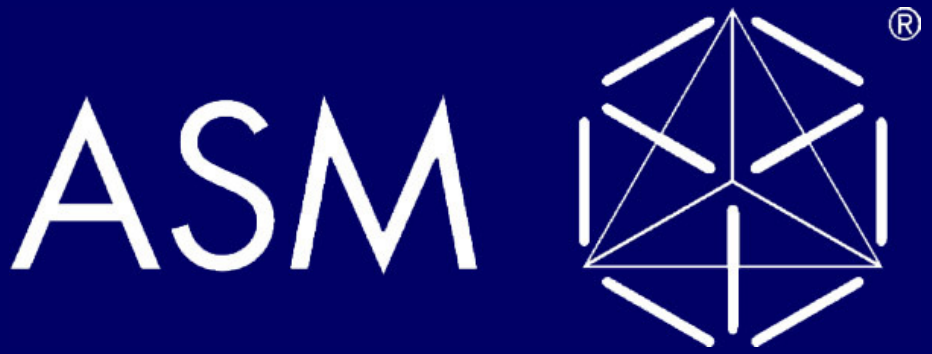


Products and Technologies for Advanced Wafer Processing

Drive Innovation, Deliver Excellence

ASM International
Analyst and Investor Technology Seminar
Semicon West July 11 2012

Outline

- **ASM Front-end Products and selected applications**
  - ALD High-k gate/metal gate
  - PEALD for Spacer Defined Double Patterning
  - Epitaxy
  - Low-k
  - Vertical Furnace
- **Platform roadmap**
- **Summary**

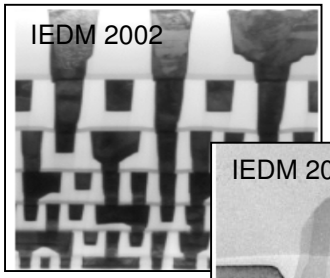
Scaling will increasingly be enabled by New Materials and 3D Technologies

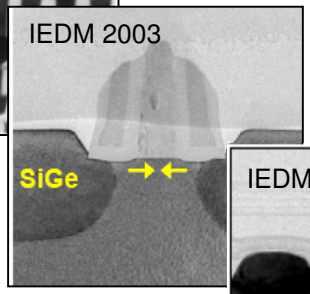
1990 1995 2000 2005 2010 2015 2020 2025

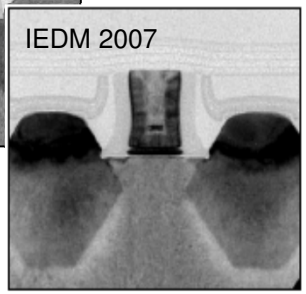
Scaling enabled by Litho

Scaling enabled by Materials

Scaling enabled by 3D







Low-k

Strained Si

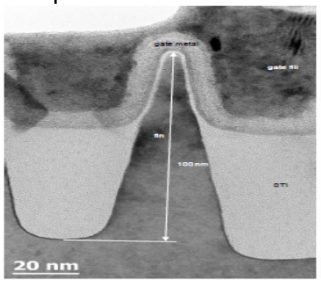
High-k

FinFET

3D SIC

3D Memory

Chipworks 2012



ASM Products – Front-end

Market Requirements: 32nm→22nm →14nm and beyond

Process	Application	ASM Relative Positioning
ALD and PEALD • **ALD solution (Hafnium oxide)** • **PEALD Low temp dielectrics**	• ALD key for High-k Metal Gate technology • 3D FinFET requires more conformal layers, strength of ALD • SDDP-application of PE-ALD	✓ #1 in the served ALD market ✓ Qualified by nearly all Logic manufacturers ✓ Strengthening inroads into Memory with PEALD
Diffusion Furnace • **Advanced batch processing** • **Unique "dual reactor dual boat" design**	• Smallest footprint per reactor • Lowest Cost of Ownership	✓ Leading IC manufacturers are customers
Epitaxy • **Epitaxial films for analog devices** • **Epitaxial films for NMOS/PMOS**	• Affordable method of high quality crystal growth • Thick Epi layers for power devices • Strained Epi films for CMOS	✓ ASM one of only two top vendors
PECVD • **Extreme low-k films**	• Advanced intermetal dielectric film	✓ ASM one of only three top vendors in PE-CVD

