



ACADEMIA ENGELBERG

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in Engelberg, Switzerland

Pervasive Nanotechnologie

Folien zum Vortrag

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SCIENCE & TECHNOLOGY
on the
NANOMETER SCALE

CONTINUATION of a **DEVELOPMENT**

MINIATURIZATION

MACRO- MOLECULES

NEW NANO - TERRITORY

NEW POSSIBILITIES

MERGE DIFFERENT DEVELOPMENTS

NOVEL APPROACHES & CONCEPTS

→ **NEW OPPORTUNITIES**

NANO is DIFFERENT



PERVASIVE:

EVERYWHERE AT ANYTIME

PENETRATING EVERYTHING EVERYWHERE

PERVASIVE COMPUTING

WAS ENABLED BY

PERVASIVE ELECTRONICS

AND

PERVASIVE COMMUNICATION



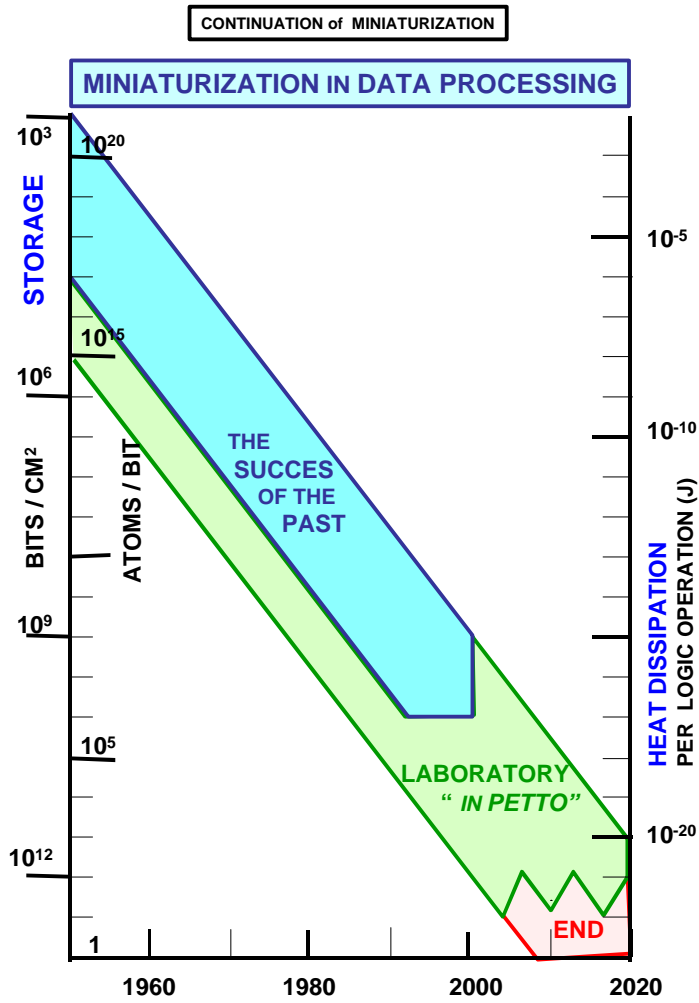
**PERVASIVE REQUIRES
SMALL AND INEXPENSIVE**

**MINIATURIZATION OF ELECTRONICS
REDUCED**

- | | | |
|----------------------|----|------------------|
| • SIZE | BY | $10^4 - 10^{12}$ |
| • PRIZE | | $10^4 - 10^7$ |
| • ENERGY CONSUMPTION | | $10^6 - 10^{12}$ |
| • TIMES | | $10^5 - 10^{10}$ |

THE **SUCCESS** OF THE PAST
WAS **SCALABILITY**

“ SMALLER, FASTER, CHEAPER ”





THE SUCCESS OF MINIATURIZATION

THE TRANSISTOR:

THE BEGIN
OF MICROELECTRONICS
THE SUCCESS

CAN BE MADE SMALL
DISSIPATES LITTLE ENERGY



SMALLER, FASTER, CHEAPER

SMALLER	:	THOUSEND - BILLION
FASTER	:	THOUSEND - BILLION
CHEAPER	:	MILLION
LESS ENERGY	:	TRILLION



THE SUCCESS OF MINIATURIZATION

SMALL → LITTLE ENERGY

**1 TRILLION x LESS ENERGY
PER CALCULATION**

**NEVERTHELESS, THE ENERGY COSTS OF
OF DATA PROCESSING AMOUNT TO**

1 TRILLION USD / YEAR

HUMAN: 80 USD / YEAR

AND **CAN THINK**

FOR **8 USD / YEAR**



THE SUCCESS OF MINIATURIZATION

SMALL → PERVASIVE

MICROELECTRONICS:

