



HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Industrial Collaboration in Thin Film Research at University of Helsinki

Laboratory of Inorganic Chemistry



Personal background

- PhD student at TKK 1974-1979
- Associate professor at University of Oulu 1979-1986
- Professor at University of Turku 1986-1990
- Professor at University of Helsinki 1990-
- Academy professor 2004-2009



Laboratory of Inorganic Chemistry

- 3 professors
- 4 senior lecturers
- 9 teaching assistants
- 4 supporting staff
- 32 people (3 post docs) by external funding

Total 52

- Two larger research groups:
 - Thin film group, 20 people
 - Catalyst group, 16 people (part of center of excellence funded by Academy of Finland)



Long-term Industrial Collaboration

- Kemira Oy, Oulu 1974-1987
 - Luminescent materials for CRTs and lighting
- Lohja Electronics/Planar Systems Oy 1983-2002
 - ALD materials for EL displays
- Mikrokemia Oy/ASM Microchemistry Oy 1994-
 - ALD technology, ALD for IC industry
- Neste Oy/Borealis Polymers Oy (1988) 1992-2004
 - New catalysts for polyolefins



Long-term Industrial Collaboration

- Before the time of Tekes (since 1985) the collaboration was only in small scale (MSc theses)
- Tekes and the increasing funds of Academy of Finland made the creation of research groups possible
- Industrial collaboration is the prerequisite for Tekes funding
- Positive flow (funding, academic degrees, scientific papers, patents) increases also the university funding → infrastructure can be built and strengthened



Long-term Industrial Collaboration

- Common in the industrial collaboration has been:
 - Initiations also from industry
 - The problems were challenging and important for the company
 - Long-term commitment by both partners to the collaboration
 - Basic science and applications very close to each other (high-tech)
 - Making of PhD theses possible
 - International collaboration involved



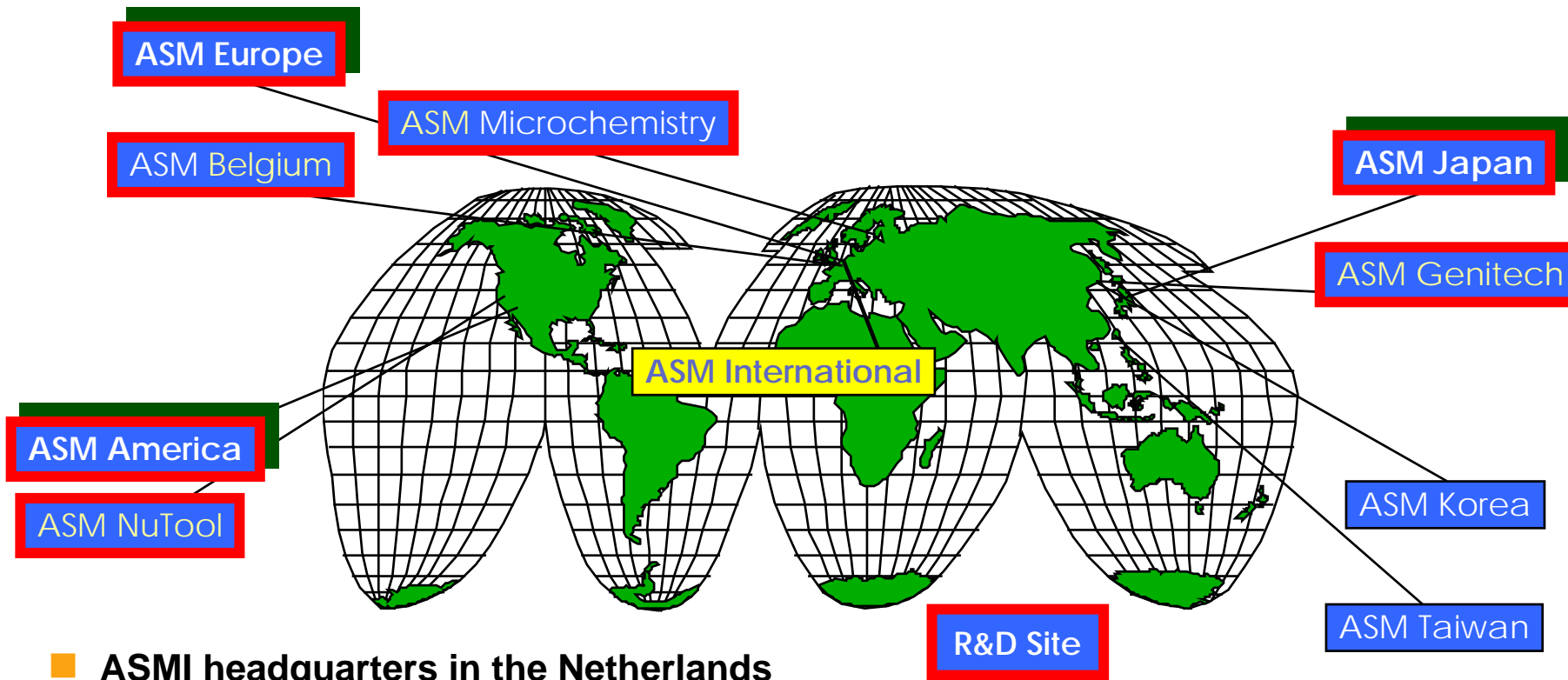
University of Helsinki – ASM Microchemistry (ASMM) Collaboration