Strong IP protected portfolio

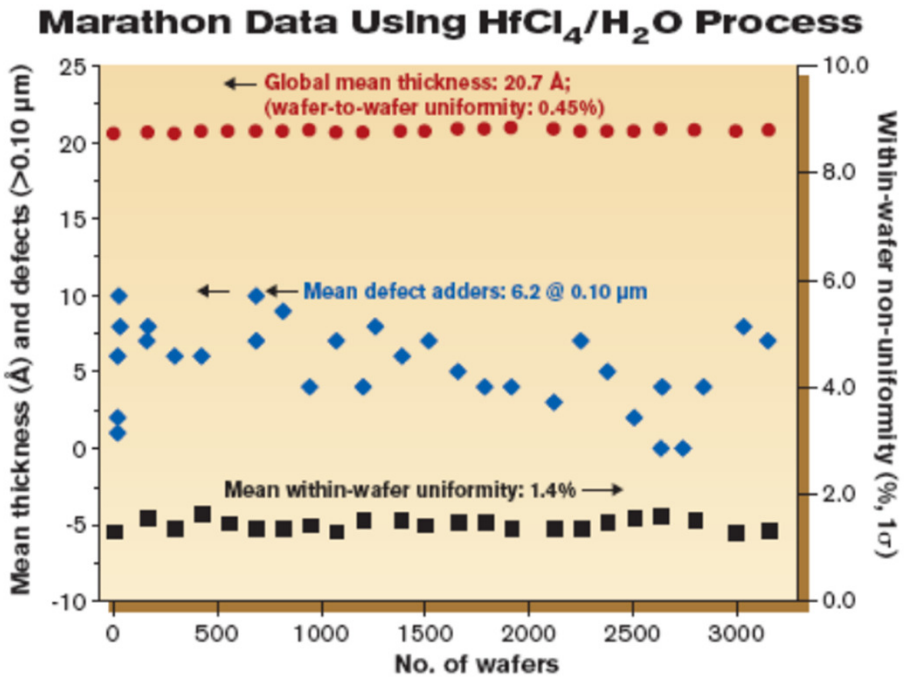
ASM Products – Front-end

Market Requirements: 32nm→22nm →14nm and beyond

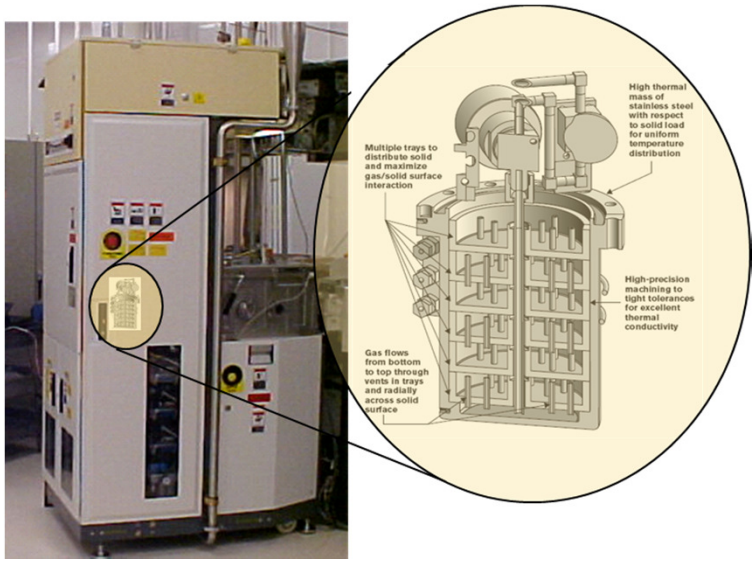
Process	Application	ASM Relative Positioning
ALD and PEALD		
• **ALD solution (Hafnium oxide)**	• ALD key for High-k Metal Gate technology • 3D FinFET requires more conformal layers, strength of ALD	✓ #1 in the served ALD market ✓ Qualified by nearly all Logic manufacturers
• **PEALD Low temp dielectrics**	• SDDP-application of PE-ALD	✓ Strengthening inroads into Memory with PEALD
Diffusion Furnace		
• **Advanced batch processing** • **Unique "dual reactor dual boat" design**	• Smallest footprint per reactor • Lowest Cost of Ownership	✓ Leading IC manufacturers are customers
Epitaxy		
• **Epitaxial films for analog devices**	• Affordable method of high quality crystal growth • Thick Epi layers for power devices	✓ ASM one of only two top vendors
• **Epitaxial films for NMOS/PMOS**	• Strained Epi films for CMOS	
PECVD		
• **Extreme low-k films**	• Advanced intermetal dielectric film	✓ ASM one of only three top vendors in PE-CVD

