORY CONCEPTS

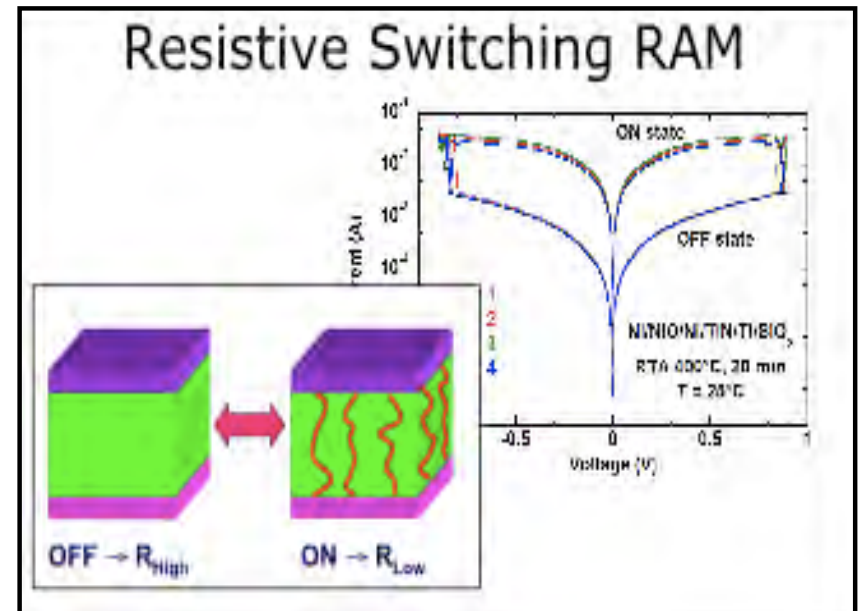


BiCS (ref. Toshiba)

NEW MEMORY CONCEPTS



Cross-bar memory



LIKELY FLASH ROADMAP

2010

2011

2012

2013

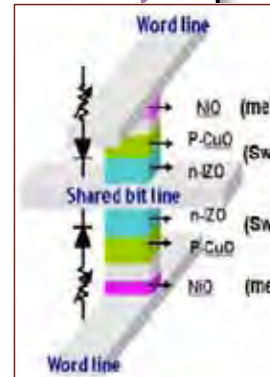
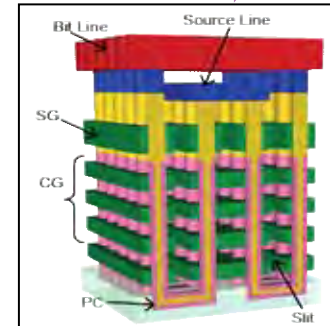
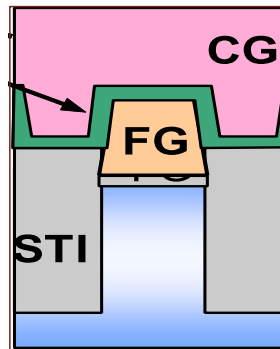
2014