- Started in 1994 and focus was in ALD technology
- Several TEKES projects were carried out
- ASM International (ASMI) acquired Mikrokemia in 1999 and ASMM was formed
- ASMI is a well-known company which produces equipment for microelectronic industry
- ALD is needed in future generation integrated circuits



ASM International N.V.

Front-End Operations



- ASMI headquarters in the Netherlands
- Front-End personnel 1400 of which 220 in R&D
- ASMM a Center of Excellence in ALCVD™
 - Organisationally part of ASME
 - R&D assignments from all Front-End product lines



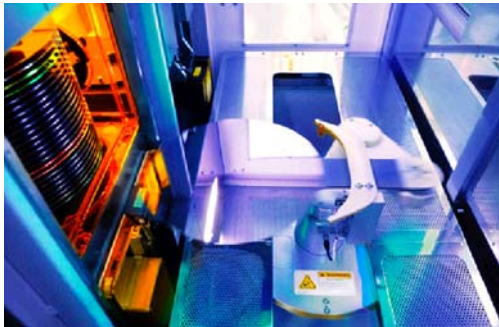
“Wafer Processing” Markets 2003

(Total \$27.8 Billion)

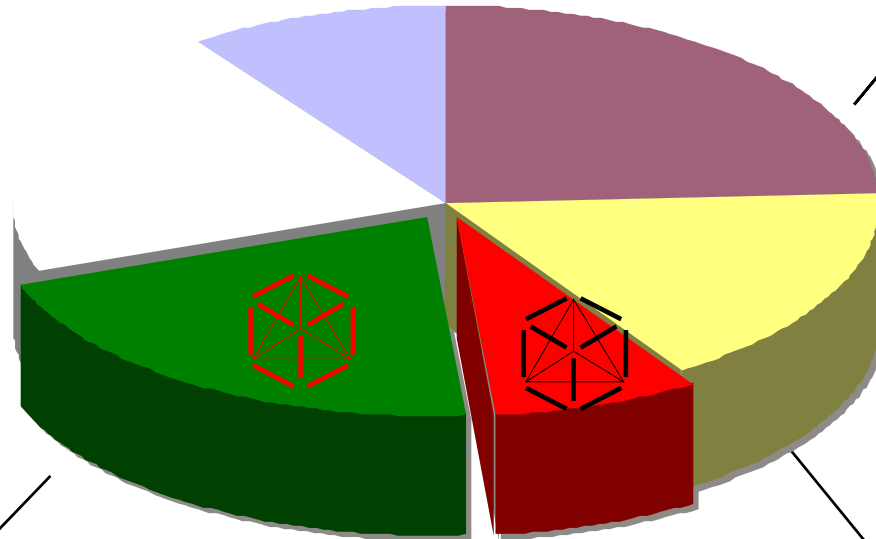
Lithography
\$5.7 B