Strong IP protected portfolio

High-k Metal Gate: Gate Dielectric

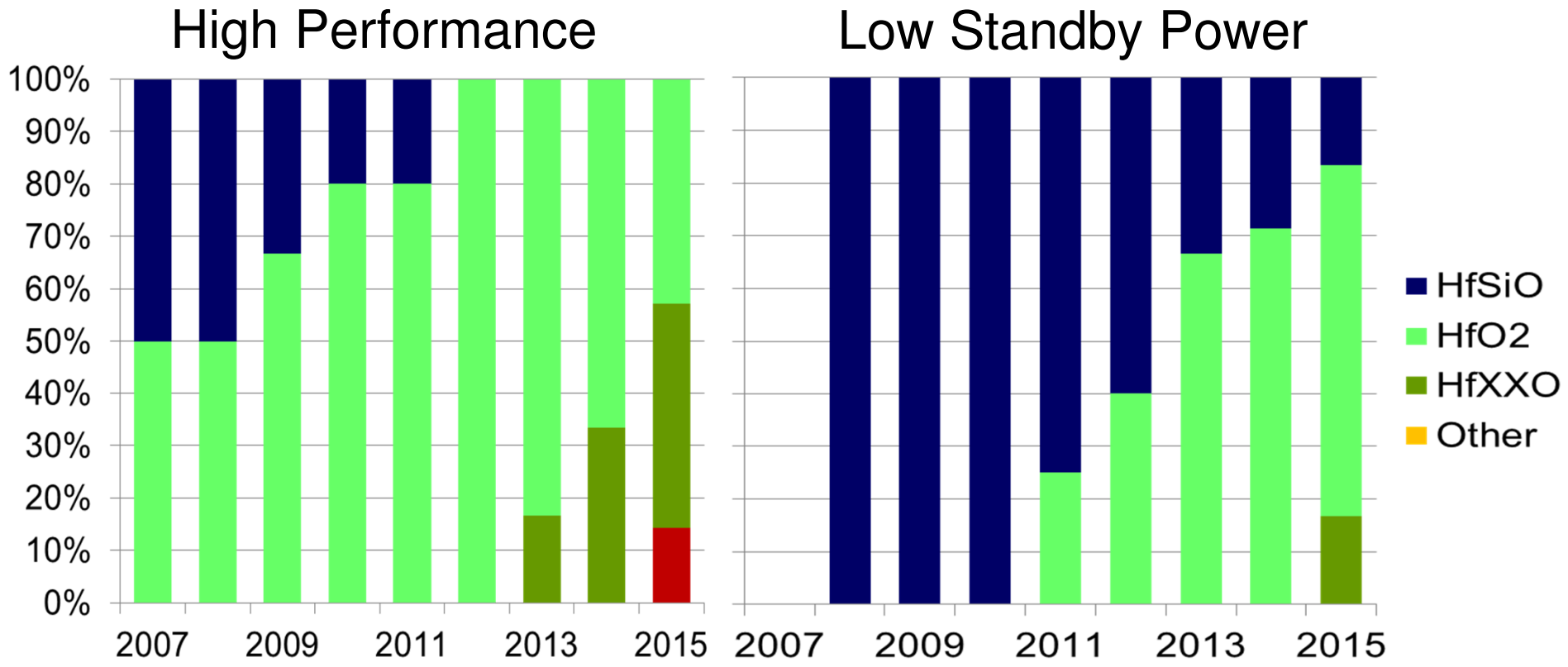


Pulsar 3000 with solid source



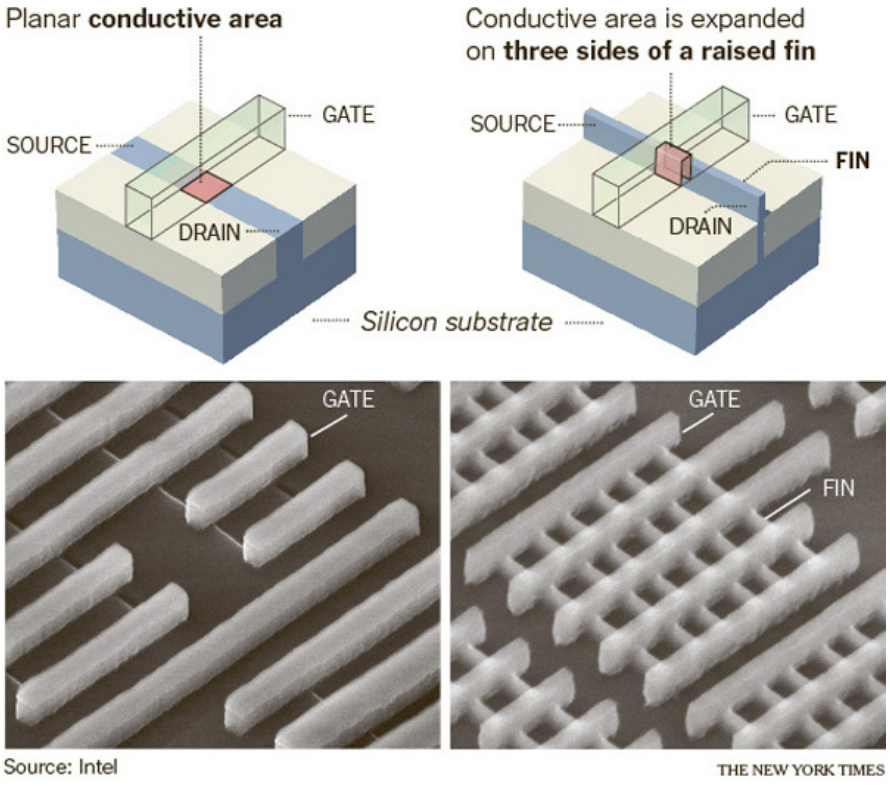
- **Current practice: Hf based (HfO_2 or $HfSiO_4$) from $HfCl_4/SiCl_4/H_2O$**
  - So far, MO chemistries have proven to be inferior (roughness, leakage, reliability)
- **Migration towards HfO_2 as the standard because lower Equivalent Oxide Thicknesses (EOT) can be reached**
  - EOT's in the range of 0.7-1.2nm demonstrated with HfO2

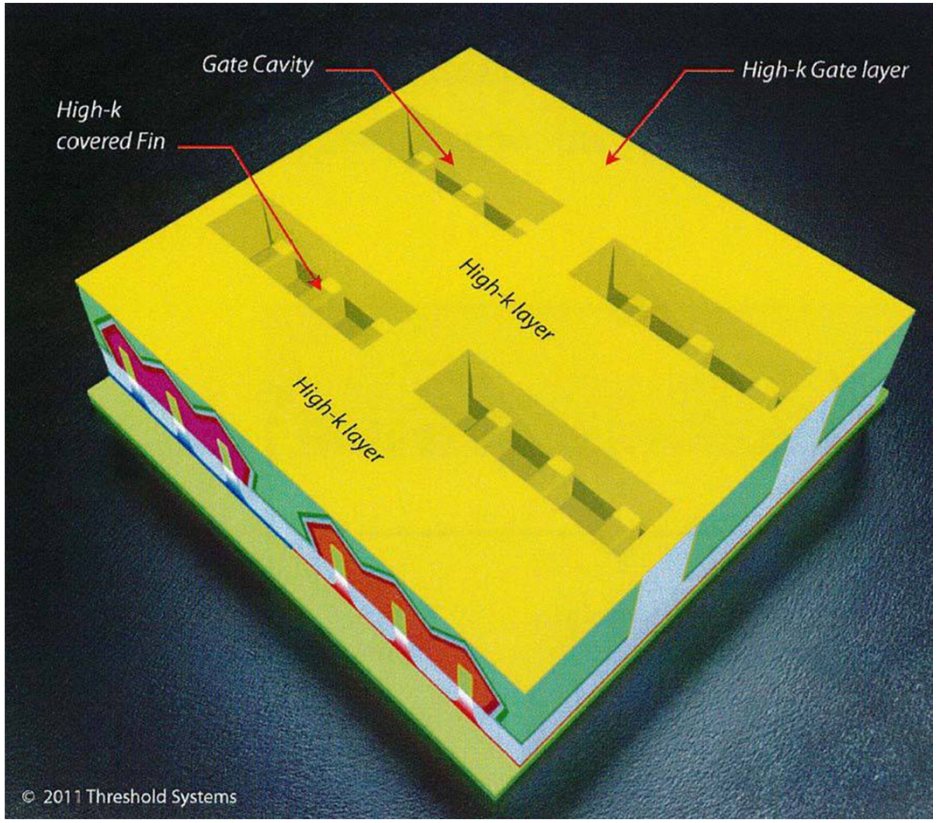
High-k Material Adoption Trend
High Performance and Low Standby Power



- **ALD HfO_2 is the only material for HP devices**
- **High-k for LSTP devices will transition to ALD HfO_2**
- **Convergence to gate last process for all logic to enable optimization of work function**

Transition to 3D Fully Depleted Devices and the Importance of Conformality

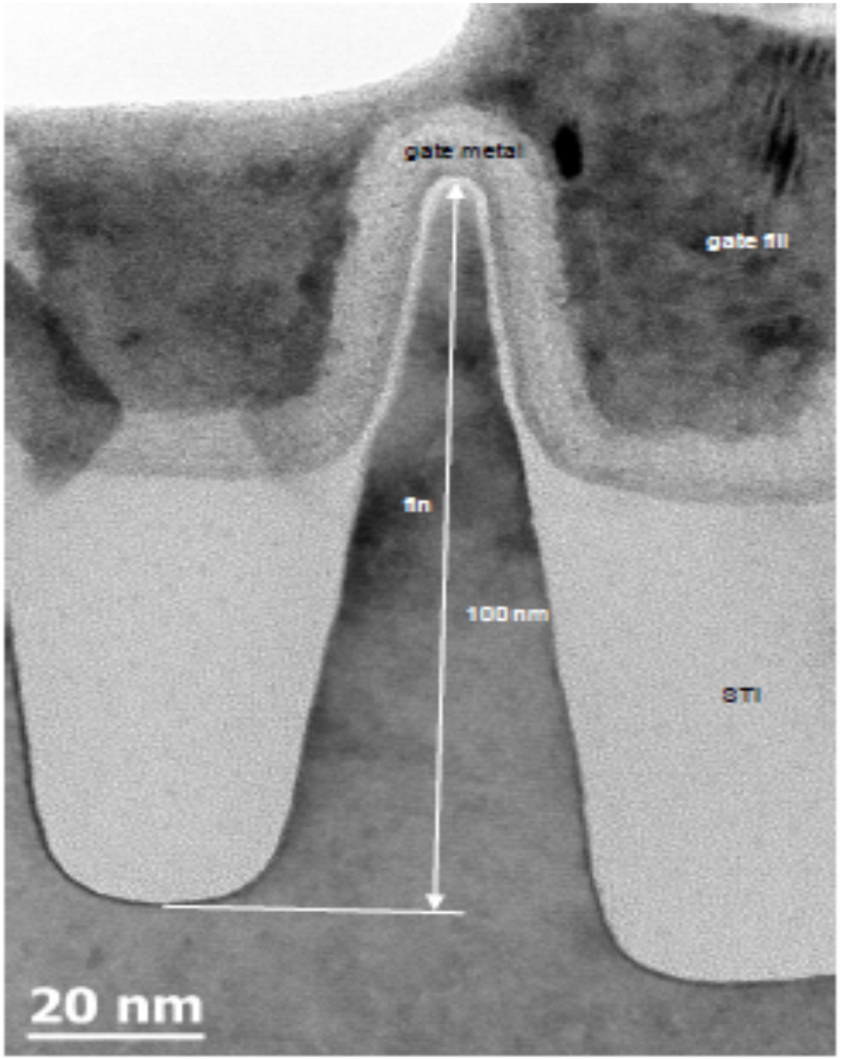




- **Metal and high-k over very challenging topography**
- **EOT and work function have to be uniform over fin height**
- **FinFET's drive need for conformal films with uniform thickness, composition and micro-structure**

