Benchmarking for Beyond CMOS technologies

Prof Jouni Ahopelto
VTT, Finland,
jouni.ahopelto@vtt.fi

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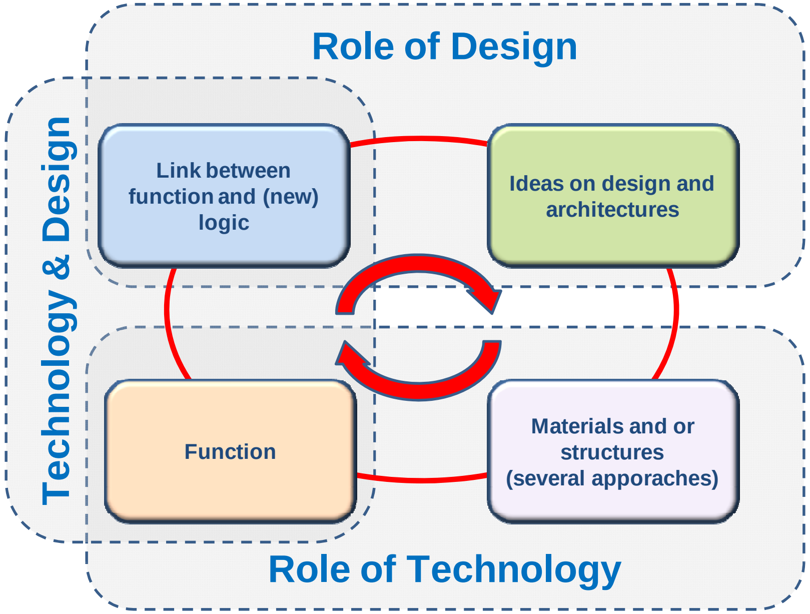
Outline

- Motivation
- NANO-TEC project
- Benchmarking procedure
- Examples
- Conclusions

Motivation

- Large number of emerging ”Beyond CMOS” device concepts
- Various types of functions
- Can those be used for data processing (computation/memory/interconnects…)?
- Device fabrication/production?
- Architectures, design tools, libraries?
- Prospects?
- Unique exercise in advancing the research of future emerging devices in Europe.

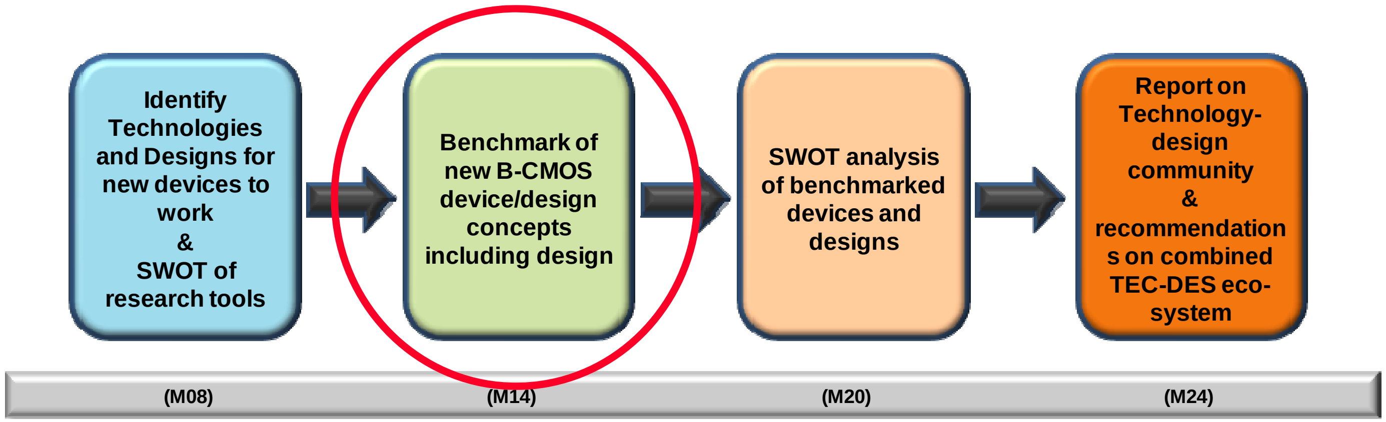
NANO-TEC project



Aim is to:

- **To identify the emerging device concepts and technologies**
- **To bridge the gap between the emerging technologies and design**

Modus operandi: Series of workshops with converging focus



Benchmarking procedure

Benchmarking exercise in US

SRC® Semiconductor Research Corporation
PIONEERS IN COLLABORATIVE RESEARCH®

NRI anoelectronics RESEARCH INITIATIVE

The Quest for a Better Switch

The SRC Nanoelectronics Research Initiative

Bernstein et al., Device and Architecture Outlook for Beyond CMOS Switches, Proc. IEEE 98 (2010) 2169.