Other wafer process
\$2.4 B

Test
\$7.7 B



Deposition
\$5.7 B



Etch & Clean
\$4.0 B

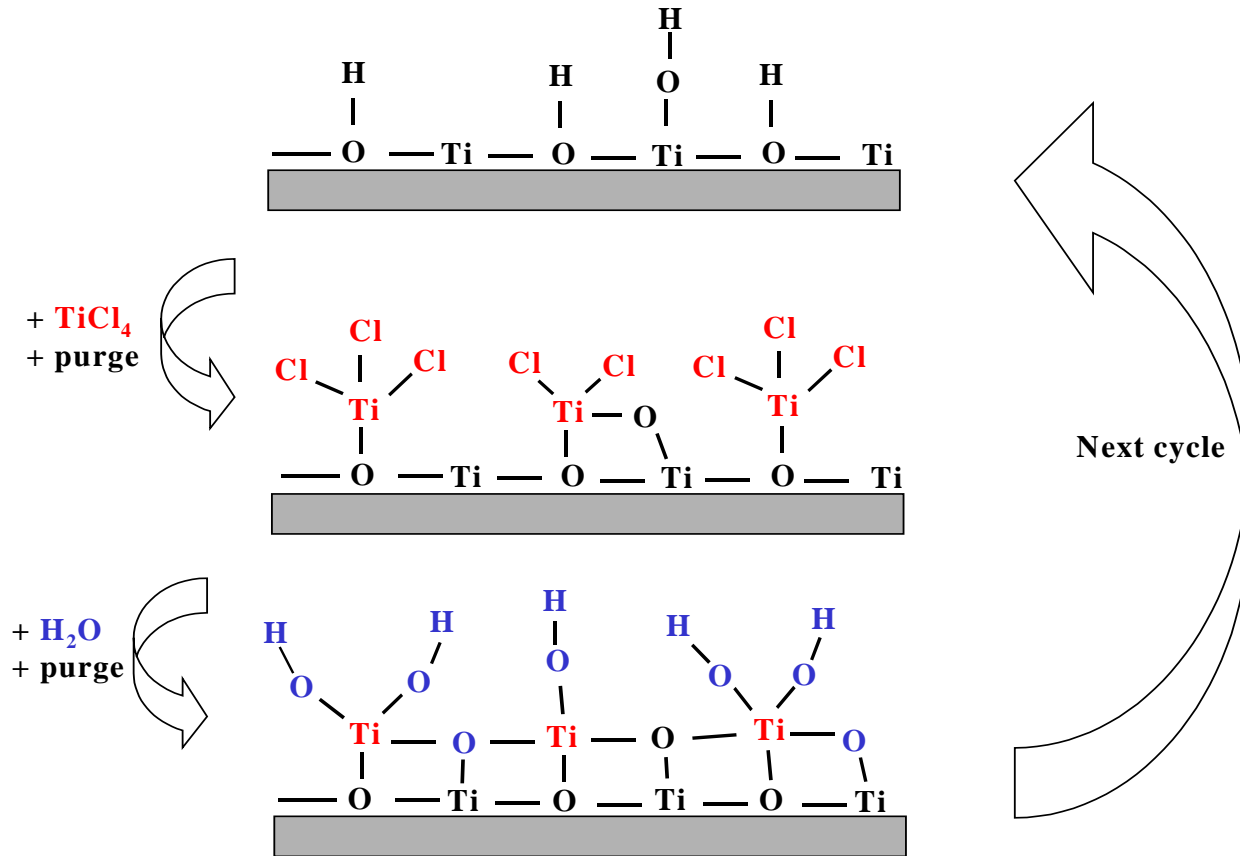
Assembly
\$2.3 B

Source: VLSI Research, July 2004

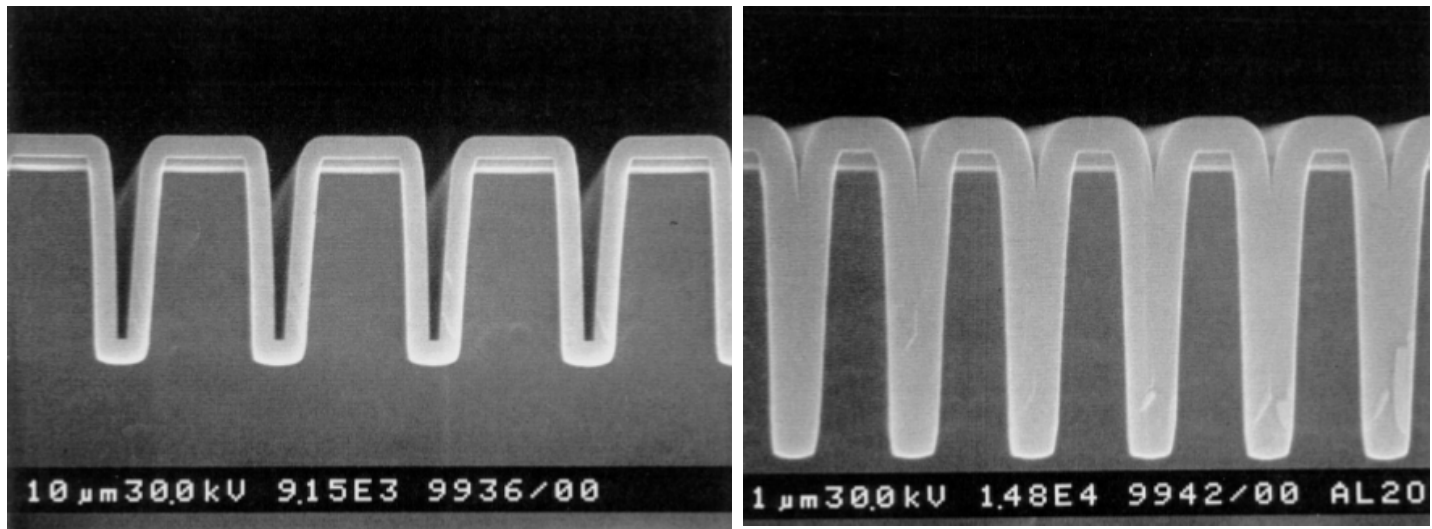


ATOMIC LAYER DEPOSITION:

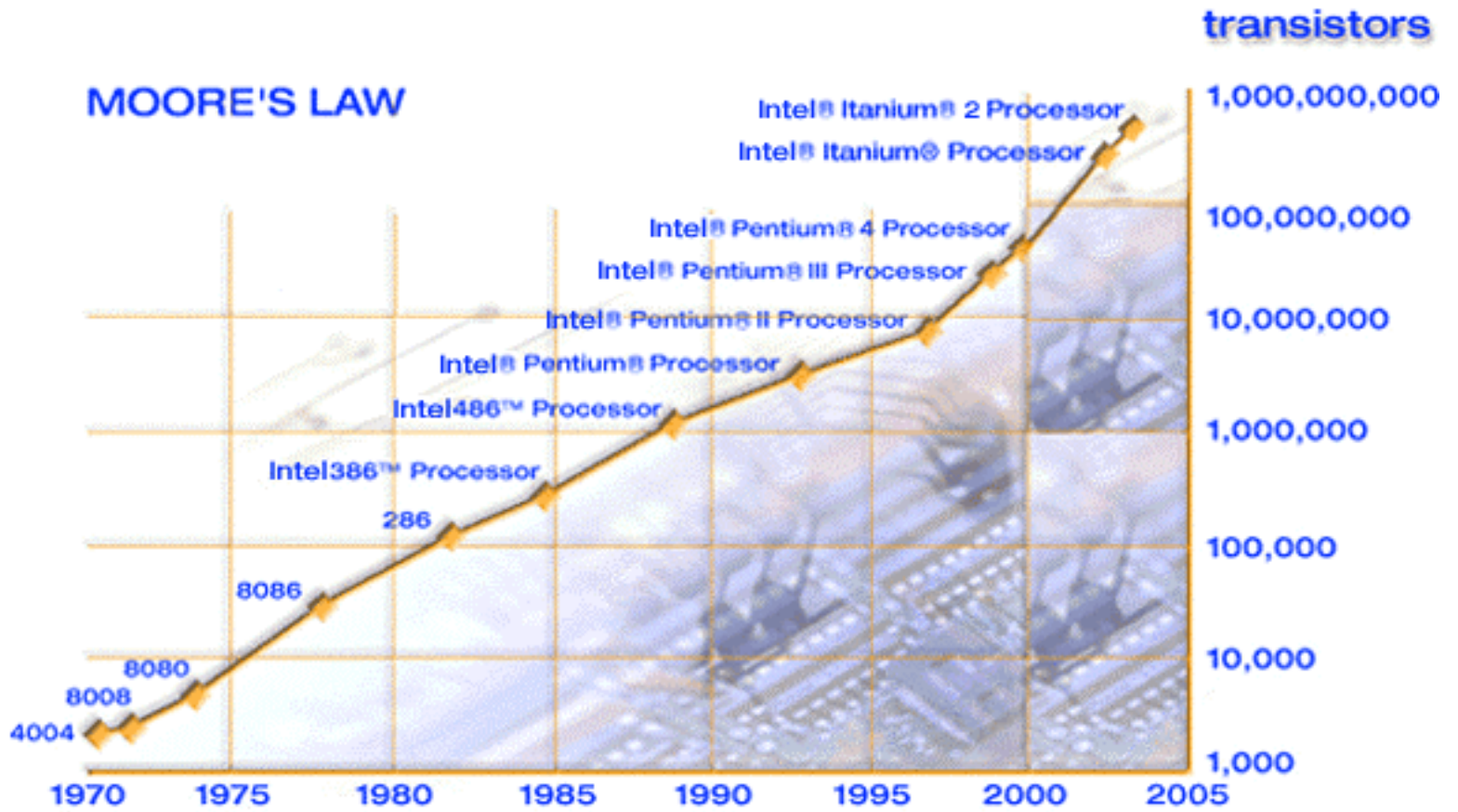
Self-limiting film growth via alternate saturative surface reactions.