Intel FinFET (Chipworks, May 2012)

Perpendicular to Fin



- **Metal and high-k over very challenging topography**
- **EOT and work function have to be uniform over fin height**
- **Success of FinFETs is enabled with ALD metal gates**
- **Entire spectrum of work functions researched and available from ASM**

High-k/metal gate

- ALD HfO_2 has become the de-facto high-k standard
- Gate last process will be used for logic to enable work function optimization of the metal gate electrodes
- 3D FinFET's drive adoption of ALD, not only for the dielectric, but now also for metals
- Metals and damascene like process flows have penetrated the Front-end of the Line

ASM Front-end Products
ALD

- **Pulsar® XP**
  - ALD for high-k
  - Cross-flow reactor
  - Solid source delivery system

- **EmerALD® XP**
  - ALD for metal gates
  - Showerhead reactor

Pulsar® XP

EmerALD® XP

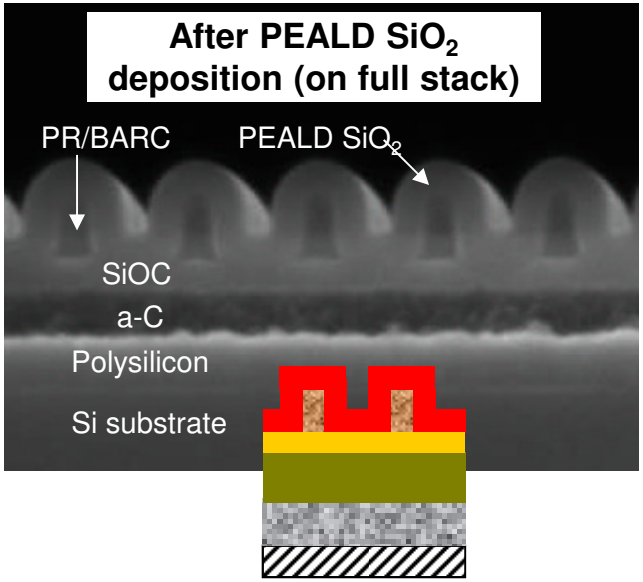
ASM Products – Front-end

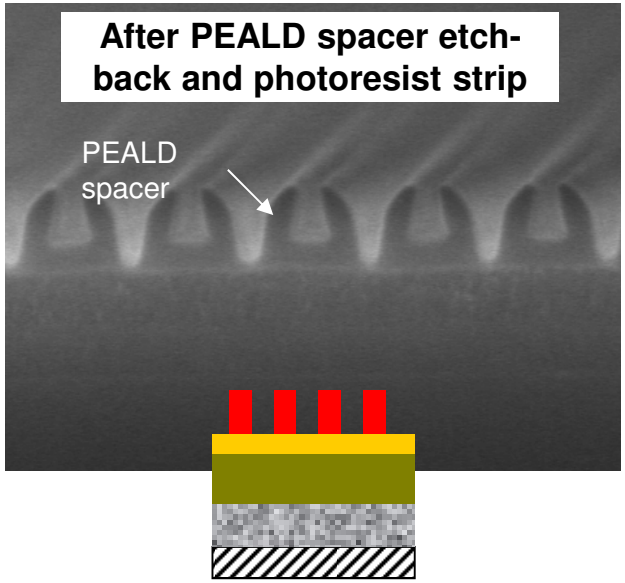
Market Requirements: 32nm→22nm →14nm and beyond

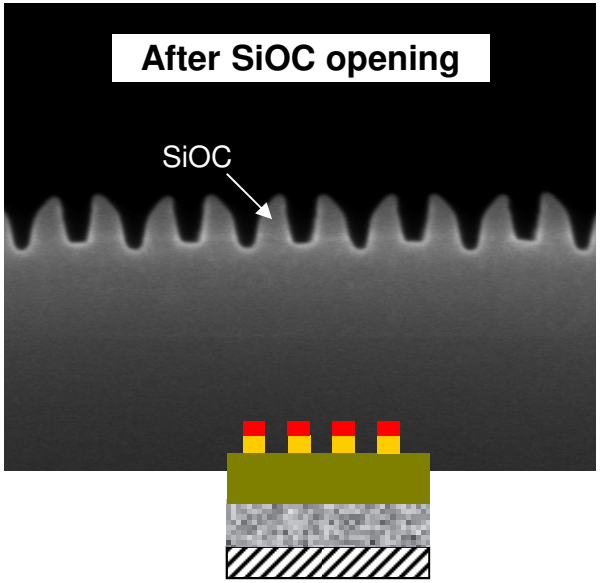
Process	Application	ASM Relative Positioning
ALD and PEALD • **ALD solution (Hafnium oxide)** • **PEALD Low temp dielectrics**	• ALD key for High-k Metal Gate technology • 3D FinFET requires more conformal layers, strength of ALD • SDDP-application of PE-ALD	✓ #1 in the served ALD market ✓ Qualified by nearly all Logic manufacturers ✓ Strengthening inroads into Memory with PEALD
Diffusion Furnace • **Advanced batch processing** • **Unique "dual reactor dual boat" design**	• Smallest footprint per reactor • Lowest Cost of Ownership	✓ Leading IC manufacturers are customers
Epitaxy • **Epitaxial films for analog devices** • **Epitaxial films for NMOS/PMOS**	• Affordable method of high quality crystal growth • Thick Epi layers for power devices • Strained Epi films for CMOS	✓ ASM one of only two top vendors
PECVD • **Extreme low-k films**	• Advanced intermetal dielectric film	✓ ASM one of only three top vendors in PE-CVD