>2015

<1F²

1F²

2F²



LIKELY DRAM ROADMAP

2010

2011

2012

2013

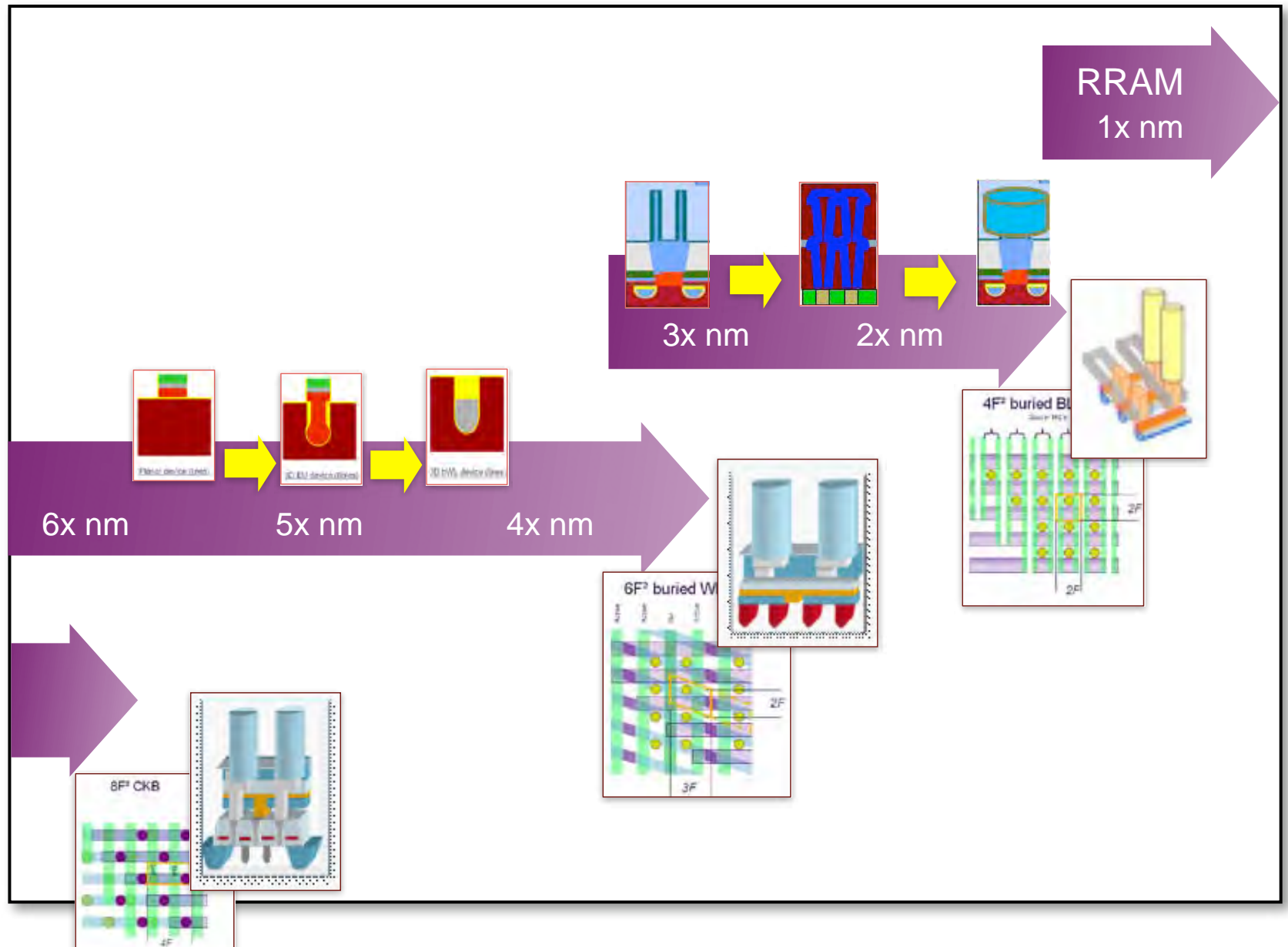
2014

>2015

4F²

6F²

8F²



RELENTLESS SCALING



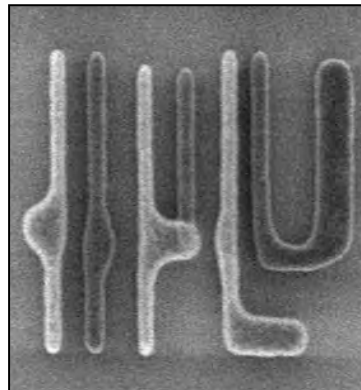
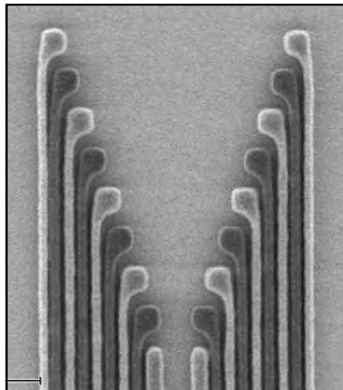
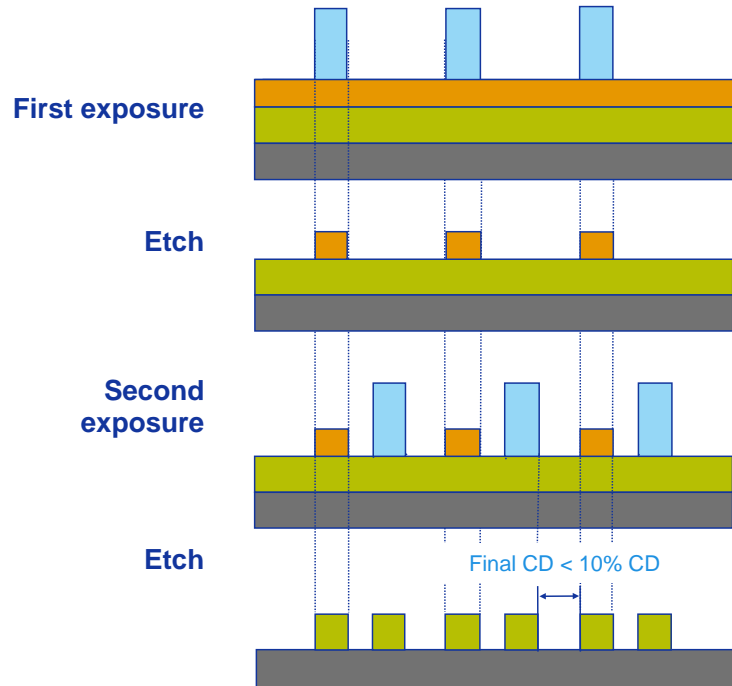
Lithography Enabled Scaling

Materials Enabled Scaling

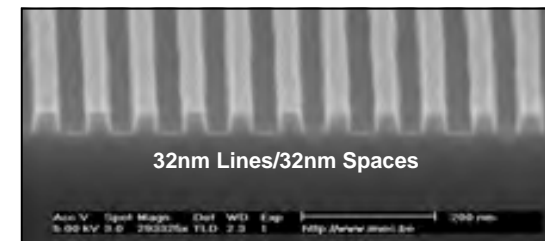
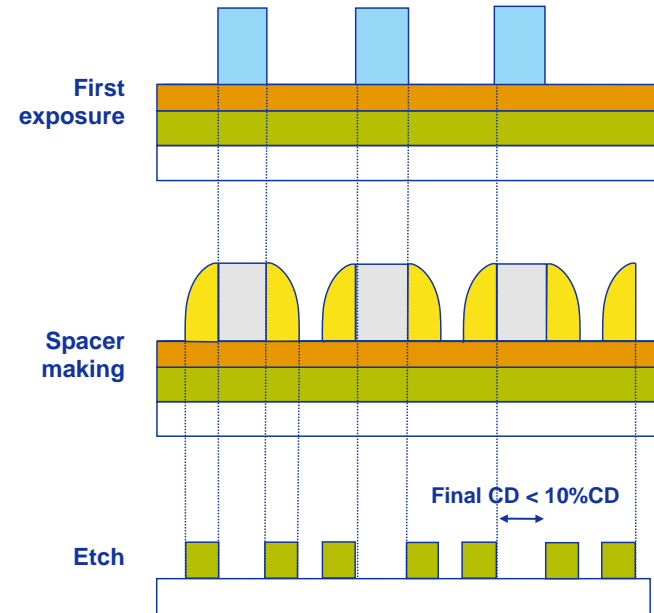
3D Enabled Scaling