Benchmarking procedure

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Aim to a broader scope:

- No direct comparison with CMOS
- Allow for other concepts in addition to digital switches
- Challenge the design community

Benchmarking procedure

Workshop 1: Focus on concepts and technologies
Workshop 2: Focus more on devices
Workshop 3: SWOT analysis

Benchmarking Beyond CMOS Devices

Technology	[Wires, graphene, MEMS etc… please insert name]
Gain **Signal/Noise ratio** **Non-linearity**	
Speed **Power consumption**	
Architecture/Integrability (Inputs/outputs, digital, multilevel, analog, size etc.)	
Other specific properties	
Manufacturability (Fabrication processes needed, tolerances etc.)	
Timeline (When exploitable or when foreseen in production)	

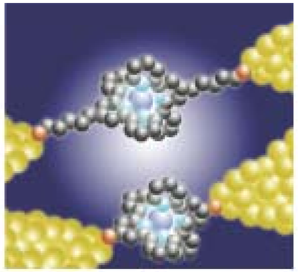
- **Molecular Electronics**
- **MEMS**
- **Solid-State Quantum Computing**
- **Spintronics**
- **Nanowires**
- **Memristors**
- **Graphene**

Presentations are available at the NANO-TEC web site www.fp7-nanotec.eu

Example: Molecular electronics

D. Vuillaume, 2nd NANO-TEC Workshop

Single molecule electronics

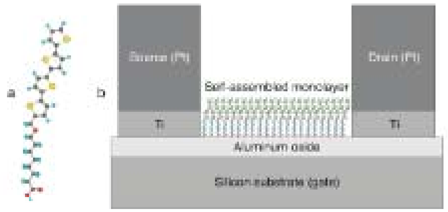


L < a few nm
t < a few nm

basic science
knowledge development

no foreseen applications
in a reasonable time-scale

Self-assembled molecular electronics



L ~ tens nm - µm
t < a few nm

basic science
knowledge development

possible applications
foreseen

Thin film molecular electronics

L > µm
t > few 10 nm

plastic electronics
(OLED, OFET, OPV)