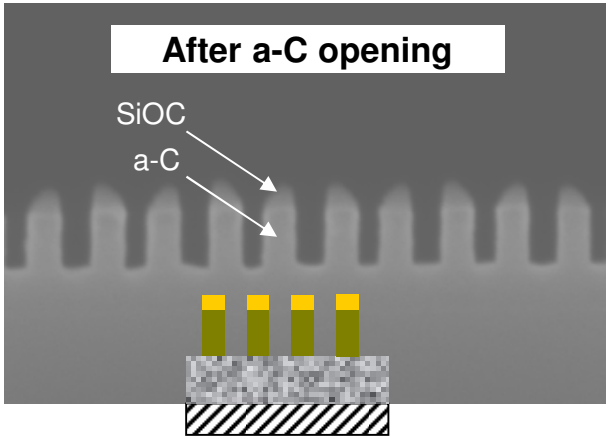
Strong IP protected portfolio

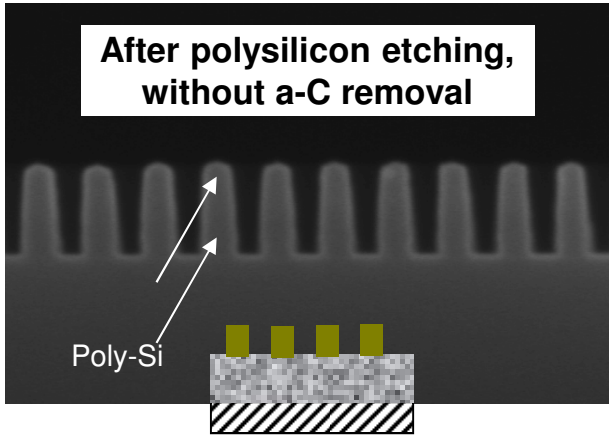
LT PEALD SiO
Spacer Defined Double Patterning

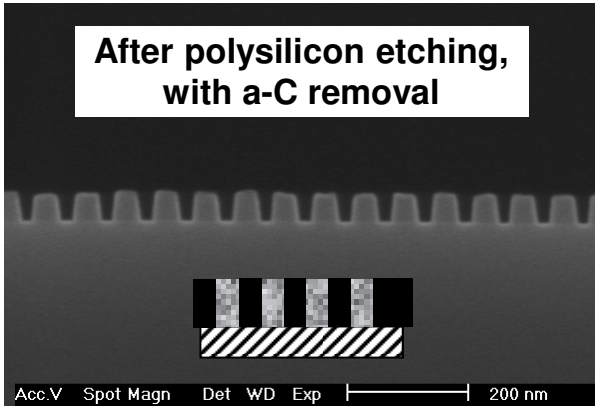




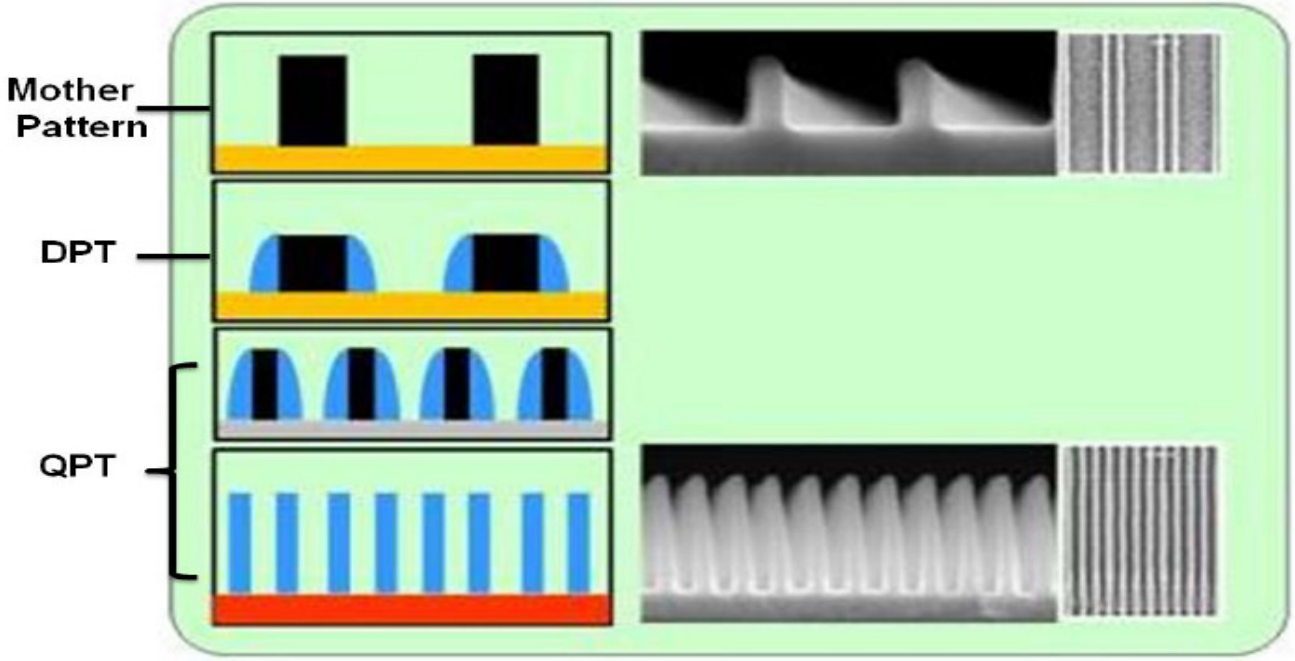








Spacer Defined Multiple Patterning



K. Kim et al, Samsung, SPIE advanced lithography 2012

- **Spacer defined quadruple patterning : two sequences of spacer pattern transfer**

ASM Front-end Products
PEALD

- **MIR 3000**
  - PEALD of SiO_2 for Spacer Defined Double Patterning
  - High productivity XP cluster with 2 PEALD modules, each processing 4 wafers
  - PEALD enables tunable SiO_2 film properties, to optimize for film quality or ease of film removal