DOUBLE PATTERNING

Litho-Etch-Litho-Etch

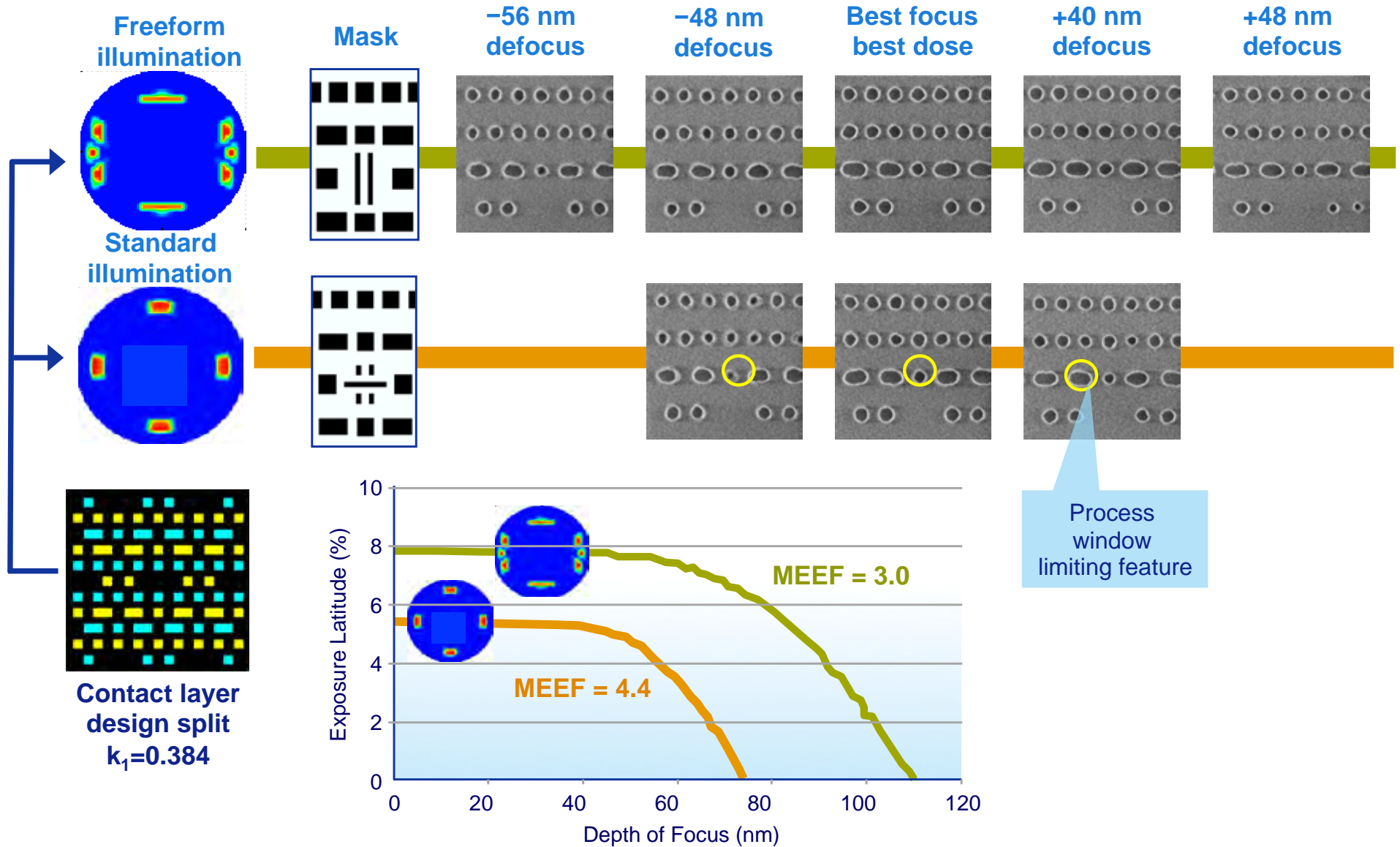


Spacer defined DP

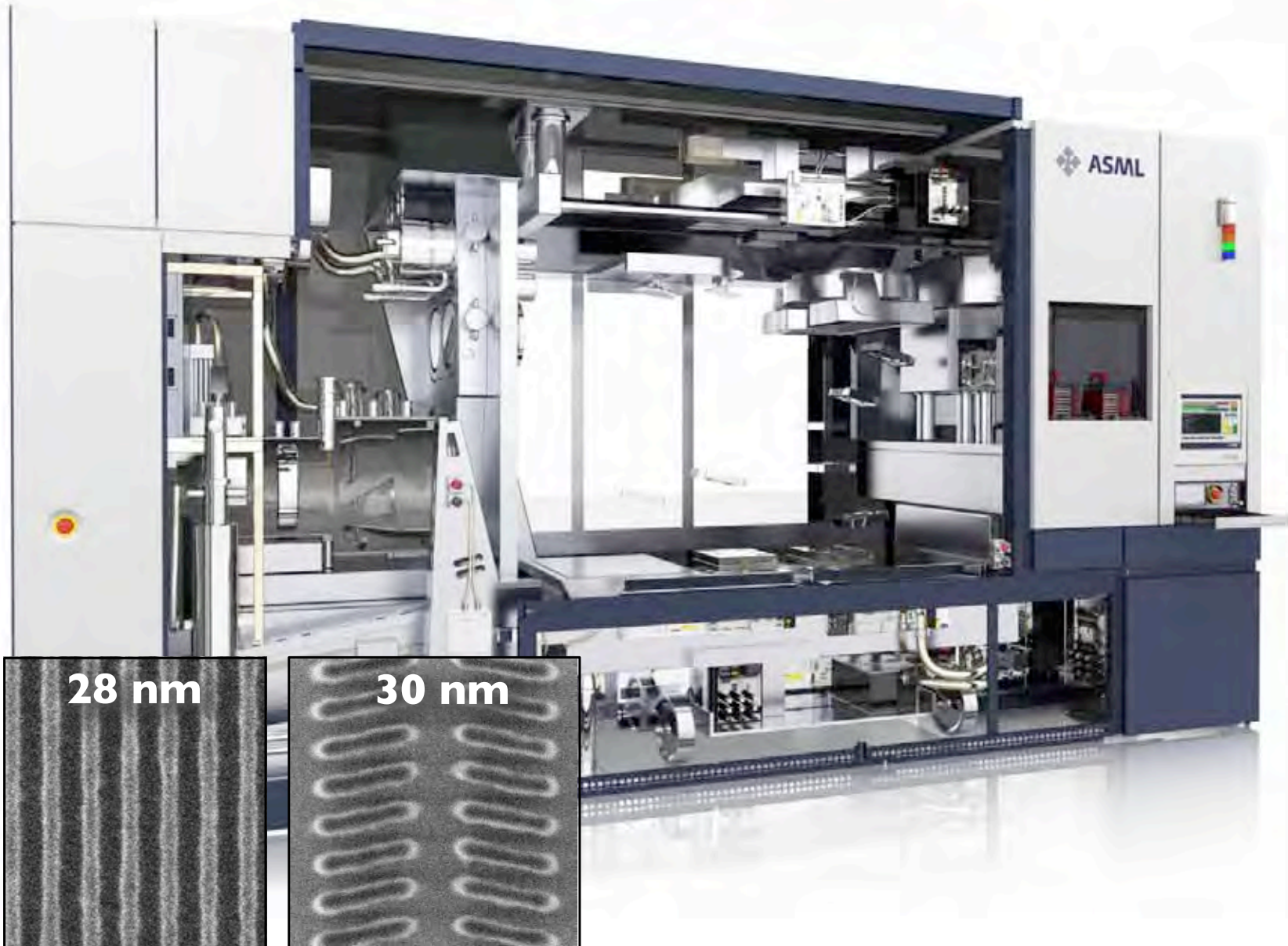


