LNQE-Kolloquium

Nanoelektronik: Von der Realität bis zur Utopie

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AMICA - Advanced Microelectronic Center Aachen, AMO GmbH

I. Einleitung
II. Realität
III. Visionen
IV. Utopie

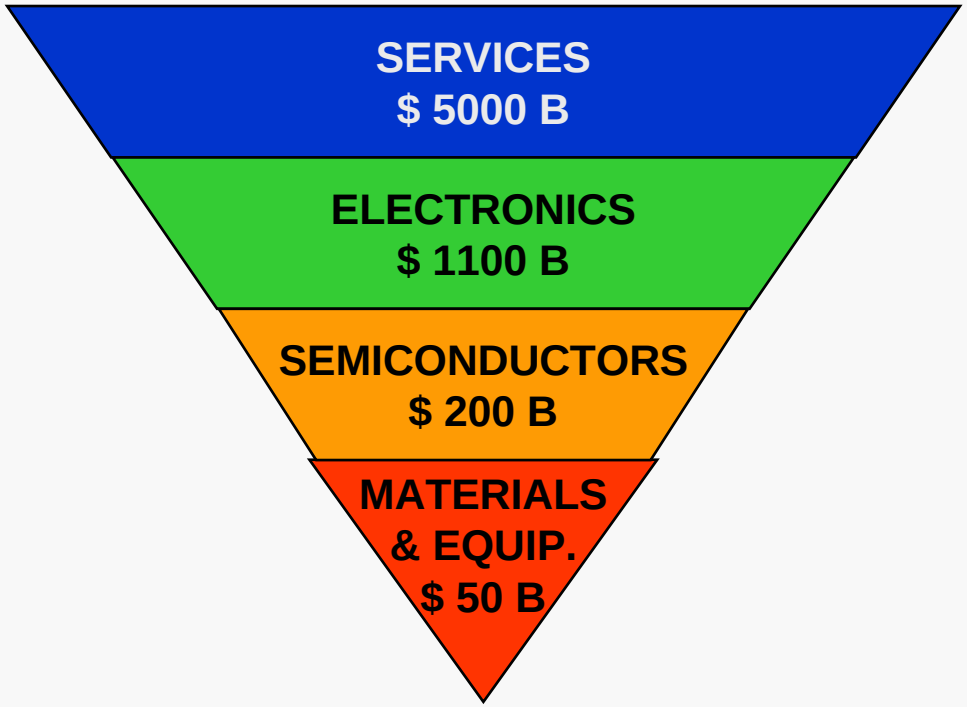
composed by Matthias Baus

AMO GmbH
Gesellschaft für angewandte Mikro- und Optoelektronik mbH

RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN
RWTH

IHT
RWTH Institut für Halbleitertechnik

Economy of Mainstream



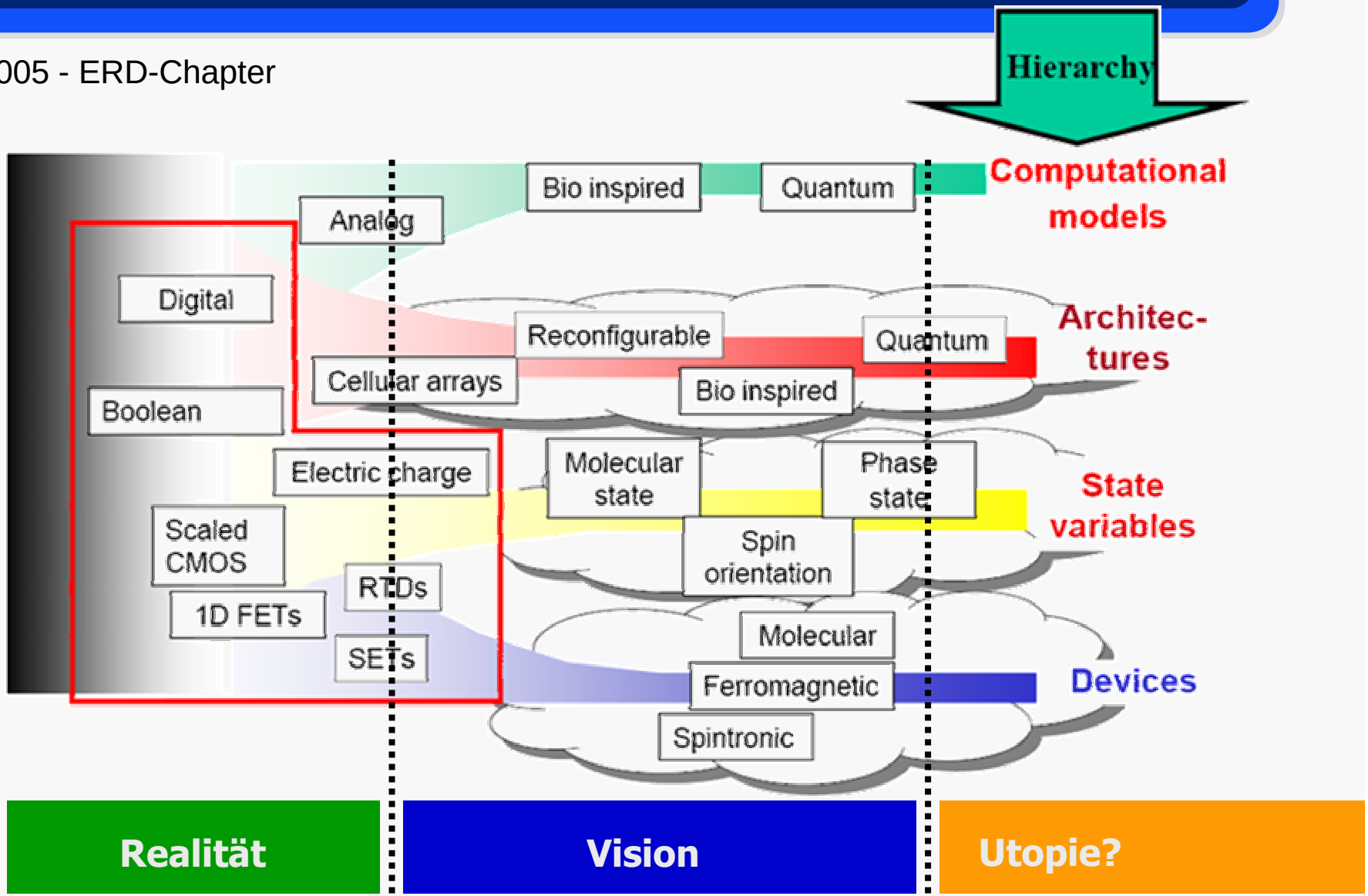
Large growing market
Strong European position
Strategic for application markets

	Ranking	Company
USA	1	Intel
Korea	2	Samsung Electronics
Japan	3	Renesas Technology
USA	4	Texas instruments
Japan	5	Toshiba
EU	6	STMircoelectronics
EU	7	Infineon Technologies
Japan	8	NEC Electronics
USA	9	Motorola
EU	10	Philips Semiconductors