MIR 3000

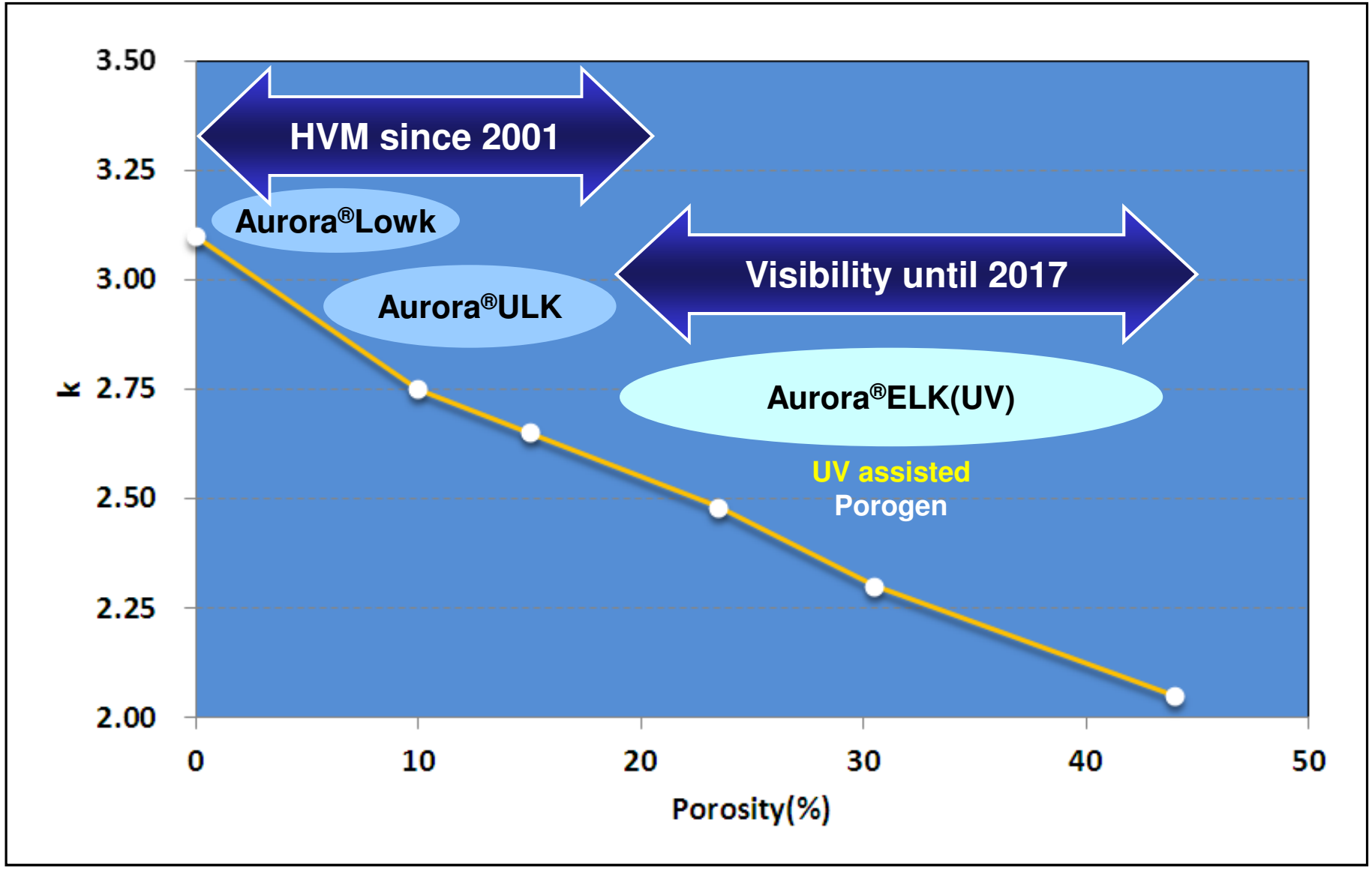
ASM Products – Front-end

Market Requirements: 32nm→22nm →14nm and beyond

Process	Application	ASM Relative Positioning
ALD and PEALD • **ALD solution (Hafnium oxide)** • **PEALD Low temp dielectrics**	• ALD key for High-k Metal Gate technology • 3D FinFET requires more conformal layers, strength of ALD • SDDP-application of PE-ALD	✓ #1 in the served ALD market ✓ Qualified by nearly all Logic manufacturers ✓ Strengthening inroads into Memory with PEALD
Diffusion Furnace • **Advanced batch processing** • **Unique "dual reactor dual boat" design**	• Smallest footprint per reactor • Lowest Cost of Ownership	✓ Leading IC manufacturers are customers
Epitaxy • **Epitaxial films for analog devices** • **Epitaxial films for NMOS/PMOS**	• Affordable method of high quality crystal growth • Thick Epi layers for power devices • Strained Epi films for CMOS	✓ ASM one of only two top vendors
PECVD • **Extreme low-k films**	• Advanced intermetal dielectric film	✓ ASM one of only three top vendors in PE-CVD

Strong IP protected portfolio

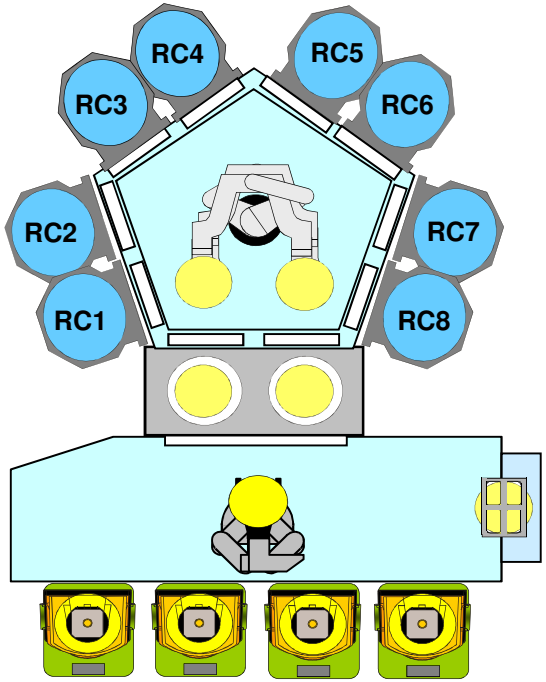
Extendibility of ASM's Low-k Solution



ASM Front-end Products PEALD and PECVD

Introduced during Semicon West 2012

- **XP8**
  - High productivity single wafer tool for both PEALD and PECVD applications
  - Accommodates up to 8 chambers for PEALD or PECVD
  - PEALD and PECVD can be integrated on the same platform