some products already
commercialized

Example: Molecular electronics

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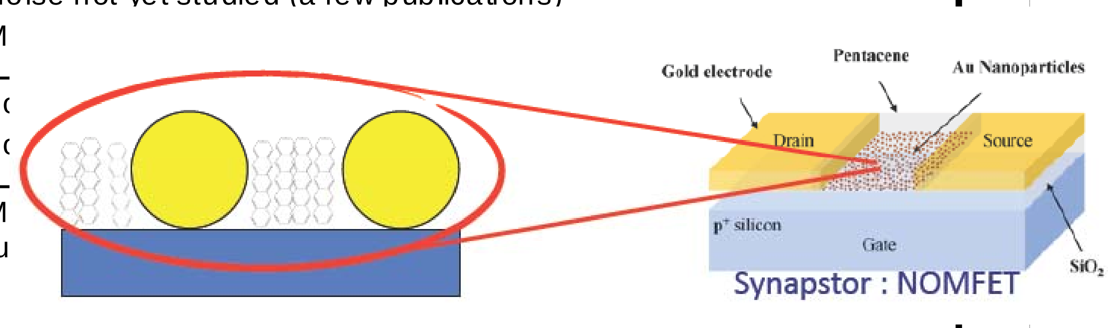
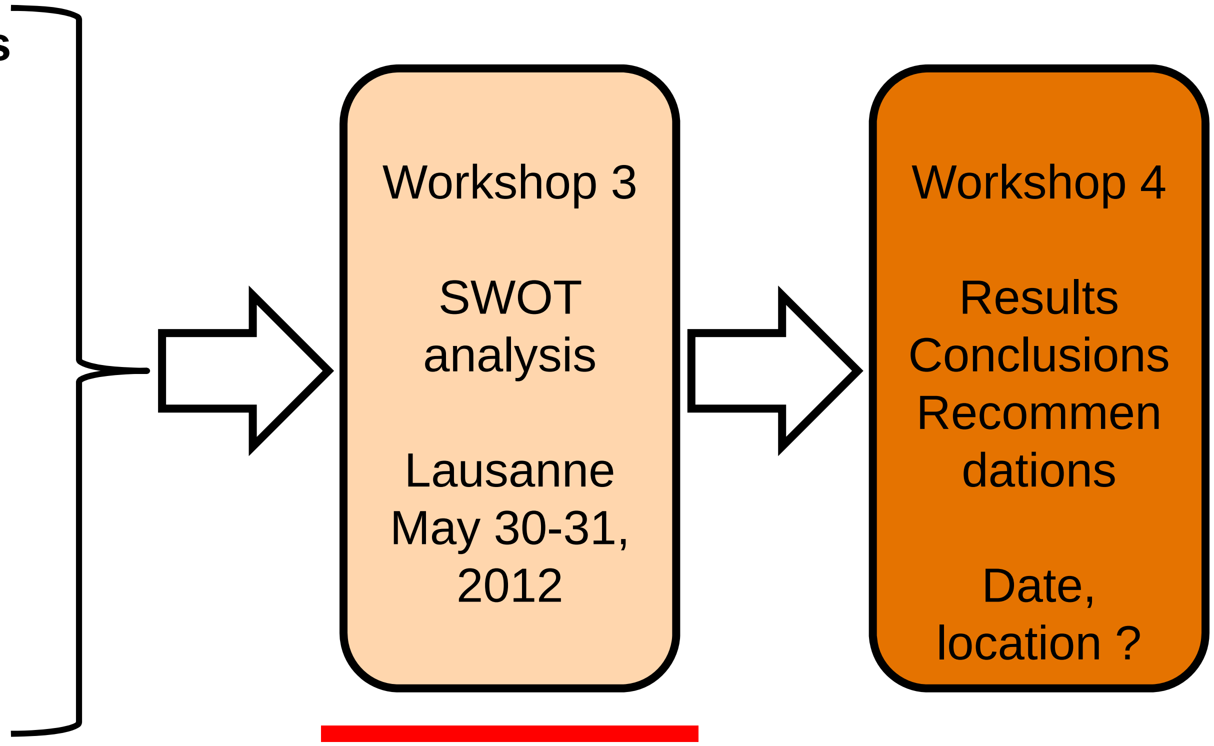
Benchmarking Beyond CMOS Devices

Technology	Molecular Electronics D. Vuillaume, CNRS & University of Lille
Gain **Signal/Noise ratio** **Non-linearity**	Ok with SAMFET (to be optimized), 2-terminal junction: low current Noise not yet studied (a few publications) M
Speed **Power consumption**	Lc Lc
Architecture/Integrability **(Inputs/outputs, digital, multilevel, analog, size etc.)**	M fu
Other specific properties	Almost infinite combination of molecules, adjustable by chemistry, specific design (1 molecule = 1 function)
Manufacturability **(Fabrication processes needed, tolerances etc.)**	Solution processing, compatible with flexible substrate. Defect control? Large variability (but not a problem if we envision artificial neural networks)
Timeline **(When exploitable or when foreseen in production)**	> 5 – 10 years (if ever?)



Benchmarking procedure

- **Molecular Electronics**
- **MEMS**
- **Solid-State Quantum Computing**
- **Spintronics**
- **Nanowires**
- **Memristors**
- **Graphene**



Conclusions

- **Technology/Emerging devices -> <- Architecture/Design**
  - **Quite apart**
- **Emerging device concepts: Not enough data for current design tools**
  - **Transfer functions, memory, intereconnects, tolerances, noise…**
- **Design tools have to develop towards multiscale approaches**
  - **Physics, non-Boolean, multilevel…**
- **Suitable benchmarking method for Beyond CMOS devices and architectures?**