Source: Dataquest March 2004

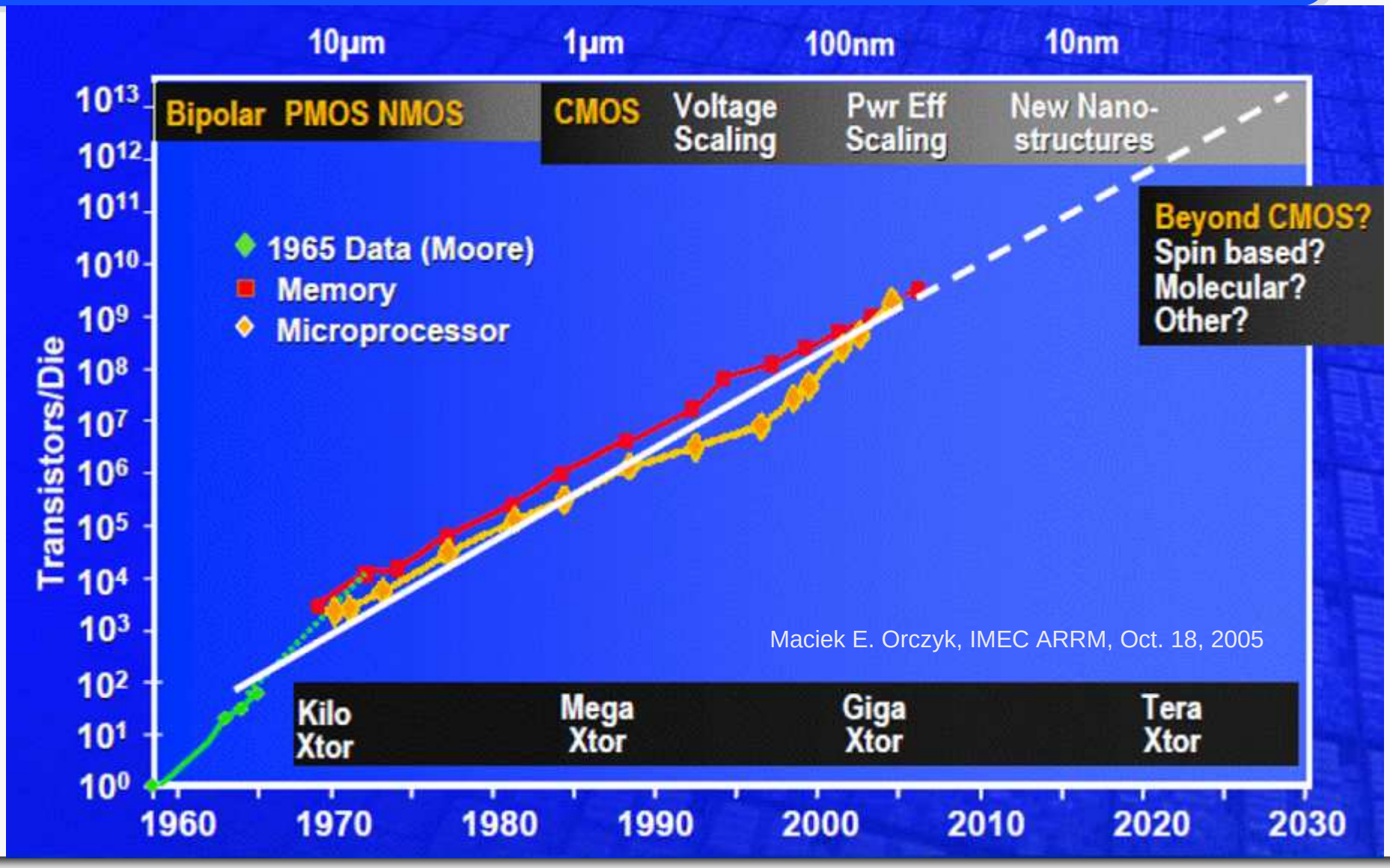
Taxonomy of Basic Principles

ITRS 2005 - ERD-Chapter

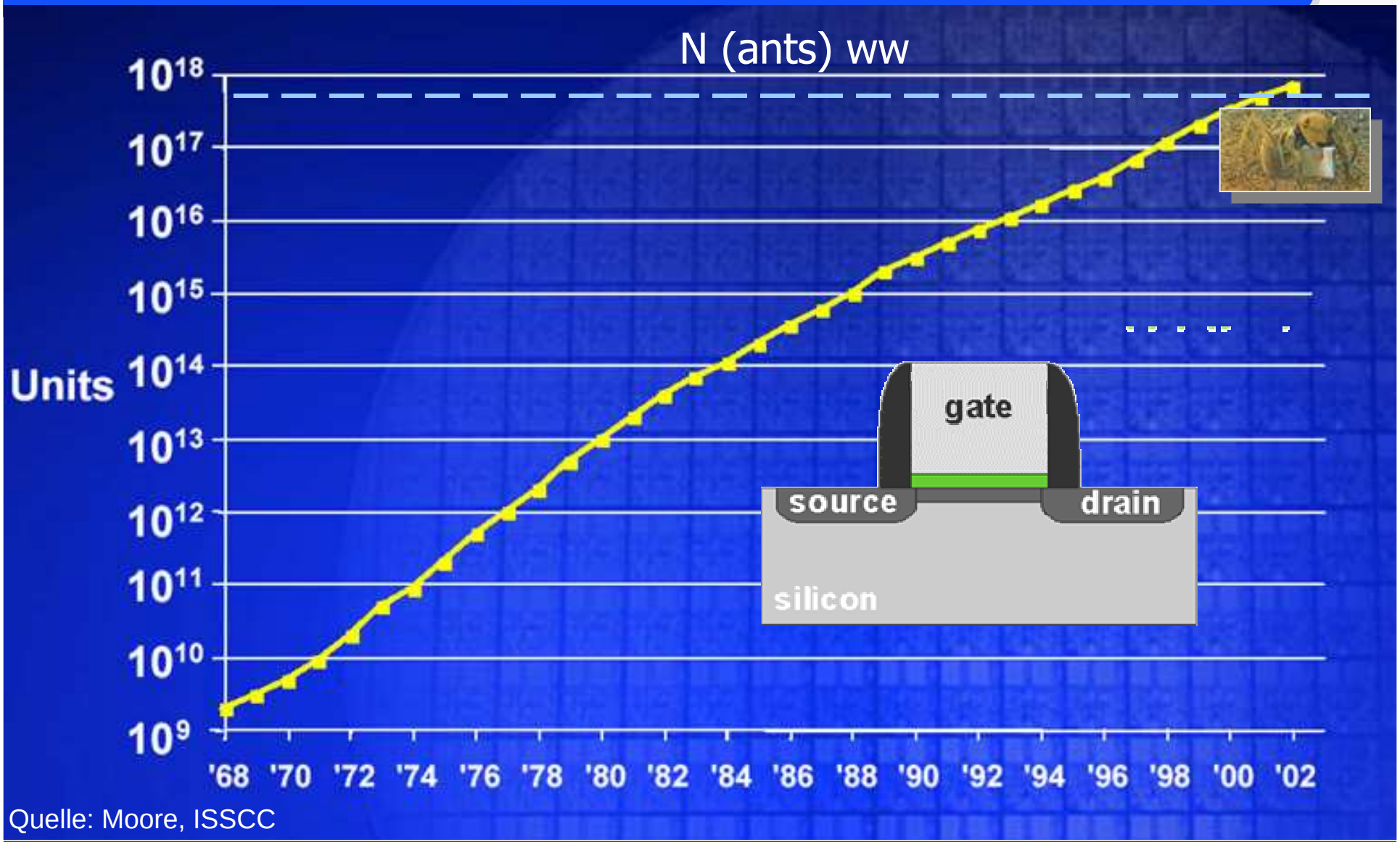


REALITÄT

Moore´s Law

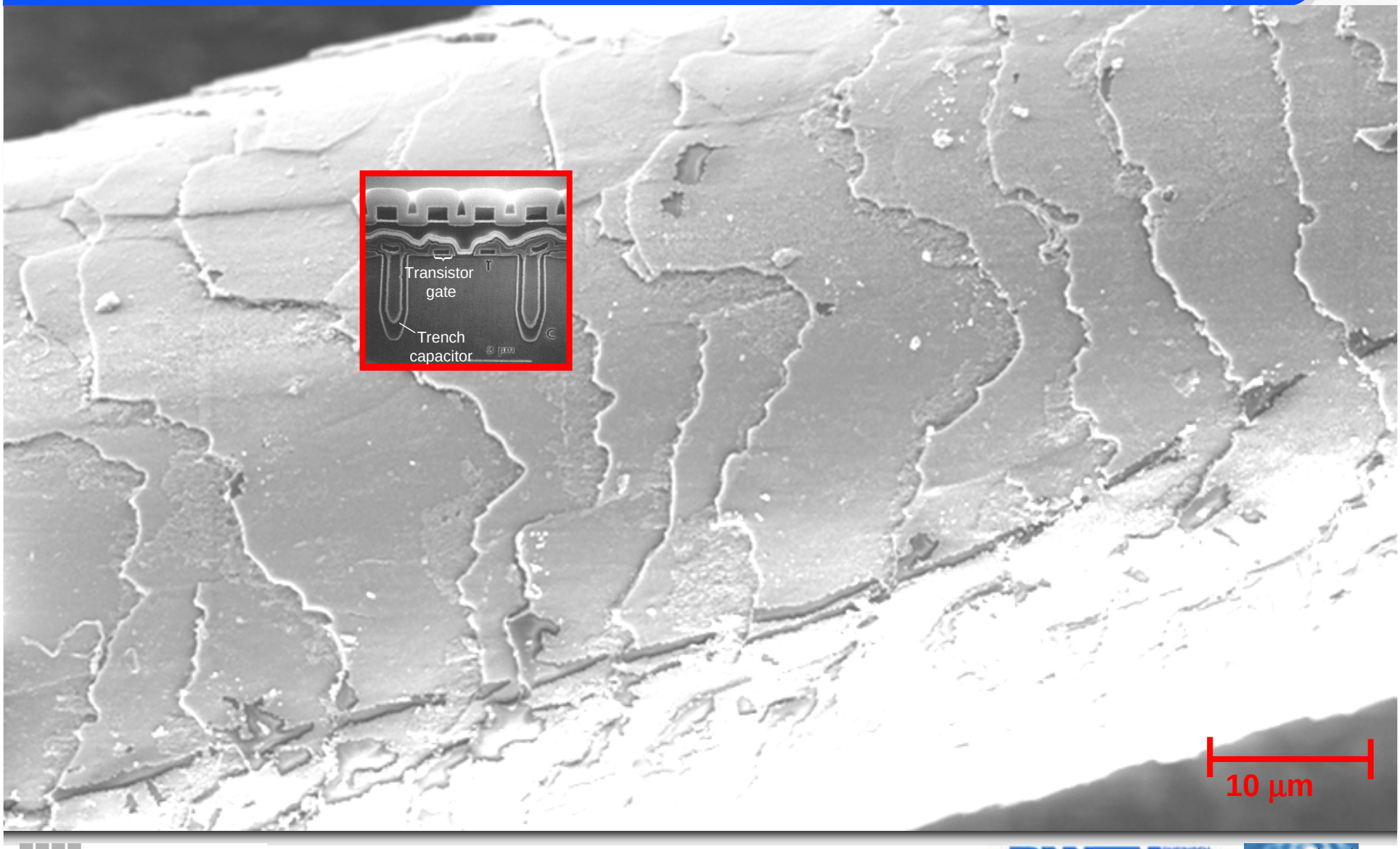

10µm
1µm
100nm
10nm
Bipolar PMOS NMOS
CMOS
Voltage Scaling
Pwr Eff Scaling
New Nano-structures
Beyond CMOS?
Spin based?
Molecular?
Other?
1965 Data (Moore)
Memory
Microprocessor
Transistors/Die
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
Maciek E. Orczyk, IMEC ARRM, Oct. 18, 2005
Kilo Xtor
Mega Xtor
Giga Xtor
Tera Xtor
1960
1970
1980
1990
2000
2010
2020
2030