SOURCE MASK OPTIMIZATION

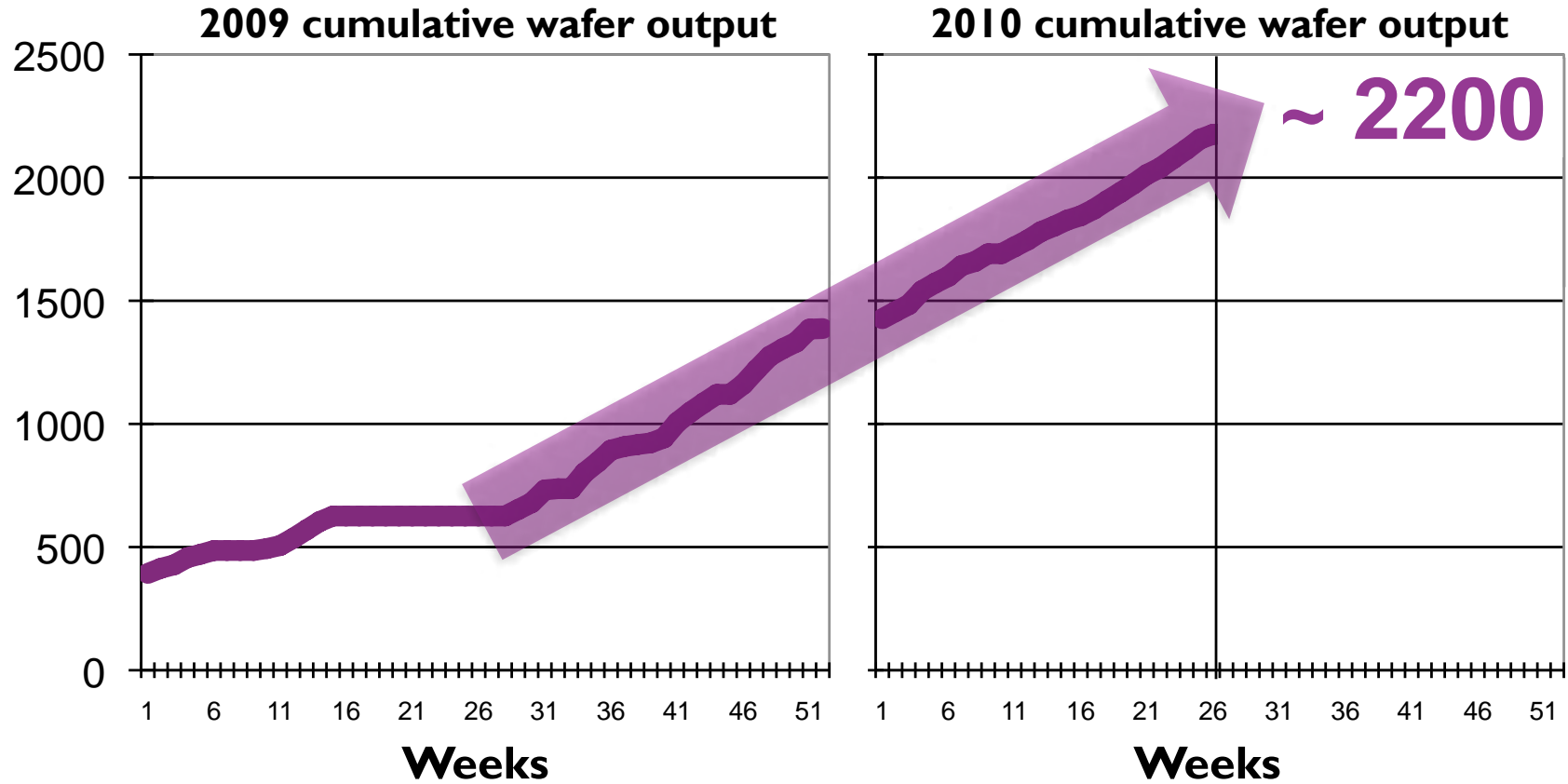
22NM SRAM PROCESS WINDOW WITH DOUBLE PATTERNING