- Advantageous characteristics of the self-limiting film growth
 - excellent conformality
 - large area uniformity
 - accurate and easy film thickness control down to atomic level
 - atomic level control of film composition
 - reproducibility



300 nm Al₂O₃ film deposited from Al(CH₃)₃ and H₂O.
(Ritala et al. Chem. Vap. Deposition 5 (1999) 7.)



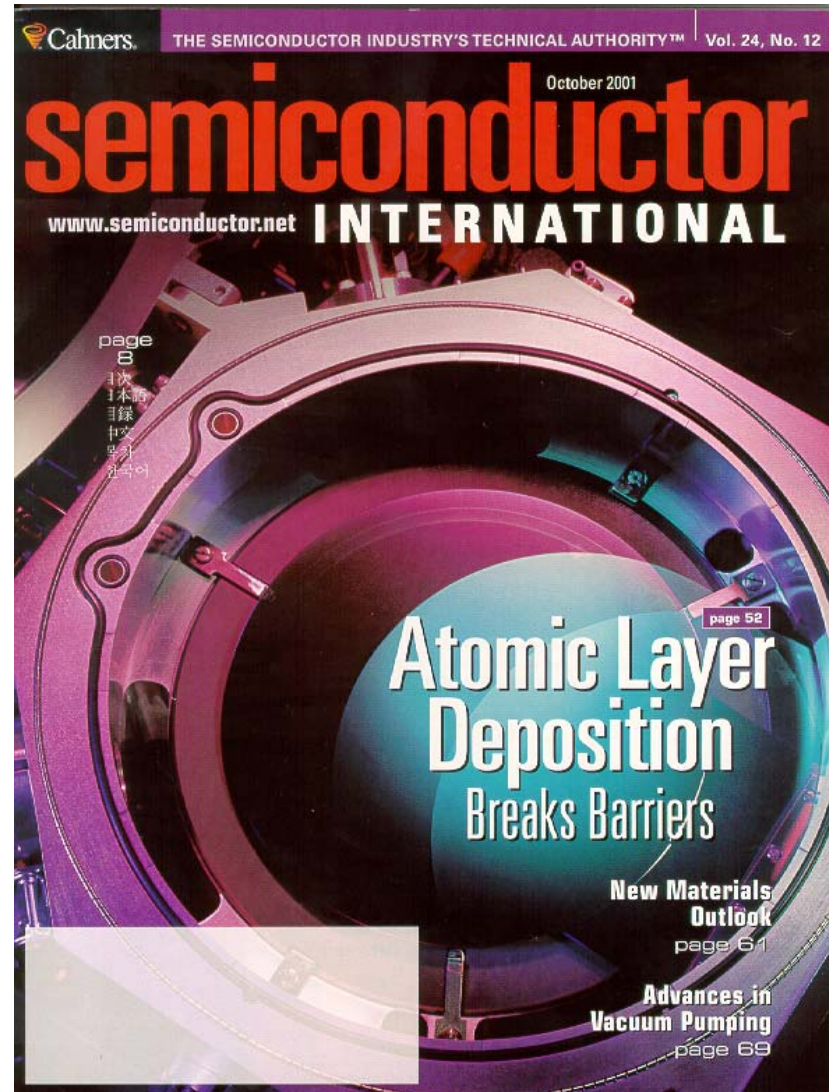


ALD has become a cover page method with lots of expectations and promises.