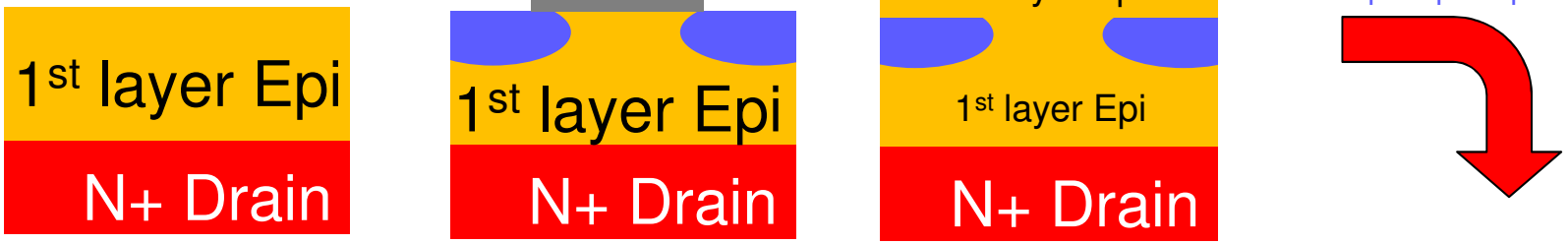
ASM Products – Front-end

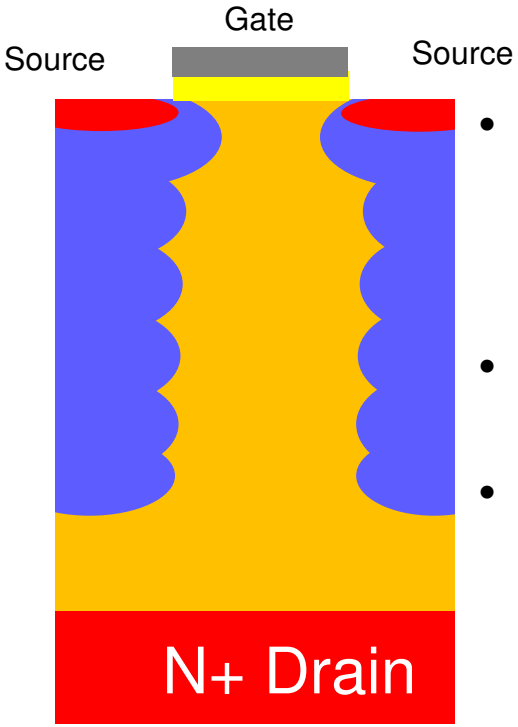
Market Requirements: 32nm→22nm →14nm and beyond

Process	Application	ASM Relative Positioning
ALD and PEALD • **ALD solution (Hafnium oxide)** • **PEALD Low temp dielectrics**	• ALD key for High-k Metal Gate technology • 3D FinFET requires more conformal layers, strength of ALD • SDDP-application of PE-ALD	✓ #1 in the served ALD market ✓ Qualified by nearly all Logic manufacturers ✓ Strengthening inroads into Memory with PEALD
Diffusion Furnace • **Advanced batch processing** • **Unique "dual reactor dual boat" design**	• Smallest footprint per reactor • Lowest Cost of Ownership	✓ Leading IC manufacturers are customers
Epitaxy • **Epitaxial films for analog devices** • **Epitaxial films for NMOS/PMOS**	• Affordable method of high quality crystal growth • Thick Epi layers for power devices • Strained Epi films for CMOS	✓ ASM one of only two top vendors
PECVD • **Extreme low-k films**	• Advanced intermetal dielectric film	✓ ASM one of only three top vendors in PE-CVD

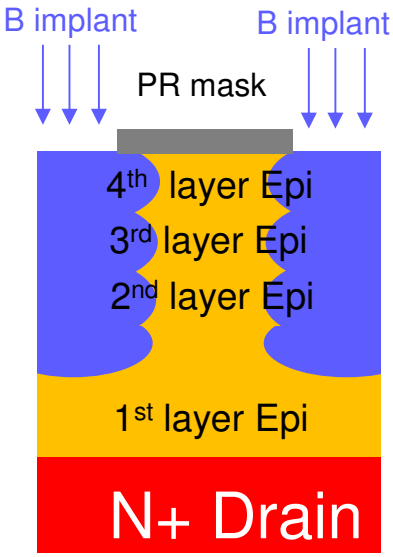
Strong IP protected portfolio

Epi layers for Power Devices
Multi-Layer Epi Technology





- **Number of epi layers dependent upon the breakdown voltage required (i.e. product application specific)**
- **Typical breakdown voltages from 600 – 800V**
- **Implemented in production by various companies**



ASM Product: Epsilon® 3200

Epi for advanced power devices

ASM Front-end Products
Epitaxy

Introduced during Semicon West 2012

- **Intrepid® XP**
  - Epi for advanced CMOS strain
  - High productivity system using ASM's XP cluster with 4 Epi reactors
  - Integrated Pre-Clean for pre-Epi interface control

Intrepid™ XP

ASM Products – Front-end

Market Requirements: 32nm→22nm →14nm and beyond

Process	Application	ASM Relative Positioning
ALD and PEALD • **ALD solution (Hafnium oxide)** • **PEALD Low temp dielectrics**	• ALD key for High-k Metal Gate technology • 3D FinFET requires more conformal layers, strength of ALD • SDDP-application of PE-ALD	✓ #1 in the served ALD market ✓ Qualified by nearly all Logic manufacturers ✓ Strengthening inroads into Memory with PEALD
Diffusion Furnace • **Advanced batch processing** • **Unique "dual reactor dual boat" design**	• Smallest footprint per reactor • Lowest Cost of Ownership	✓ Leading IC manufacturers are customers
Epitaxy • **Epitaxial films for analog devices** • **Epitaxial films for NMOS/PMOS**	• Affordable method of high quality crystal growth • Thick Epi layers for power devices • Strained Epi films for CMOS	✓ ASM one of only two top vendors
PECVD • **Extreme low-k films**	• Advanced intermetal dielectric film	✓ ASM one of only three top vendors in PE-CVD