HEARING AID
CELLULAR PHONE
GPD
PC
MAIN FRAME
JUMBO
SATTELITES

YEARLY PRODUCTION OF
TRANSISTORS:

1'000'000'000'000'000'000

WITH RADIO TUBES OF 1960

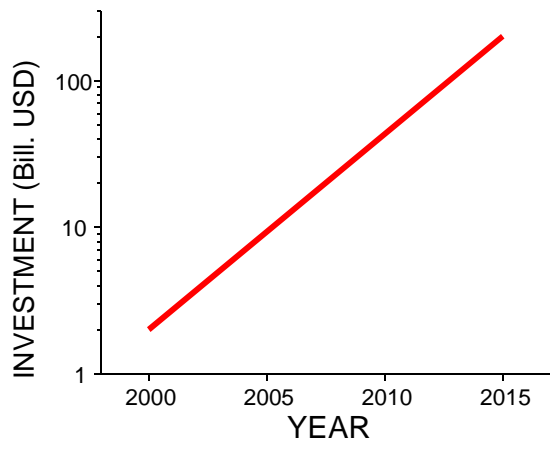
WE WOULD **STAND**
KNEE-HIGH IN THEM



CONTINUATION of MINIATURIZATION

SMALL IS NOT ALWAYS CHEAP

**PROJECTED INVESTMENT FOR
MICRO FABRICATION FACILITY**



NANO FABRICATION FACILITY

?



THE NEW NANO - TERRITORY

MICROELECTRONICS

PERFORMS

- DATA PROCESSING AND
- DATA TRANSMISSION

NANO TECHNOLOGY

SMART SENSORS

CREATE , PROCESS & TRANSMIT DATA

SMART ACTUATORS

CONTROL & EXECUTE ACTION

INTEGRATED PROCESSOR SYSTEMS

**INCLUDE SENSING AND ACTUATION FOR
“*in situ*” PROCESSING**



ULTIMATE GOAL OF SCI. & TECH. ON THE nm SCALE

PERFORM

ELECTRICAL,
MECHANICAL,
CHEMICAL,
THERMAL, } ↔ { SENSING
PROCESSING
ACTUATION

WITH

**SYSTEMS WORKING ON THE
NANOMETER SCALE**

BUILD PERVASIVE BRIDGES

BETWEEN

VIRTUAL WORLD AND **REAL WORLD**
OF PROCESSING OF ACTION



ULTIMATE TECHNICAL REQUIREMENT

**ADDRESS, MEASURE, CONTROL
STRUCTURE, and MODIFY**

on the **NANOMETER SCALE**

**PROPERTIES
STRUCTURES
COMPONENTS
FUNCTIONS
PROCESSES**

including

**THEIR SYNTHESIS to SYSTEMS of
MICRO and MACRO DIMENSIONS**

and

**PREPARATION of APPROPRIATE
MATERIALS**



THE NEW NANO - TERRITORY

NANO IS DIFFERENT

- **NOVEL PROPERTIES & FUNCTIONS**
From CONDENSED MATTER BEHAVIOR
to ATOMIC and MOLECULAR PROPERTIES
NEAR FIELD, BALLISTIC, COUNTING
- **FAST**
MECHANICS, "CHEMICS", AND "THERMICS"
- **SENSITIVITY**
ATOMIC and MOLECULAR LEVEL
- **PERVASIVE BEYOND ELECTRONICS**
ELECTRICAL, MECHANICAL, and CHEMICAL
SENSING, PROCESSING, and ACTUATION
- **DISCIPLINES MERGE**
COMMON NANO SCALE
- **NOVEL STRATEGIES**
NATURE'S WAY, COUNTING, DISCRETE