Full utilization of ALD still requires

- reactor improvements
- development of new processes for new materials

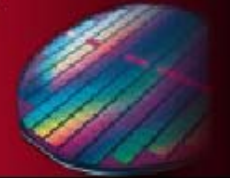
outperforming existing processes





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ASM International N.V. teams up with University of Helsinki for Atomic Layer Deposition Research; Restructures its ASM Microchemistry Operations

BILTHOVEN, the Netherlands, August 25, 2003 --- ASM International N.V. (Nasdaq: ASMI and Euronext Stock Exchange in Amsterdam: ASM) announced today that it intends to enter into a long-term co-operative agreement with the University of Helsinki to jointly pursue further development of Atomic Layer Deposition (ALD) technology. As part of this agreement, ASM intends to relocate its Espoo, Finland, research and development activities to the nearby campus of the University of Helsinki, Finland.

Atomic Layer Deposition is an advanced technology that deposits single atomic layers on semiconductor wafers one at a time at low temperatures. The process is used to create ultra-thin films of exceptional quality and flatness. Through its Microchemistry subsidiary, ASM has pioneered development of ALD applications for the semiconductor industry. The University of Helsinki is one of the world's leading academic research institutes active in the field of ALD.

The co-operation is scheduled to take full effect in November 2003. Pending completion of the necessary procedures with the employees and the co-operation agreement with the University, it will involve the deployment of equipment and about 10 to 15 ASM Microchemistry scientists and engineers at the University campus. The Microchemistry subsidiary will continue to be committed to the development of new ALD applications for the semiconductor industry, and the transfer of these processes to other ASM subsidiaries for commercialization.