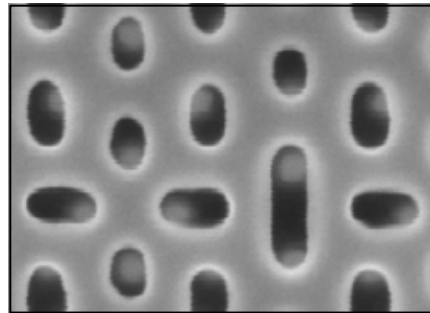
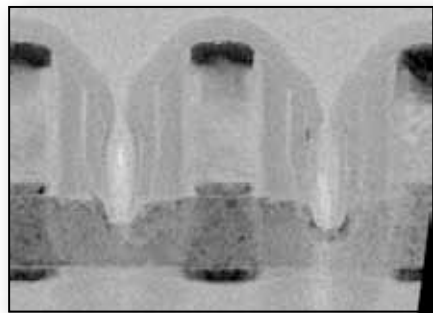
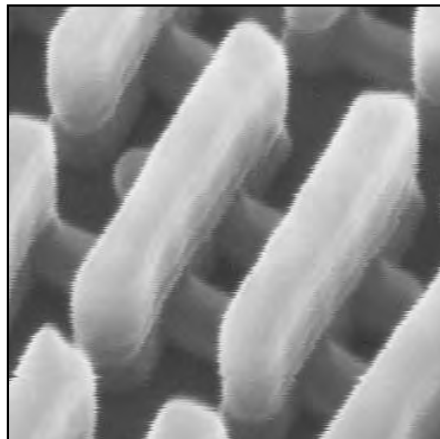
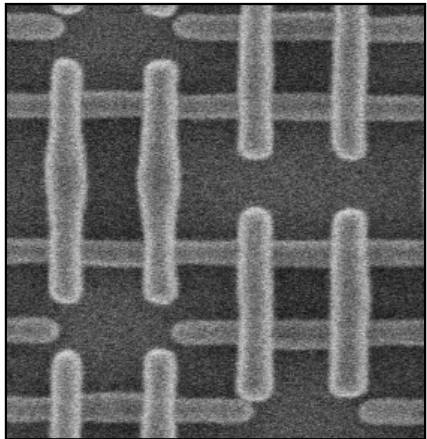
EUV LITHOGRAPHY



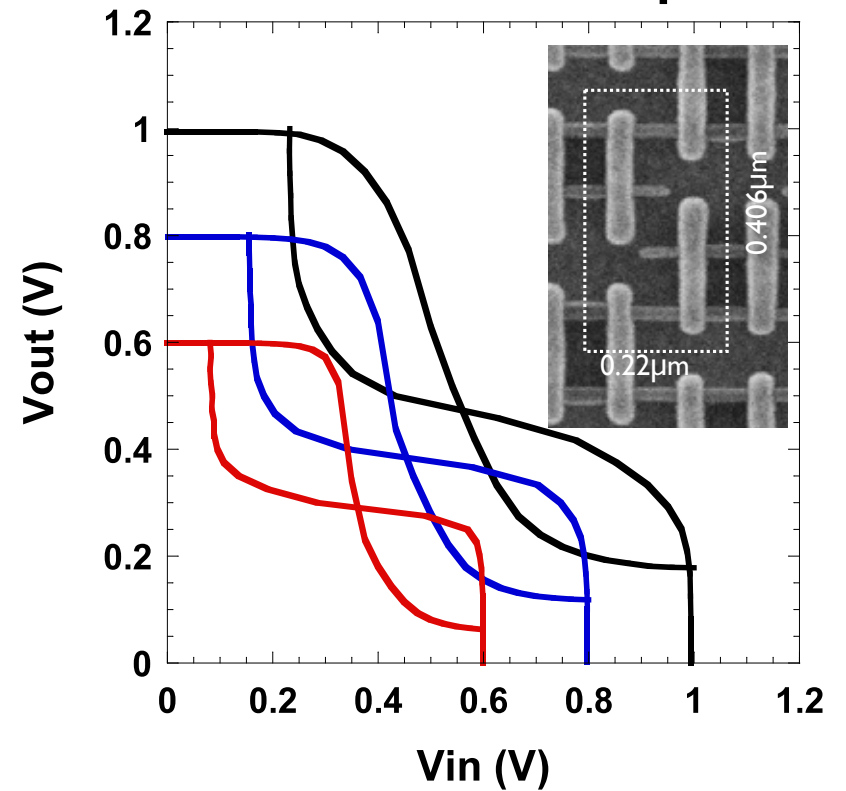
EUV TOOL OUTPUT



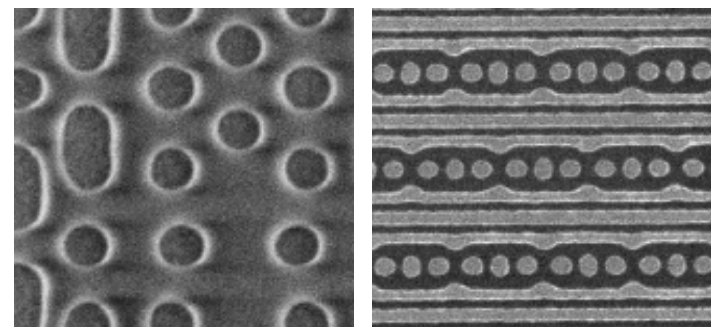
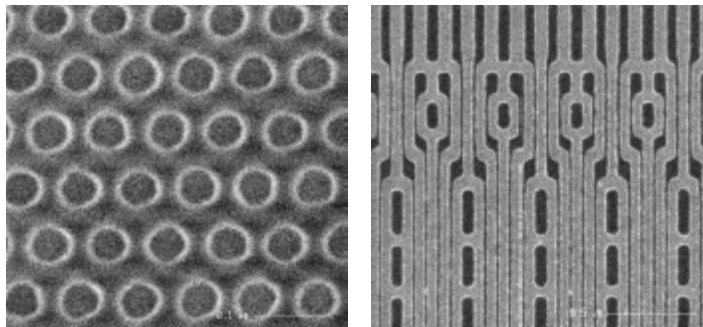
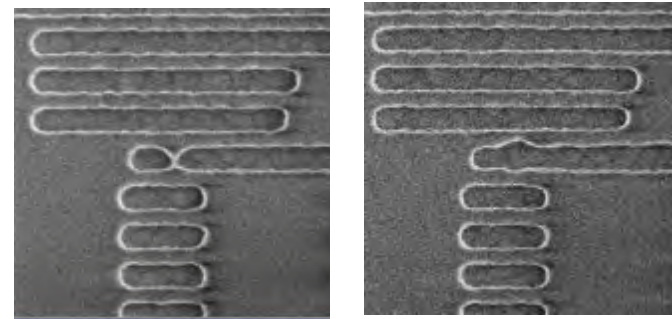
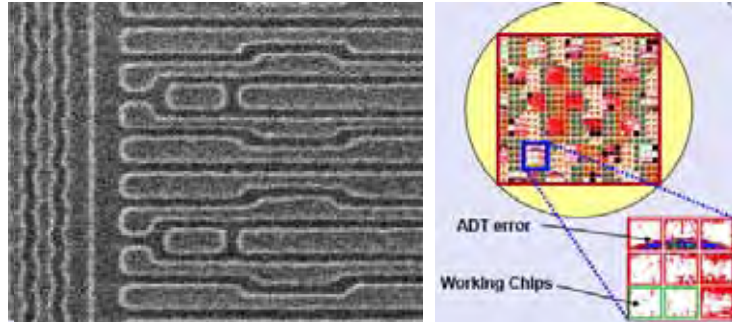
22nm NODE SRAM PATTERNING WITH EUV