Evolution: Transistors shipped per year

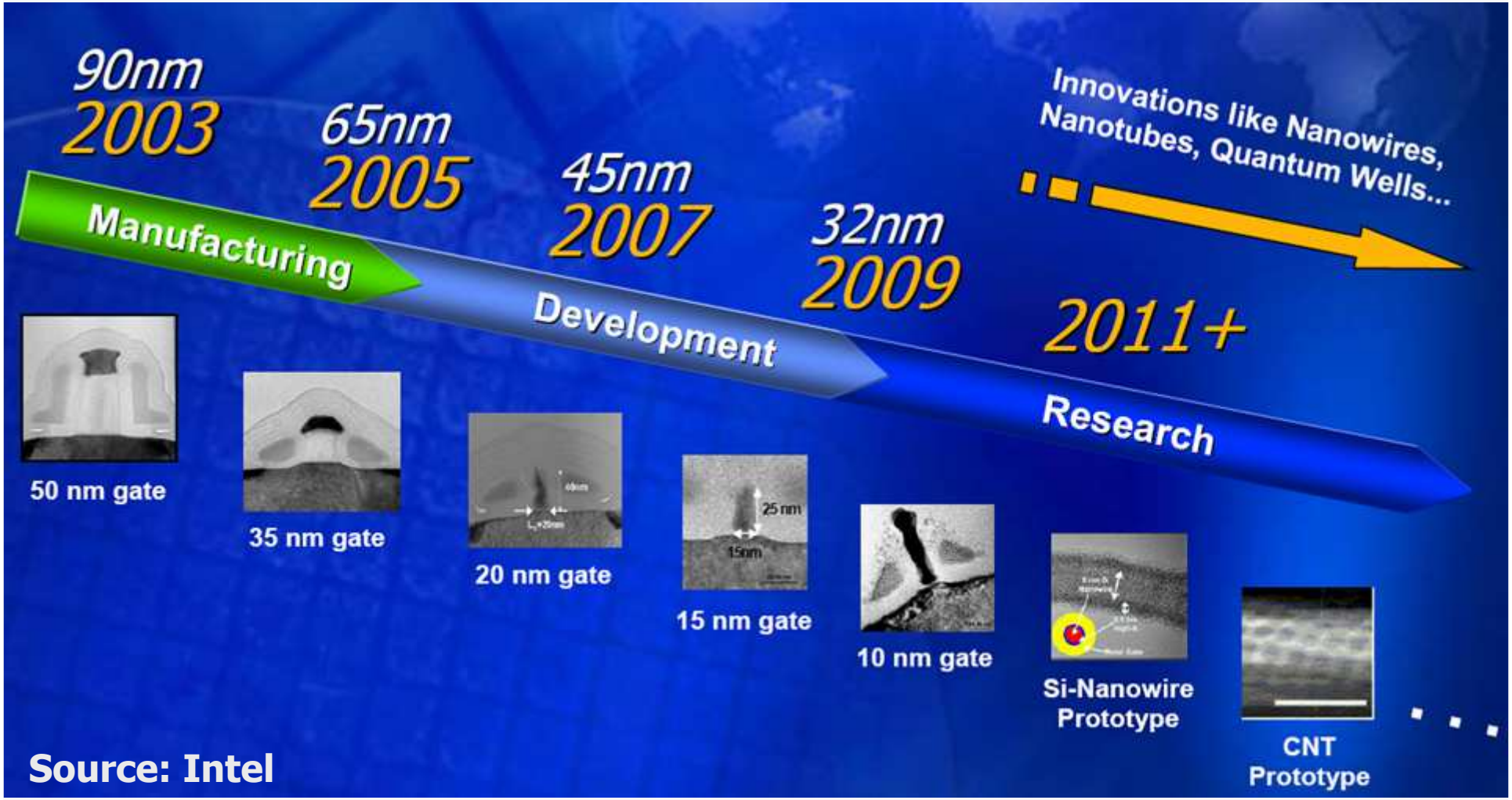


Quelle: Moore, ISSCC

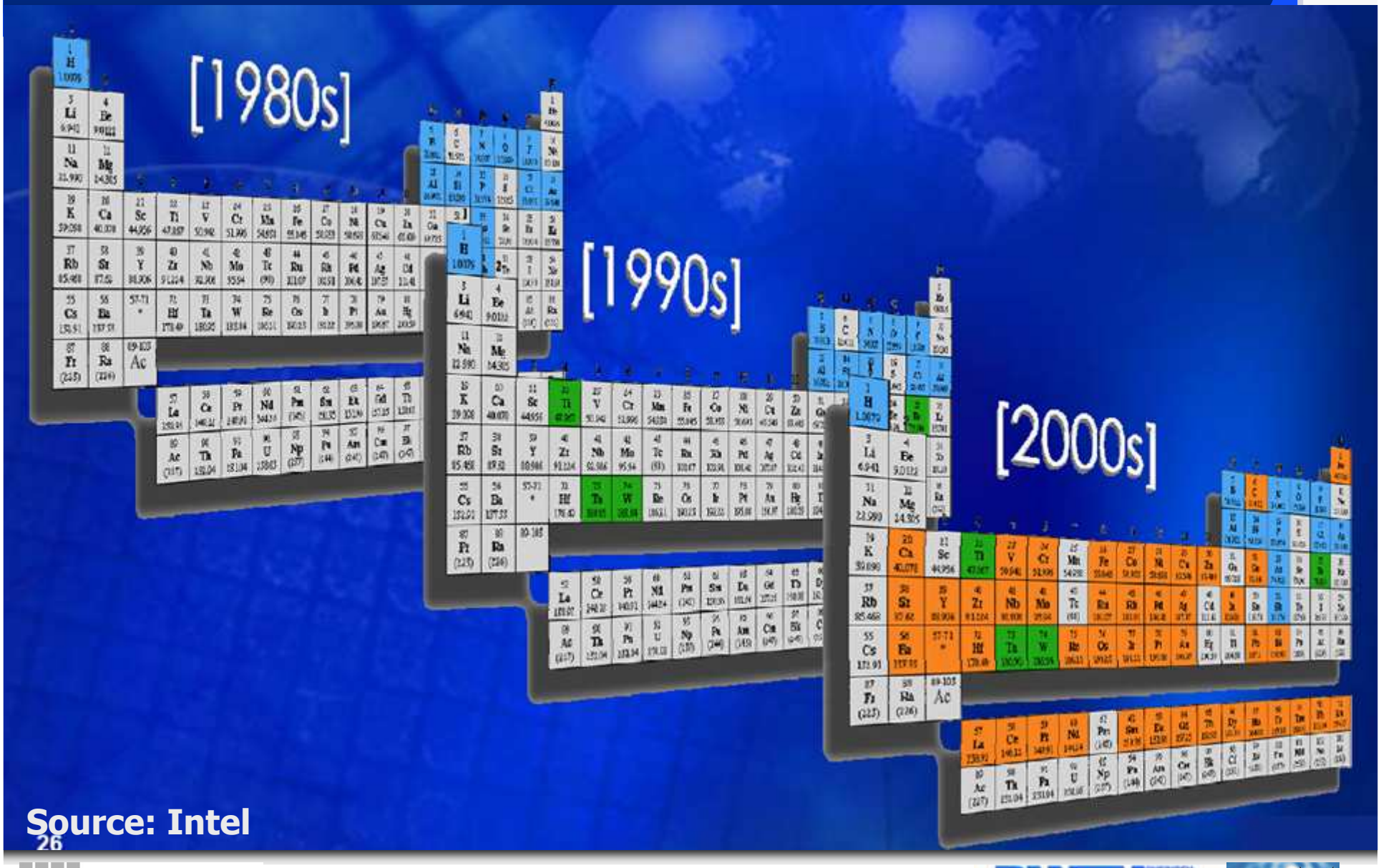
Dimensionsvergleich:. Transistor und menschliches Haar