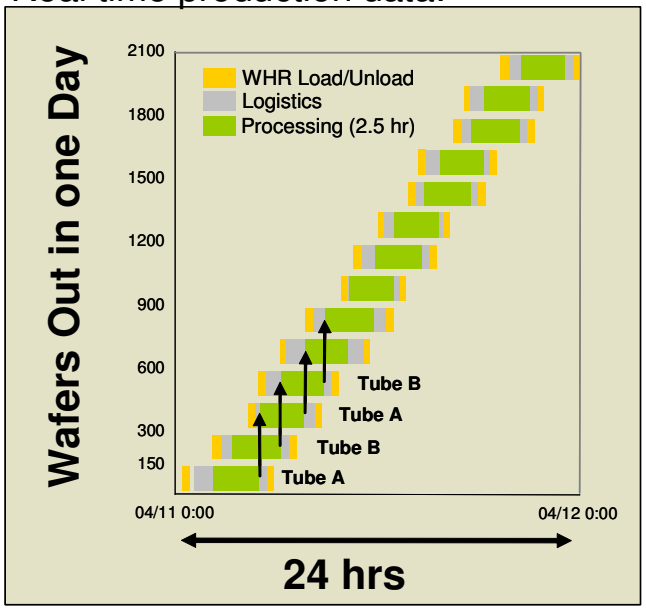
Strong IP protected portfolio

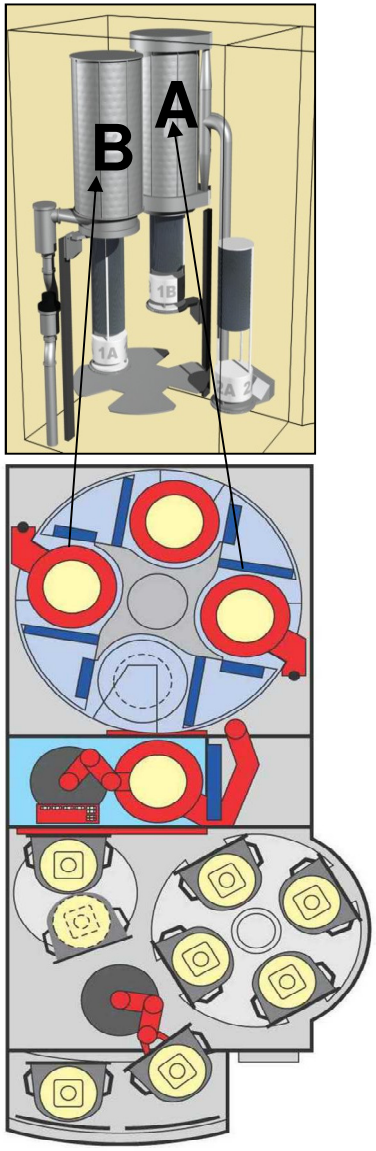
A412 PLUS: Productivity and Innovation

Productivity

- One A412 PLUS = up to 80 kwpm (2.5 hr process, 95% available, 150 wafer boat)
- About 40% lower capex per m^2 as competitors
- Dual boat/dual reactor system

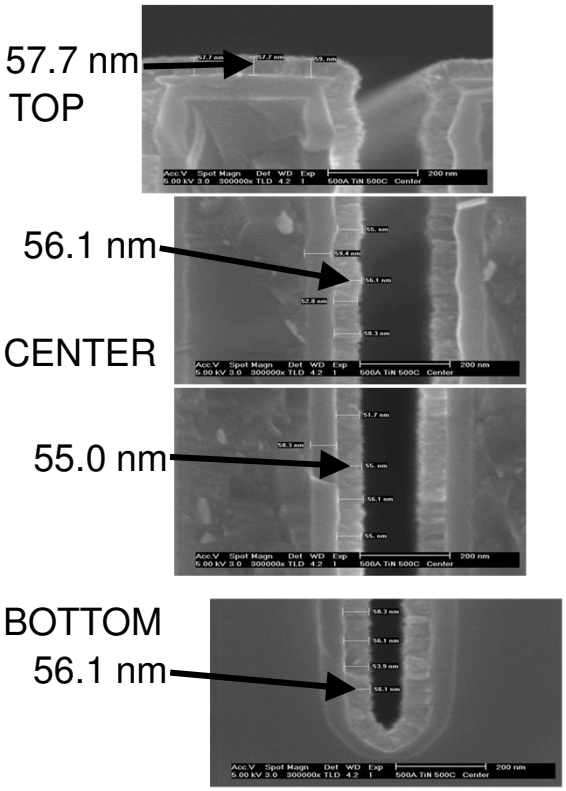
Real time production data:



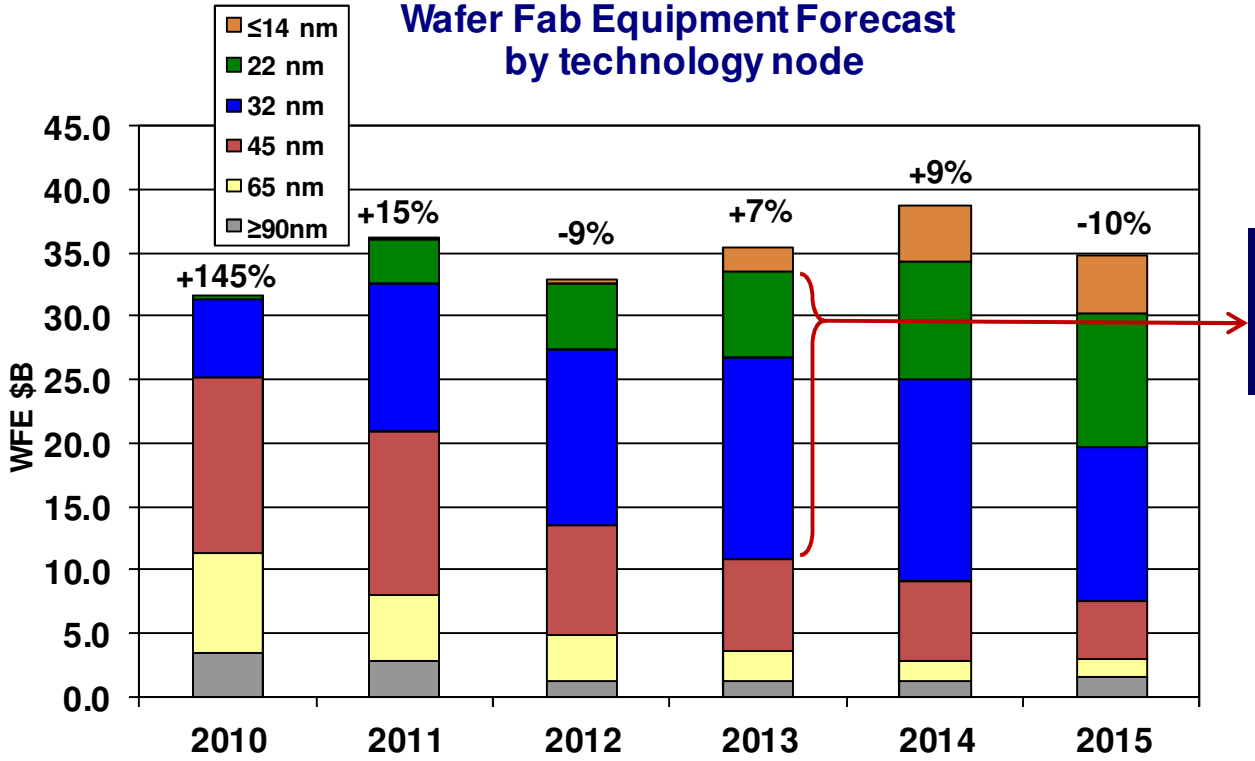


Innovation

- Addition of ALD processes
- Example: Batch ALD TiN process



Wafer Fab Equipment Forecast



Share of 28nm, 22nm and 14nm of total Equipment spending increasing in 2012-2013

Key customer ALD penetrations in 28 and 22nm: market segments with high expected growth

Gartner June, 2012

Summary

- **Adoption of more ALD and PEALD applications in HVM continues**
  - #1 position in ALD for High-k gate
  - 3D FinFET's drive adoption of ALD, not only for the dielectric, but also for metals
  - strong inroads into patterning applications with PEALD
- **Introduced Intrepid® XP, system with 4 Epi reactors, for CMOS strain Epi**
- **Introduced XP8, high productivity system for PEALD and PECVD applications**
- **ASM's Vertical Furnace is providing the lowest CoO and footprint per reactor**
- **450mm development started and first tools have been shipped**

Drive Innovation, Deliver Excellence