0.089 μm^2

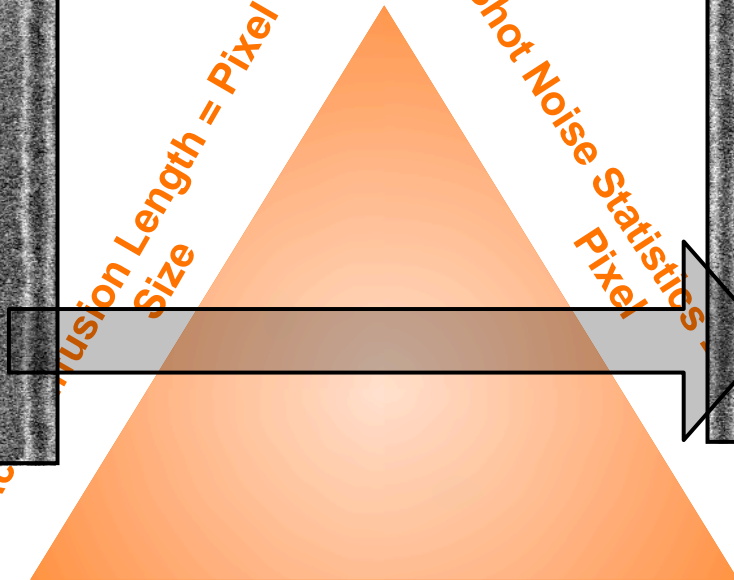
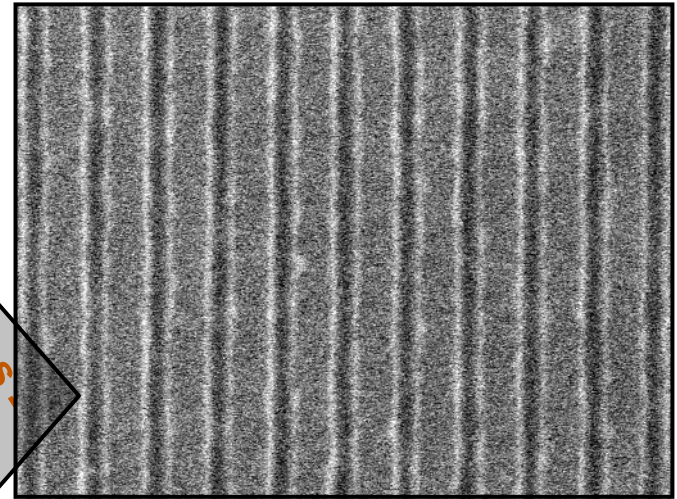
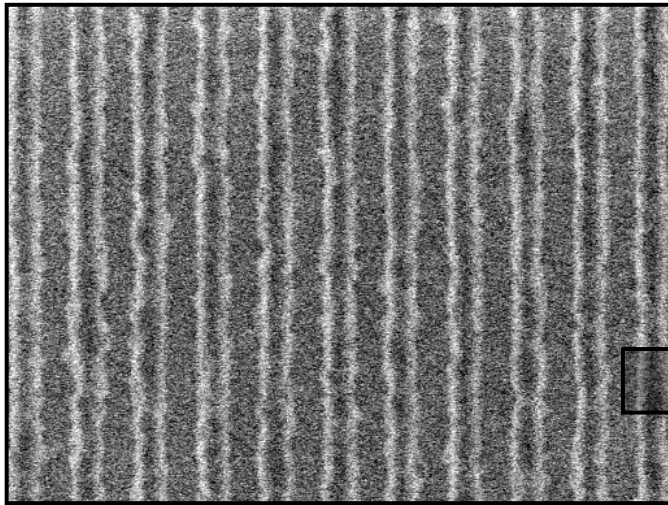