Evolution: MOSFET-Scaling

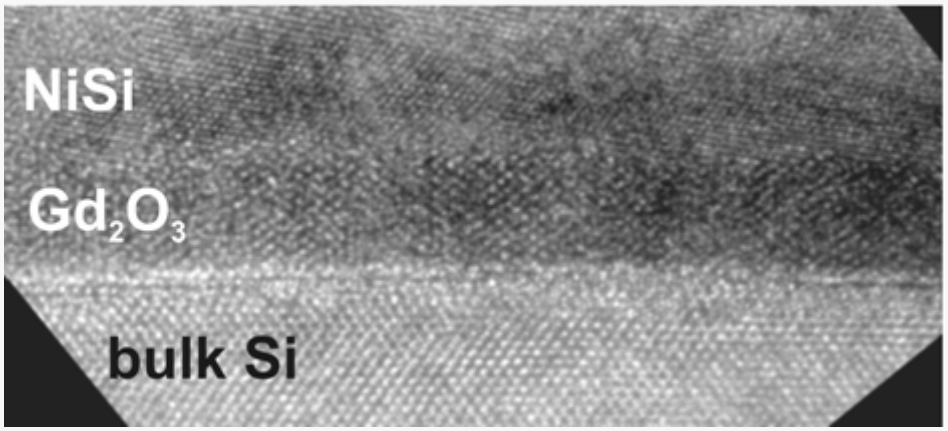


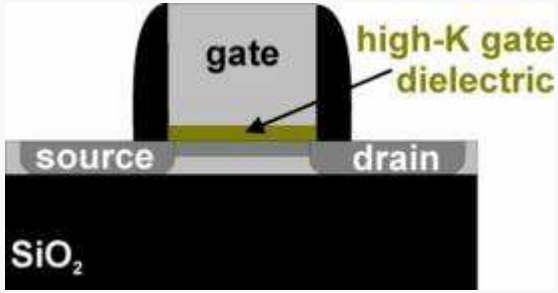
Dekade of New Materials



Source: Intel

Crystalline High-k Gate Dielectric

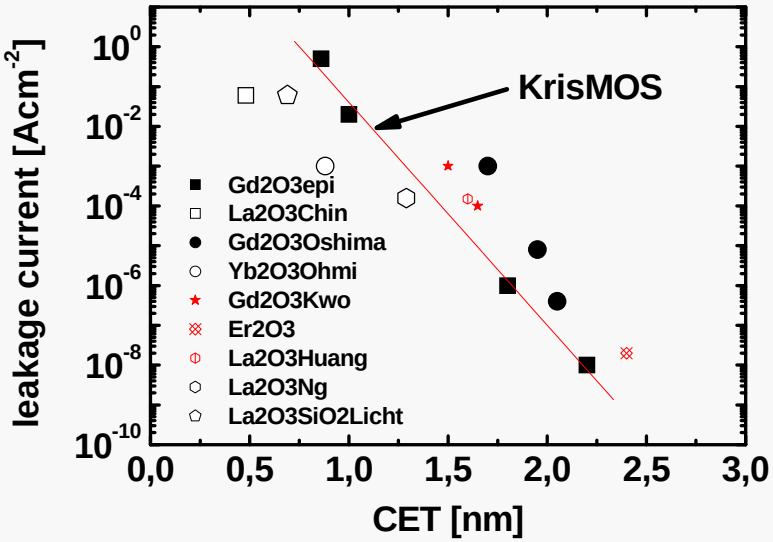




NiSi @ 500℃

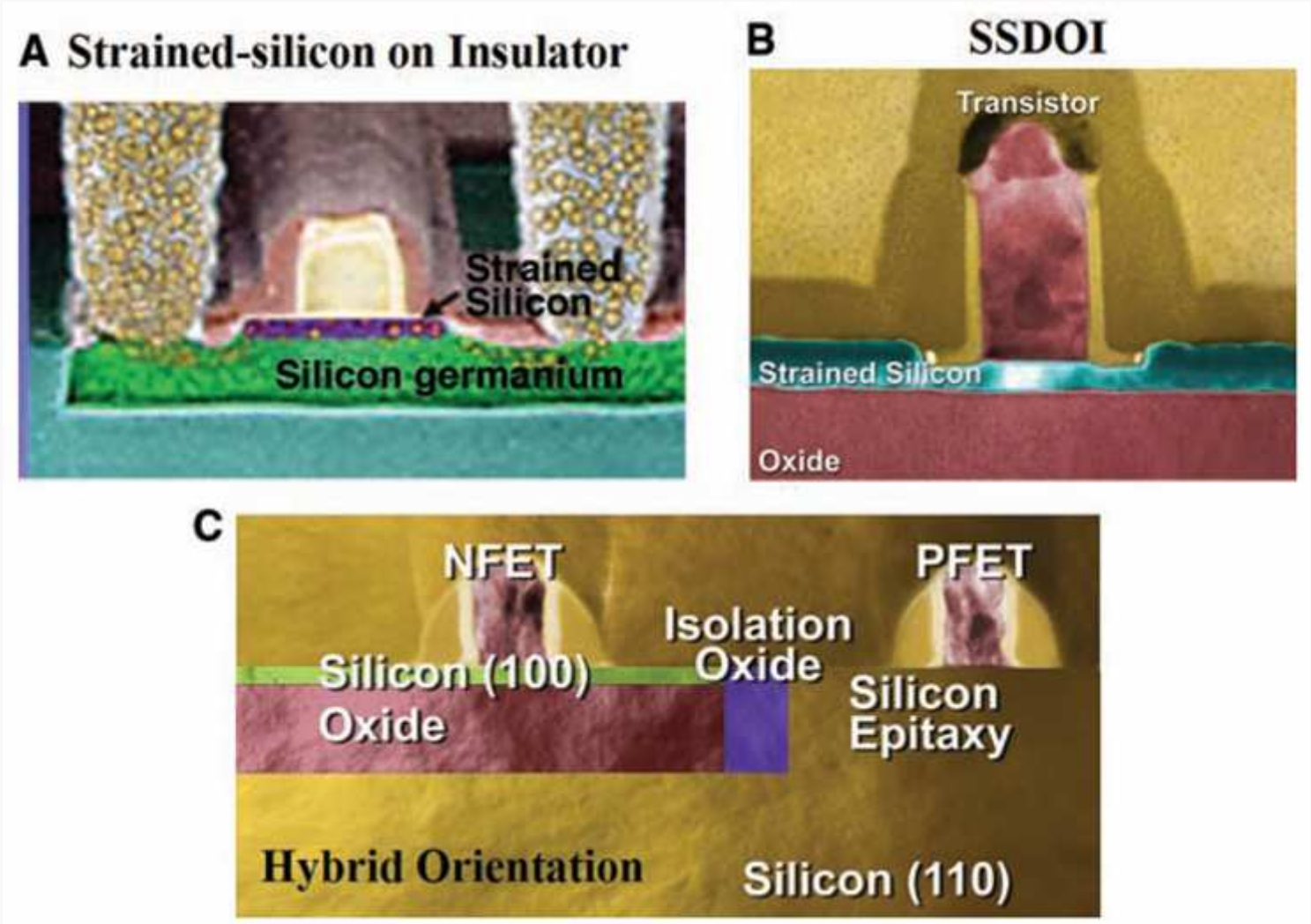
3,1nm Gd2O3

Aufnahme von Dr. Bugiel, Uni-Hannover (Mitarbeiter von Prof. Osten)



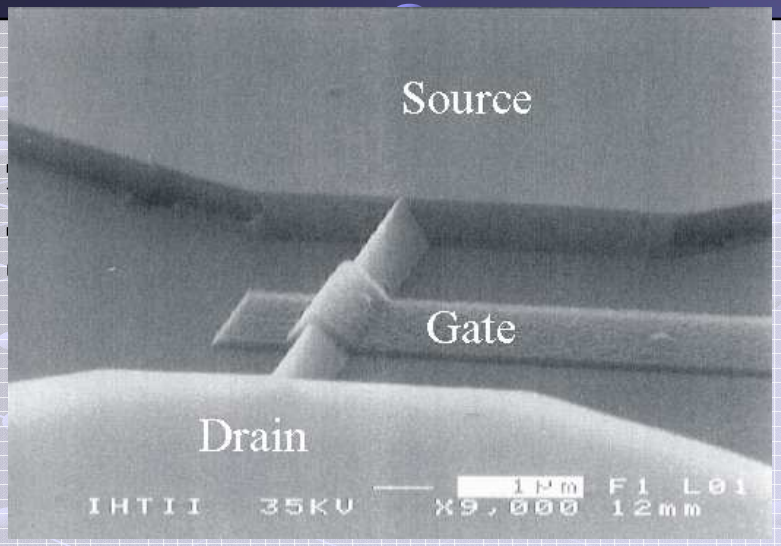
November 2005: World's first MOSFETs with epitaxial Gd2O3 (AMO, TU-Darmstadt, Uni-Hannover: KrisMOS Projekt)

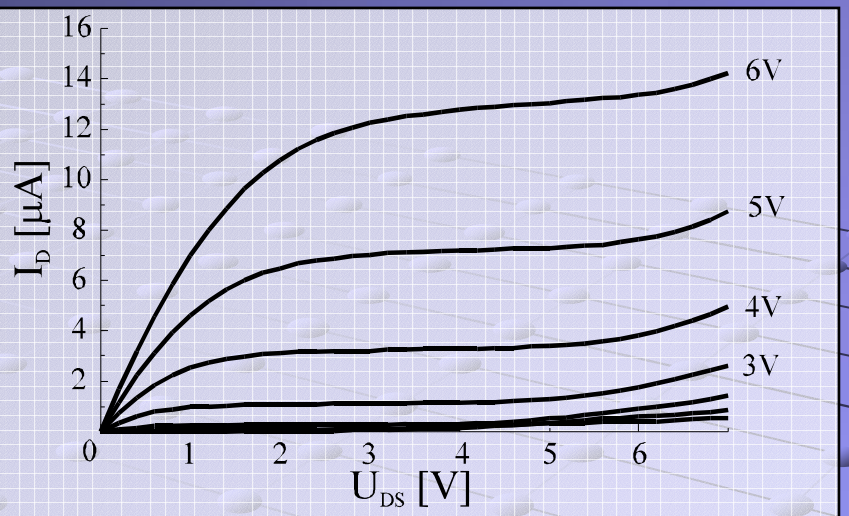
Further Variations



M. Ieong, Science, Vol. 306 (2004)

Precursor: Triangle-Shaped Nanoscale MOSFET





Output characteristics of the fabricated triangle-shaped MOSFETs with 1µm and 2µm gate length (left and right side, respectively).