THE NEW NANO - TERRITORY

SPEED and SENSITIVITY

are **KEY INGREDIENTS** of a

NEW, POWERFUL, and PERVASIVE

NANO - MECHANICS
- CHEMISTRY
-THERMODYNAMICS

For

INTEGRATED
- SENSING
- PROCESSING
- ACTUATION



THE NEW NANO - TERRITORY

NANO - MECHANICS

MECHANICS UNDERSTOOD AS
MOTION OF ATOMIC CORES (MASS)
AND DEFORMATION OF THEIR
ARRANGEMENT

- FAST Mhz - Ghz, μsec - psec
→ **MECHANICS COMPLEMENTS ELECTRONICS**
- SENSITIVE $\text{STIFFNESS} \propto d$
 $?m \propto d^4$
- EXTREM DEFORMATIONS
 - $\sigma_{\text{yield}} \gg \sigma_{\text{yield, bulk}}$ (COLLECTIVE SLIP)
 - $R_{\text{curv}} \propto d$
 - “REVERSIBLE” MASS TRANSPORT
 - **MICRO- & MACRO MOTION SYNTHESIZED
FROM DEFORMATION & MASS TRANSPORT**
- LOW ENERGY
ELASTIC ENERGY IN THE kT RANGE
→ “BEAT” kT
- VARIETY OF BASIC FUNCTIONALITY
→ **HIGH SENSITIVITY, INTEGRATED
SENSOR-PROCESSOR-ACTUATOR SYSTEMS**



THE NEW NANO - TERRITORY

FAST

▪ MOTION

$$n^2 \mu \text{ STIFFNESS / MASS } \mu d^{-2}$$

$$n \mu \text{ VELOCITY / } d$$

d: 10cm	10 μ m	10nm
v: 400Hz	4MHz	4GHz

▪ DIFFUSION

$$t_{\text{DIFF}} \mu \langle d^2 \rangle / D_{\text{DIFF}}$$

Volume:	1L	1000 μ m ³	1000nm ³
τ_{DIFF} :	1Day	1msec	1nsec

▪ THERMAL RELAXATION

$$t_{\text{TH}} \mu Q / \dot{Q} \mu d$$

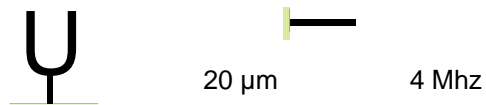
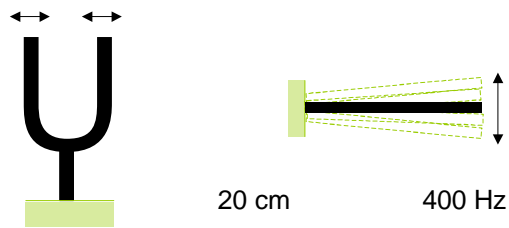
nm \rightarrow nsec



THE NEW NANO - TERRITORY

SMALLER - FASTER

MECHANICS: $n \propto 1/d$



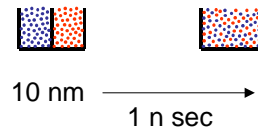
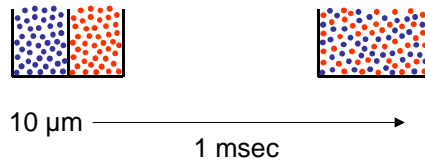
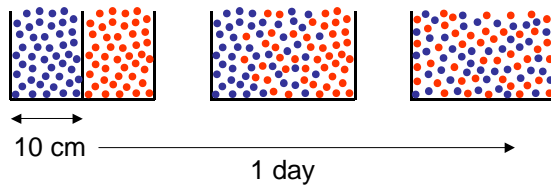


THE NEW NANO - TERRITORY

SMALLER - FASTER

DIFFUSION: $t_{\text{DIFF}} \propto d^2$

1 LITER





THE NEW NANO - TERRITORY

SENSITIVITY

RECOGNIZE, CONTROL, MODIFY
SMALL BY SMALL
WEAK BY WEAK

▪ LOCAL PROBE METHODS

ONE OR A FEW ATOMS INTERACT WITH ONE
OTHER OR FEW OTHER ATOMS

▪ MOLECULAR RECOGNITION

MOLECULE RECOGNIZES MOLECULE

▪ MECHANICS

STIFFNESS $\propto d$

MICROBALANCE: $\Delta m \propto m \cdot \Delta\omega/\omega$
 $\propto d^4$ or d^3

▪ DISCRETE PROPERTIES

e.g. ENERGY LEVELS

→ "DISCRETIZING"