IMEC PARTNER EXPOSURES



RESIST MATERIALS

Sensitivity

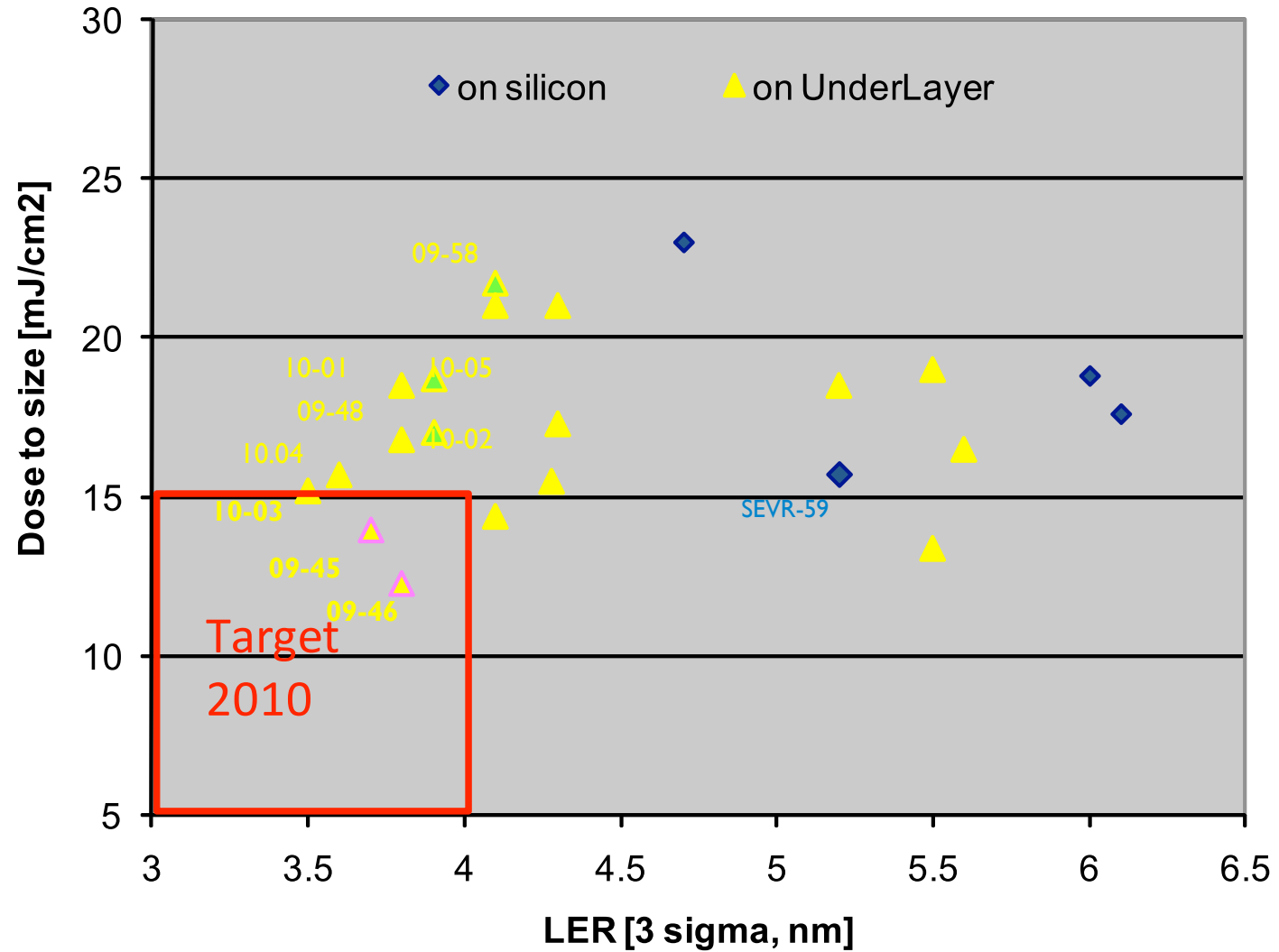


Resolution

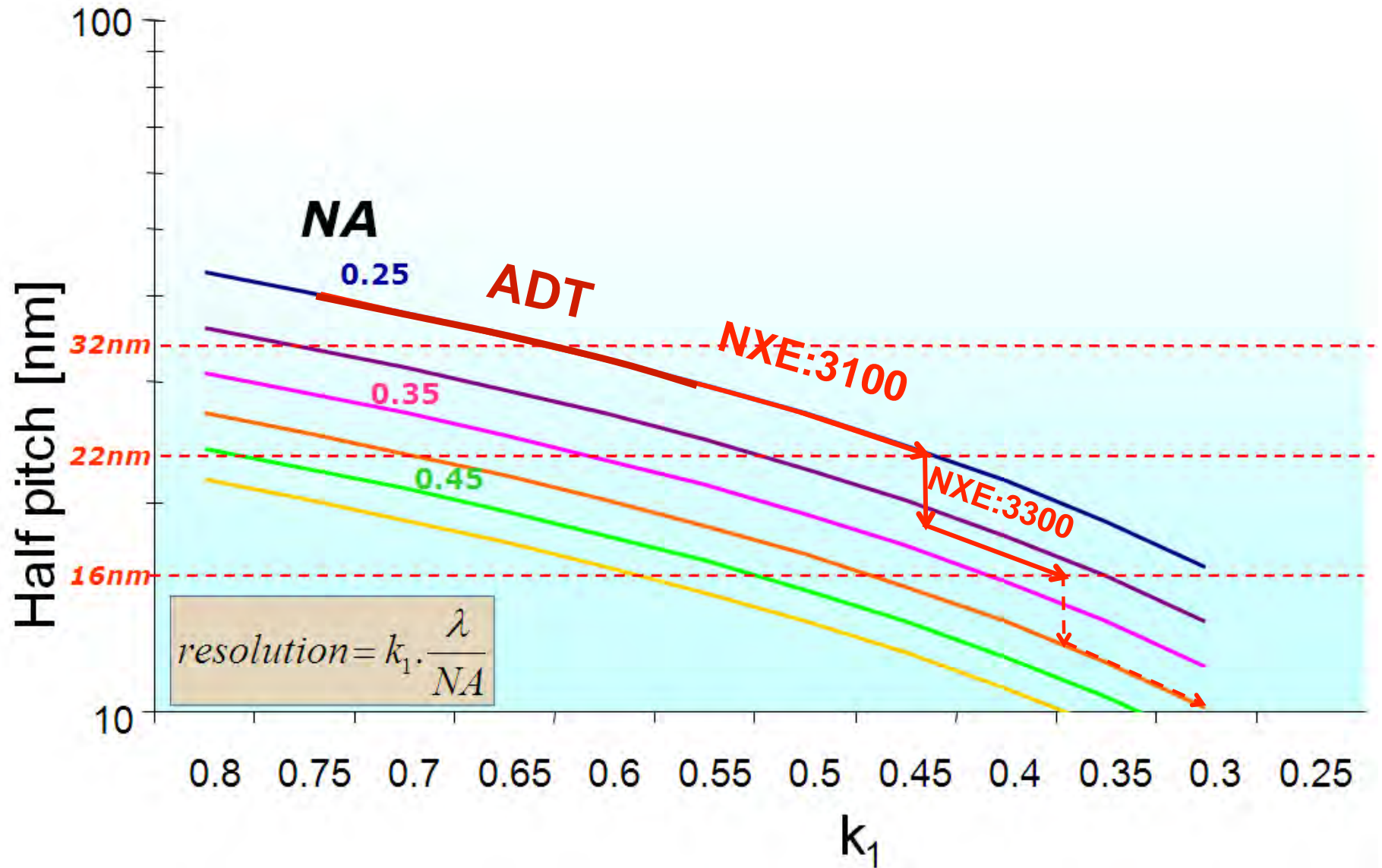
Acid Diffusion Length

**Line Width
Roughness**

RESIST MATERIALS



EUV ROADMAP TOWARDS 10nm



ML2 LITHO DEVELOPMENT

Meeting the 3 key targets (resolution, overlay, throughput) for direct write on Si is extremely challenging

- ▶ Targets are rapidly moving according to Moore's law. Missing the targeted insertion node can have major impact on the ROI

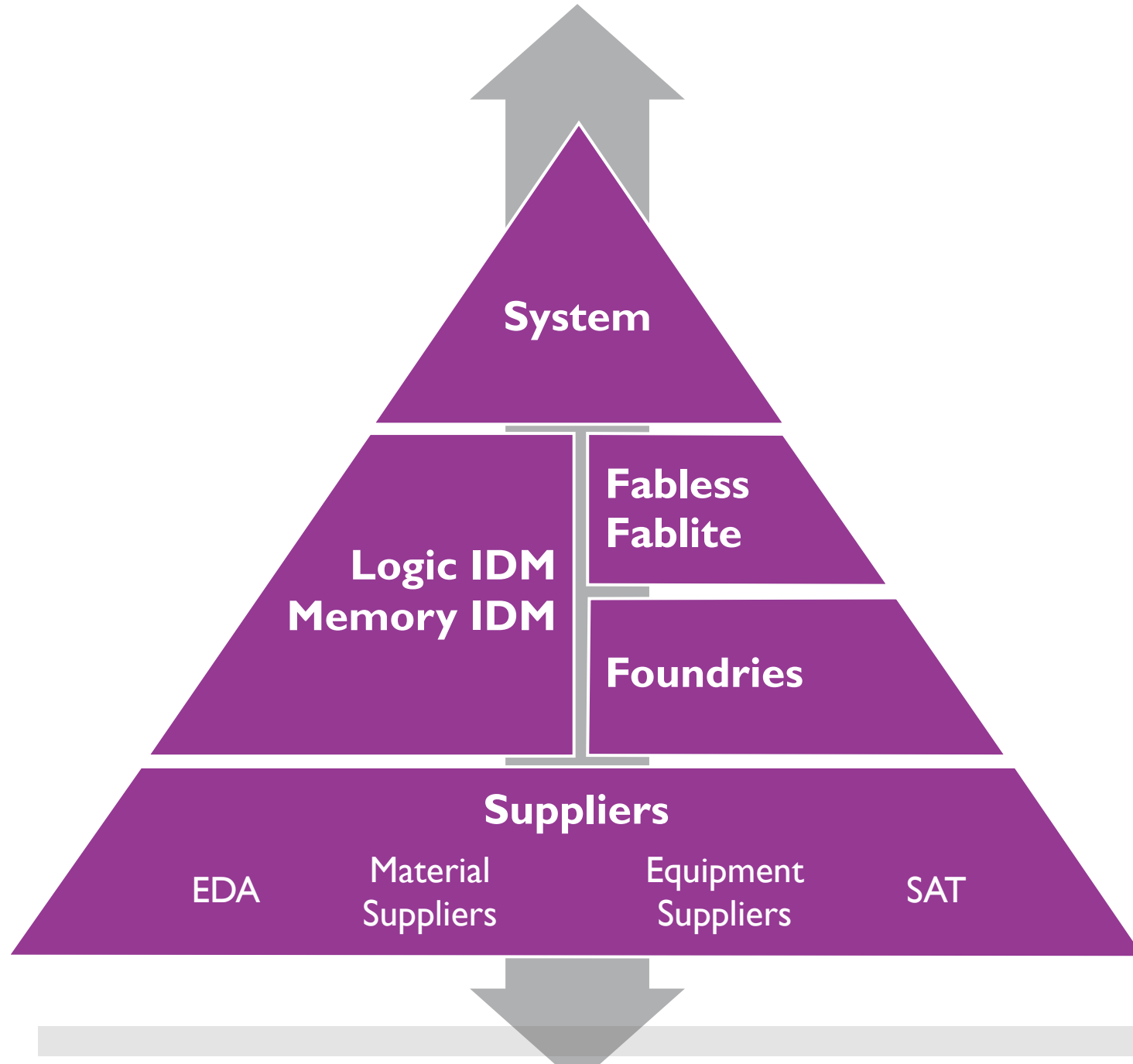
Focusing on mask writing as intermediate milestone

- ▶ Reduces the risk: any throughput improvement is welcome
Both 193nm and EUVL can use this

OUTLINE

- ▶ Industry drivers
- ▶ Roadmap extension
- ▶ Lithography options
- ▶ Innovation through global collaboration

BRINGING TOGETHER FULL ECO SYSTEM



BRINGING TOGETHER FULL ECO SYSTEM



CONCLUSIONS

- ▶ Nano-electronics will continue to bring innovation into many converging application fields
- ▶ Concurrent scaling enabled by
 - lithography
 - materials innovations
 - 3D
- ▶ Momentum on EUV has increased tremendously during last year
- ▶ Global collaboration (including entire value chain) is required to address the huge R&D challenges

A vibrant purple ink splash or smoke effect, starting from the top left and trailing downwards towards the center of the page. The ink is thick and billowing, creating a sense of movement and energy.

**ASPIRE
INVENT
ACHIEVE**