"I lost the sense of why this work is interesting. Tell me why I am interested in this device"
*(Reviewer comment, JVST-B, **1996**)*

***ITRS roadmap prediction 2001:** Non-classical CMOS devices: non planar gate, double & triple gate devices on SOI, FinFET, ultra thin body (fully depleted) SOI, vertical transistor…*

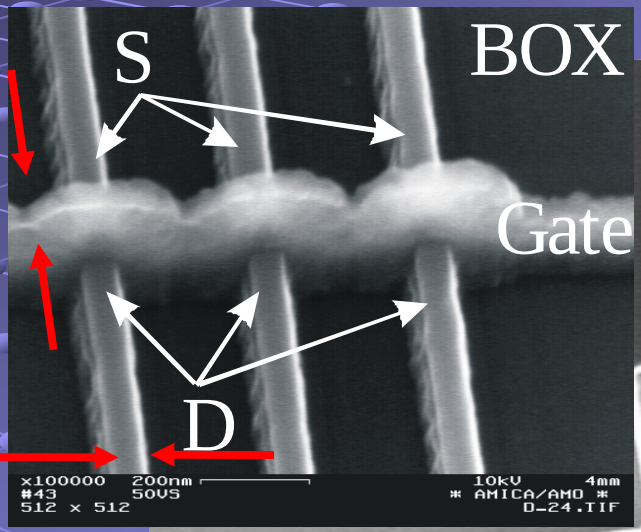
J.Gondermann et al
A triangle-shaped nanoscale MOS device, JVST B, 14, 6, 4042-45 (1996)
New concept for ultra small N-MOSFETs, Microelectronic Eng. 35, 305 (1997)

AMO/AMICA

Realisation Triple-Gate SOI-MOSFET

L_G=70nm

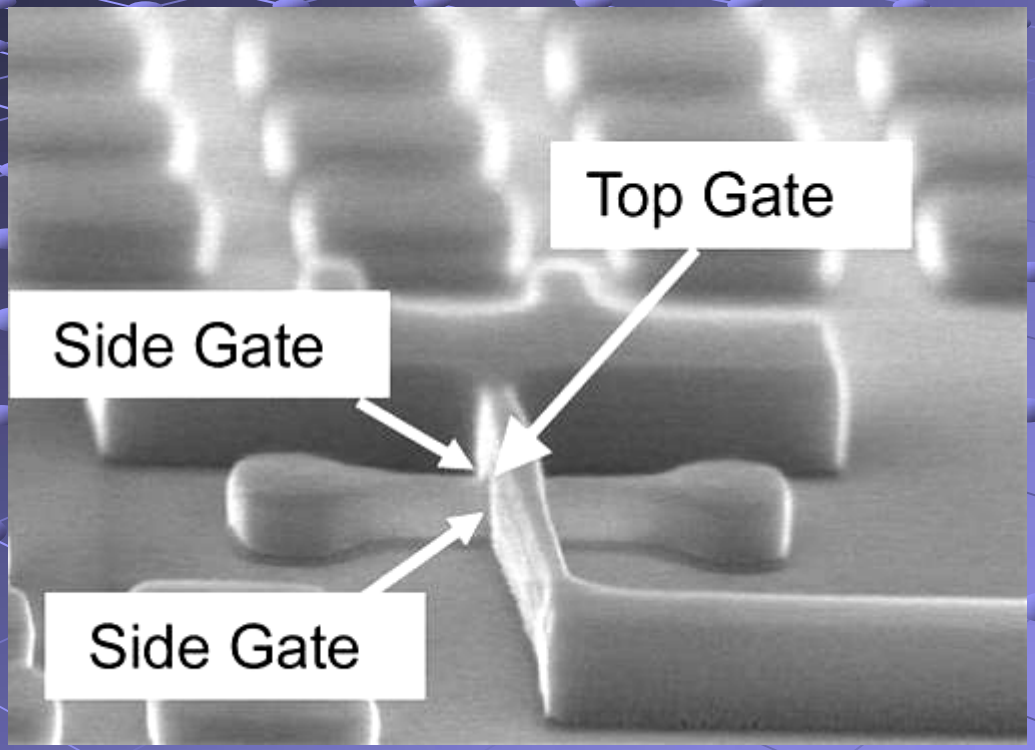
W_M=22nm



t_{Top-Si}=	100nm
t_{BOX}=	200nm
t_{Oxide}=	8nm
$N_{Channel}$=	3e17/cm³
$N_{S/D/G}$=	1e20/cm³

M. Lemme et al., Solid-State Electronics, Vol. 48, 2004

Intel Tri-gate Transistor



30-60nm Gate-Length

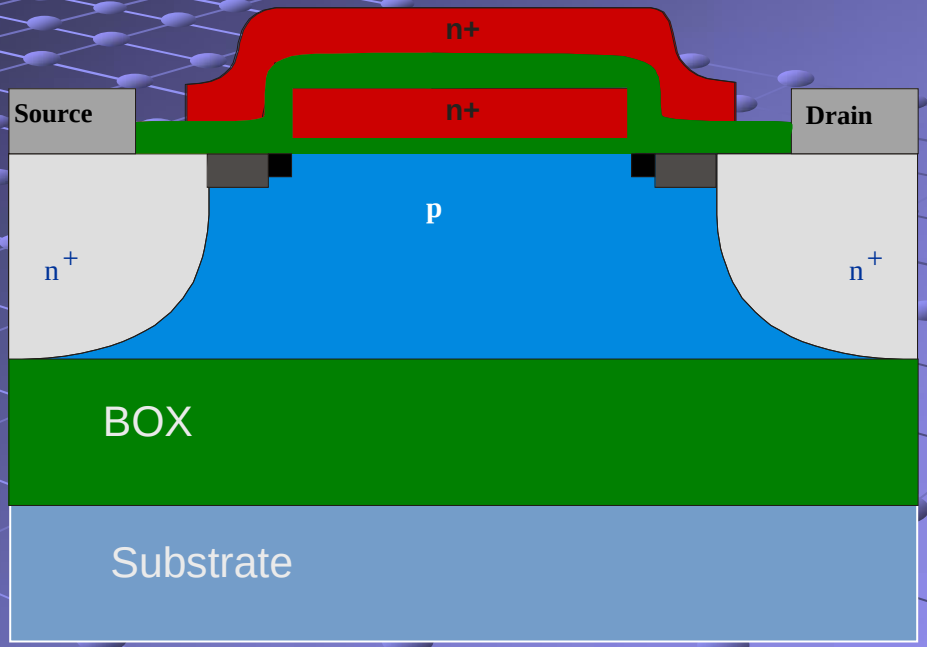
That‘s the reason while we are searching for smaller devices!

R. Chau et al., 2002 International Conference on Solid State Devices and Materials, Nagoya, Japan 2002

The EJFET- concept on SOI

MOSFET

one gate
spacer
implantation
activation



EJ-MOSFET

two gates
intergate oxide
electr. extensions
implantation
activation

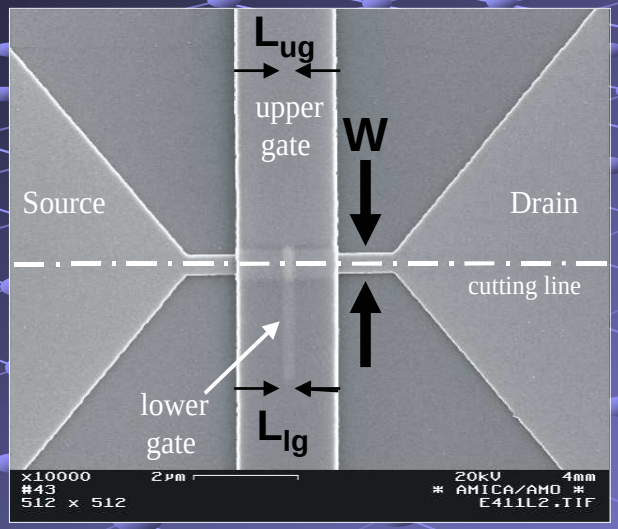
Electrically induced S/D extensions:

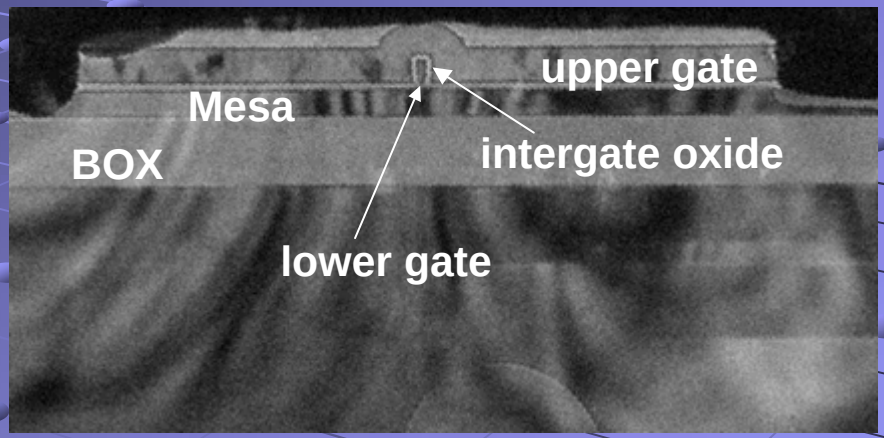
shallow junctions
relaxed source/drain implantation

Investigation of MOSFETs in the deca-nanometer regime

W. Henschel et al., Solid-State Electronics, Vol 48 (2004)

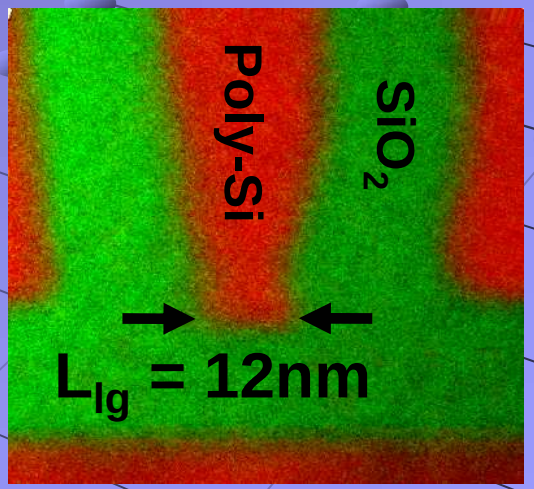
The technological realization of the concept





After optimizing the critical processes :

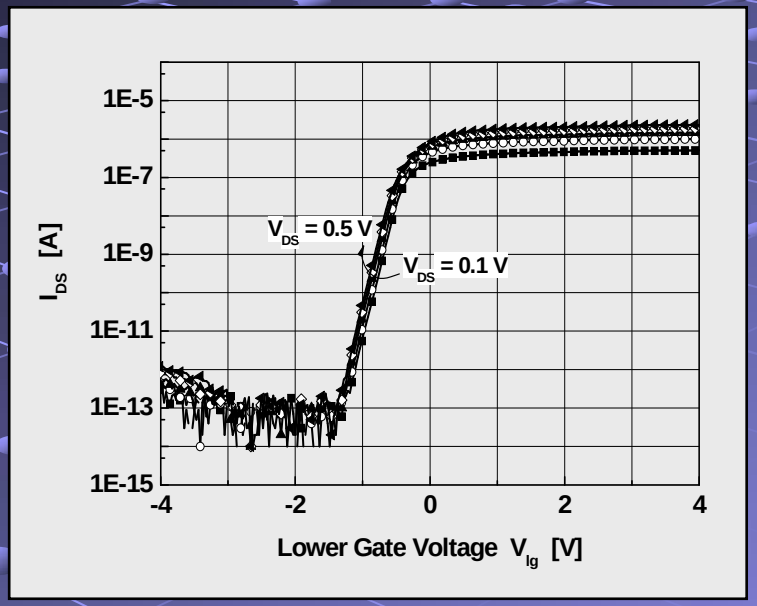
12 nm EJFET on SOI material

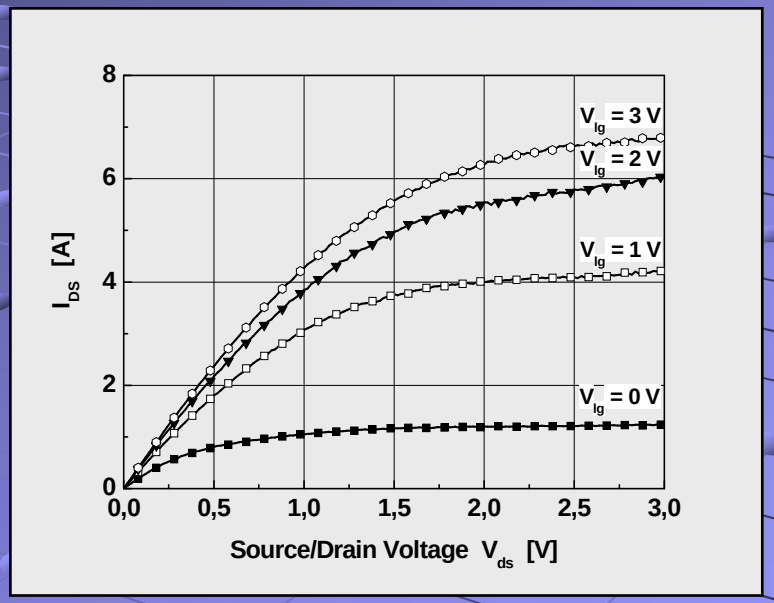


W. Henschel et al., Solid-State Electronics, Vol 48 (2004)

12 nm fully depleted triple-gate EJFET

Electrical characterization





Output characteristic (The current is not normalized) **Transfer characteristic**

FD Triple-gate EJFET:

lightly doped (N_A = 1e15cm^{-3})

L_{lg} = 12 nm

W = 20 nm

- **Current in the off-state: 10^{-13}A**
- **Ion/Ioff: 10^8**

W. Henschel et al., Solid-State Electronics, Vol 48 (2004)

VISIONEN

Components: Opportunities

CMOS PLATFORM

To 1 Billion Transistors

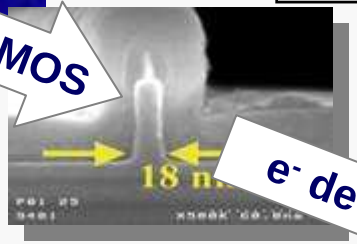
Advanced Computing Architectures

Added functions

Sensors, actuators, wet interface
Nano-electromechanics, Bio-Nano,
Quantum cryptography