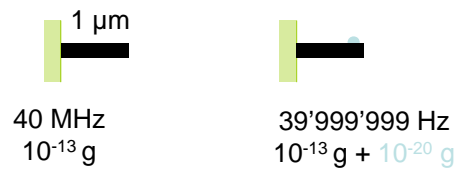
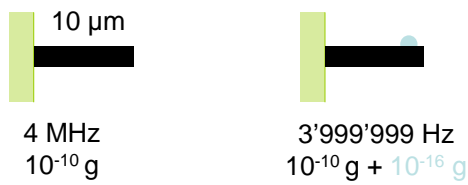
THE NEW NANO - TERRITORY

MORE SENSITIVE

$$\Delta m = -2 m \cdot \Delta \omega / \omega$$

$$m \propto d^4 \text{ or } d^3$$

$$\Delta \omega = 1 \text{ Hz}$$

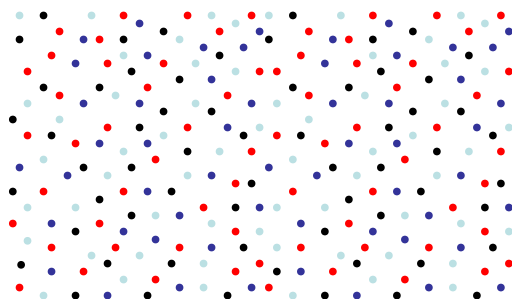




THE NEW NANO - TERRITORY

MORE SENSITIVE

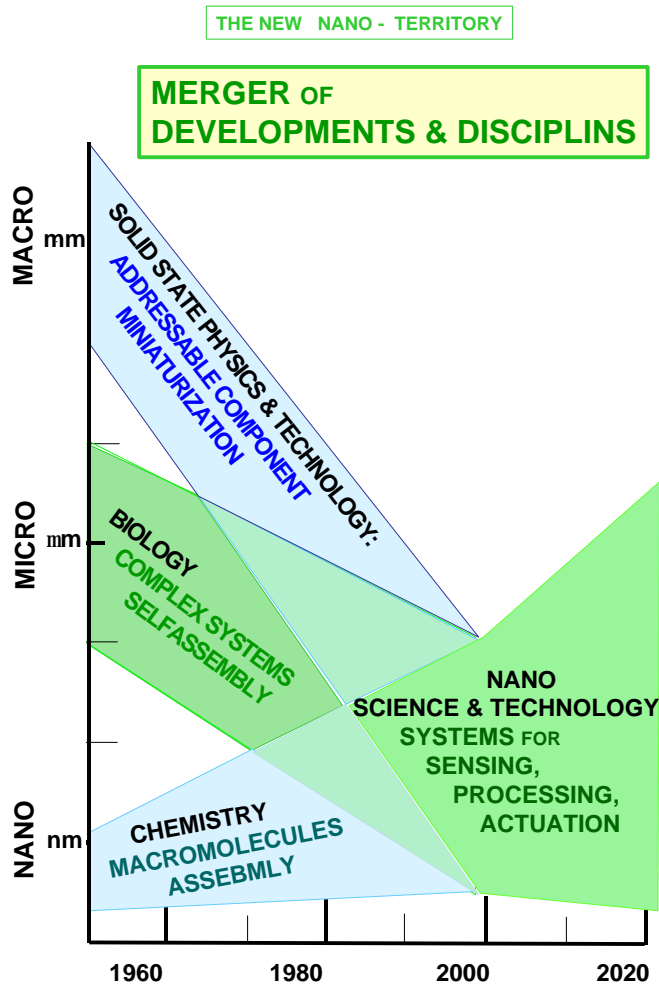
▪ STRATEGY OF “DISCRETIZING”



EACH CANTILEVER -SENSOR ACCEPTS ONE SPECIES ONLY

KEY:

FUNCTIONALIZATION of the CANTILEVERS





THE NEW NANO - TERRITORY

SOLID STATE TECHNOLOGY
WITH **MINIATURIZATION**
BRINGS THE CONCEPT OF
ADRESSABILITY
NANO OBJECTS AND COMPONENTS
BECOME **INDIVIDUALS**

(MACROMOLECULAR) CHEMISTRY
BRINGS THE CONCEPT OF
ASSEMBLY OF
NANO OBJECTS & COMPONENTS

BIOLOGY
BRINGS THE CONCEPTS OF
SELFASSEBLING & WORKING
WITH COMPLEX SYSTEMS



THE NEW NANO - TERRITORY

THE GRAND CHALLENGES

LOCAL GROWTH

NANO SCALE MATERIAL SCIENCE

NANO- INTERFACE

INVASIV,
INTERFACE **AND** CONNECTION NODES
AS ACTIVE COMPONENT

NOVEL COMPONENTS & FUNCTIONS

MECHANICAL, CHEMICAL, THERMAL...