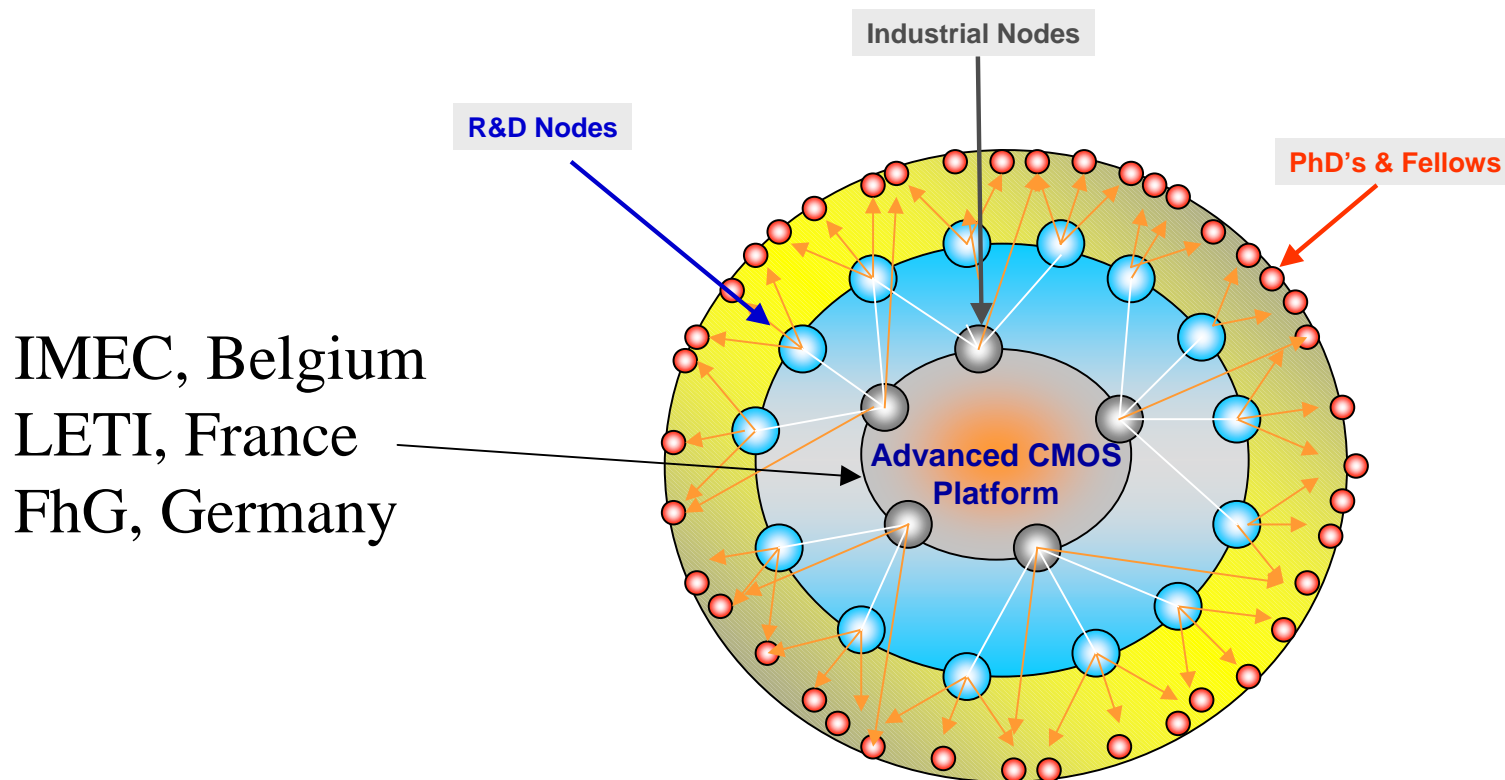
Beyond the brick wall

International Technology Roadmap for Semiconductors

YEAR TECHNOLOGY NODE	1999 180 nm	2002 130 nm	2005 100 nm	2007 90 nm	2011 50 nm	2014 35 nm
DRAM capacity [A]	1G	(3G)	(8G)	(24G)	64G	(192G)
Cell area/chip size	69.6%	70.7%	71.7%	72.4%	72.9%	73.3%
Total cell area (cm ²)	2.8	3.3	3.8	4.5	5.2	6.3
DRAM chip size at introduction (cm ²)	4.0	4.6	5.3	6.3	7.1	8.6
Cell size factor "a" [B]	8.0	6.0	4.4	3.6	3.0	2.5
Cell size [μm ²] [C]	0.26	0.10	0.044	0.01	0.0075	0.0031
	=0.36×0.72	=0.26×0.39	=0.2×0.22	=0.14×0.14	=0.1×0.08	=0.07×0.04
Storage node size [μm ²] [D]	0.097	0.034	0.012	0.003	0.0013	0.0003
	=0.18×0.54	=0.13×0.26	=0.1×0.12	=0.07×0.07	=0.05×0.03	=0.035×0.01
Capacitor - Structure - Dielectric material	Cylinder MIS Ta ₂ O ₅	Pedestal MIM Ta ₂ O ₅ [Note U]	Pedestal MIM BST	Pedestal MIM epi-B	Pedestal MIM ???	Pedestal MIM ???
Dielectric constant	22	50 [Note U]	250	700	1500	1500
SN height H [μm]	0.95	0.84	0.71	0.42	0.28	0.35
Cylinder factor [E]	1.5	1.0	1.0	1.0	1.0	1.0
Roughness factor	1.0	1.0	1.0	1.0	1.0	1.0
Total capacitor area [μm ²]	2.20	0.69	0.32	0.11	0.04	0.031
Structural coefficient [F]	8.5	6.8	7.4	6.2	5.8	10.1
t _{eq} at 25fF [nm] [G]	3.0	0.95	0.45	0.15	0.060	0.043
t _{phy} at 25fF [nm] [H]	11.5	12.2	28.7	27.2	23.0	16.4
A/R of SN (OUT) for cell plate deposition [I]	6.0	8.0	16.7	26.5	68.8	162.7



EUROPEAN RESEARCH PLATFORM FOR SUB-32nm SILICON R&D



ALD RESEARCH AT UNIVERSITY OF HELSINKI

FUNDING

- Academy of Finland
- Finnish Technology Agency (Tekes)
- companies

Dept. Chem., Inorganic Chemistry Lab.

- precursor synthesis
- process development
- characterization
- application oriented research

Dept. Physics, Accelerator Lab.

- characterization

Chemical manufacturers
- precursor development

ASM Microchemistry
- scale-up
- reactor development

Microelectronics companies
and other end users of ALD

University and research
institute collaborators





Conclusions

- ASMM-UH collaboration fulfils the requirements set for a successful industry-academia collaboration:
 - long-term
 - Challenging

- University and ASM Microchemistry form an ALD center with about dozen ALD reactors from small research scale to 200 mm wafers and 30 x 30 cm² and a broad selection of characterization tools.

- Together or separately, University and ASMM are ready to join collaborative projects both in Europe and globally.