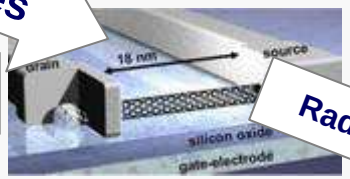
To 22 nm CMOS

Ultimate CMOS



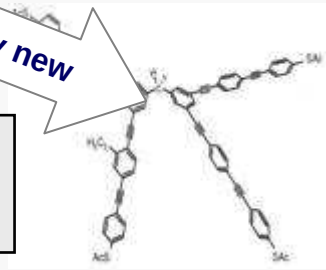
e⁻ devices

Bridging Nanoelectronics

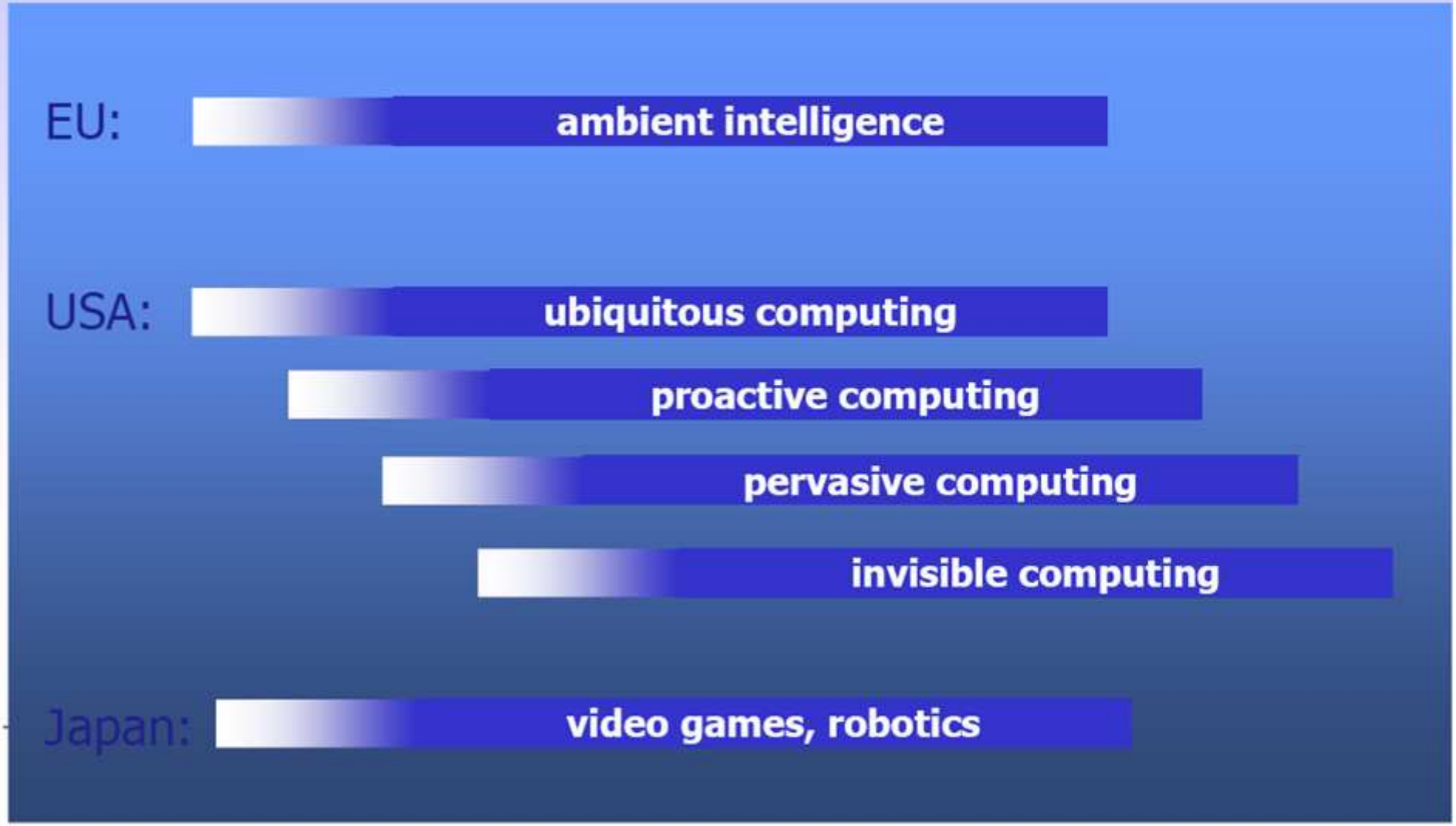


Radically new

Molecular, Spin,
Quantum, ???



Considerations



TECHNOLOGY REVIEW, Febr. 2005

Kognitive und kommunikative „Individuen“ der Gesellschaft

Elektronische “Kokons“ zur Umfeldsensorik und Information

zunehmende Anzahl von Komponenten und Antennen
erfordert auch Nano-Elektronik

Die Roboter kommen …

Electrolux Trilobite

Honda Asimo

Sony „Dream Robot“

Sony „Aibo“

Sony „SDR-4X“

US Special

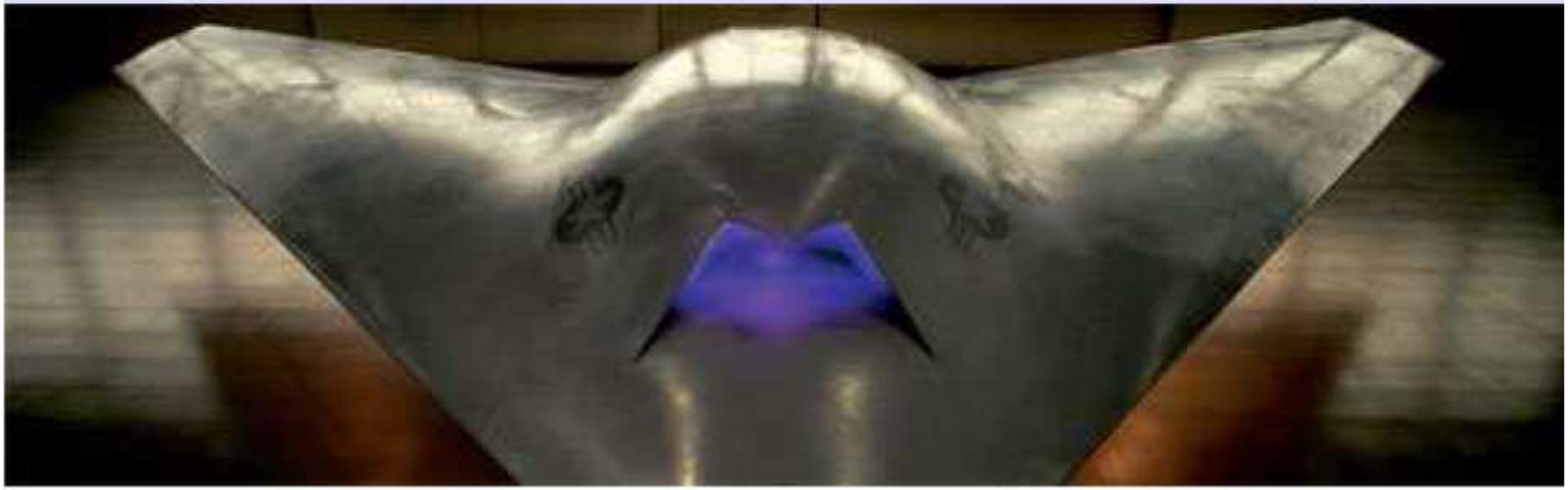


image from MIT technology review March 2005

- US special: The Ascent of the robotic attack jet

  Building the planes is easy. Making them autonomous, and constructing airborne communications networks is not.

ICT & Other Sciences

Synergy: example in ICT & Life Sciences

	Molecular & Cellular Electronics:	Neuro- & Bio- Computing
Future ICT Inspired by Nature	- Organic materials /CMOS - DNA circuits - Production w. bacteria	- Sensor data processing - Self-organisation, repair - Emergence, Evolution - Immuno computing
	Biomedical devices & nanosystems	Biomedical Informatics
ICT support to Biomedical Systems & Knowledge	- Lab-on-a-chip - Artificial organs, limbs - Robot-assisted surgery	- Genome & Phenome ICT - Molecular Imaging - Synthetic Biology - Biobanks

Physical Systems
HW & devices in contact with real world

Logical Systems
Models, Methods and Software

UTOPIE

Silizium-X-Chromosom