ENERGY and INFORMATION TRANSFER

LOCAL CHEMICAL ENERGY
FIELDS

THEORY

COMPUTATIONAL SCIENCES



NANOSCALE MATERIAL SCIENCE

NANO STRUCTURED MATERIALS
NOVEL PROPERTIES AND FUNCTIONS:

- **BULK**
FROM STEEL TO POLYMER TO NANO COMPOSITS
- **SURFACE**
SELFASSEMBLIES
- **NANO PARTICLES** **HEALTH RISK**
COLLOIDS, AEROSOLS, CLUSTERS,
MAGN.-COLUMNS, Q-DOTS, C-NANOTUBES

NANO STRUCTURING MATERIALS

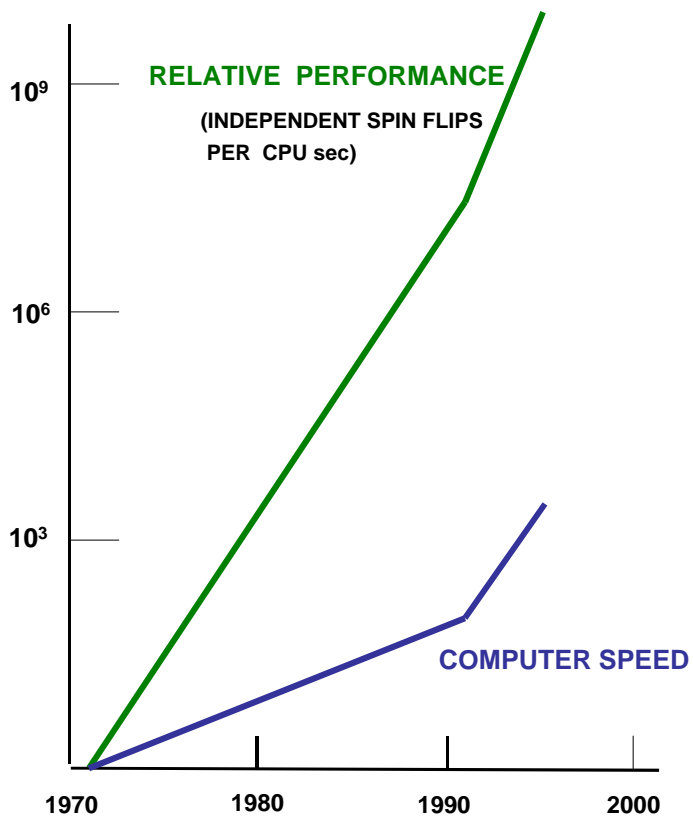
- **NANOSTRUCTURING BEYOND SILICON**
- **LOCAL NANOSTRUCTURES**
COMPONENTS, CONTACTS, CONNECTORS
CONSTRICTIONS Q-WELLS-WIRES-DOTS,

LOCAL NANO - FABRICATION

- **MANIPULATION**
- **SELFASSEMBLY OF NANO PATTERNS**
- **LOCAL GROWTH**



COMPUTERS AND COMPUTATION

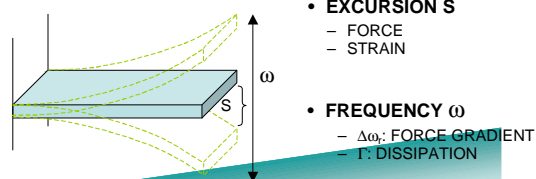




THE NEW NANO - TERRITORY

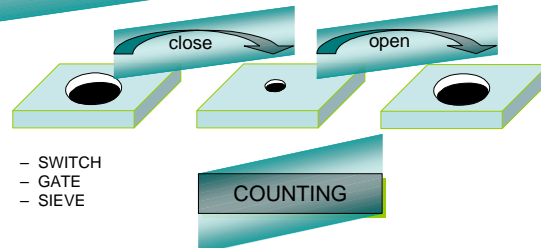
MECHANICAL COMPONENTS

▪ CANTILEVER OR SIMILAR



KEY CHALLENGE:
FUNCTIONALIZATION OF CANTILEVER

▪ ADJUSTABLE HOLES



▪ GUIDES (RAILS, TUBES)

