Fault Simulation of Heterogeneous Integrated Biological Systems

H.G. Kerkhoff
&
X. Zhang

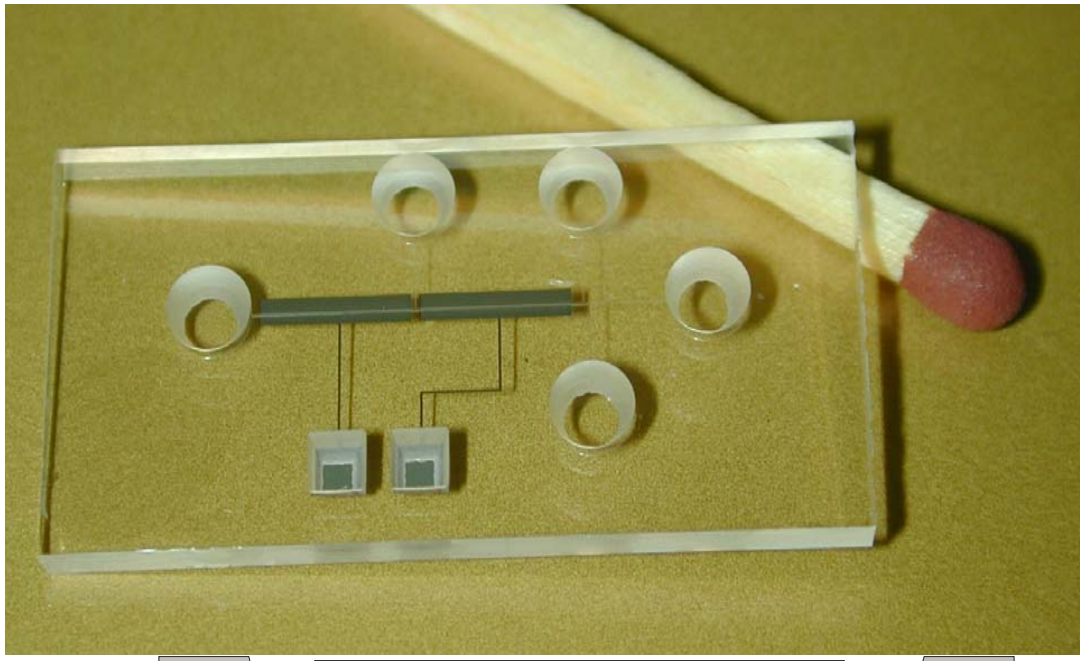
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

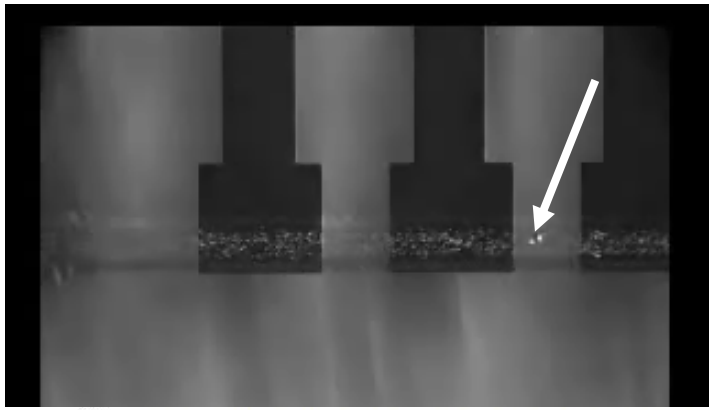
Contents

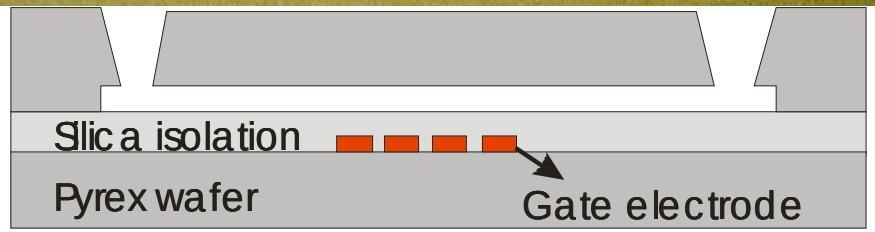
- Introduction
- Analog & digital microfluidics
- Integrated homogeneous systems
- Example: Peptide synthesis platform
- Test issues:
  fluidics, interface MEF & microelectronics
- Possible test solutions
- Joint VHDL-AMS fault-simulations for DfT
- Conclusions

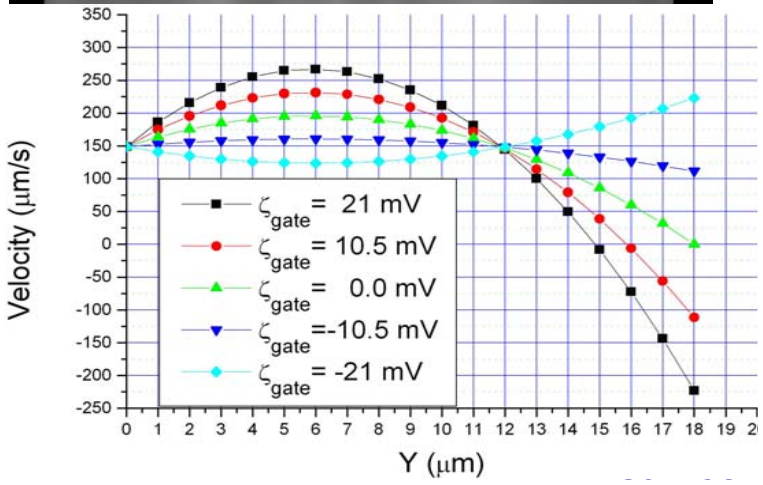
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Analog Microfluidics: EOF FlowFETs



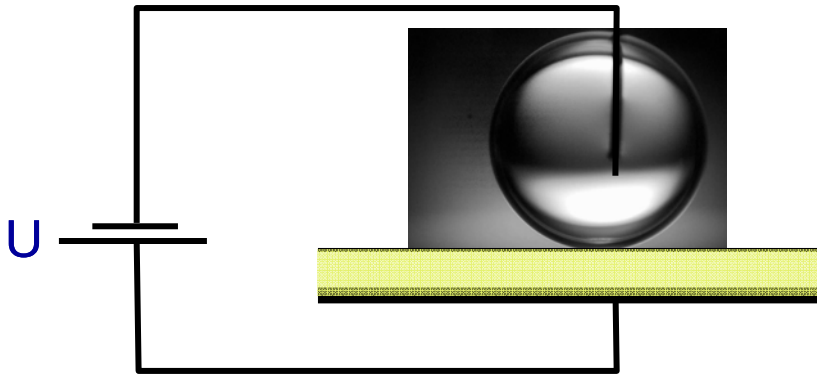






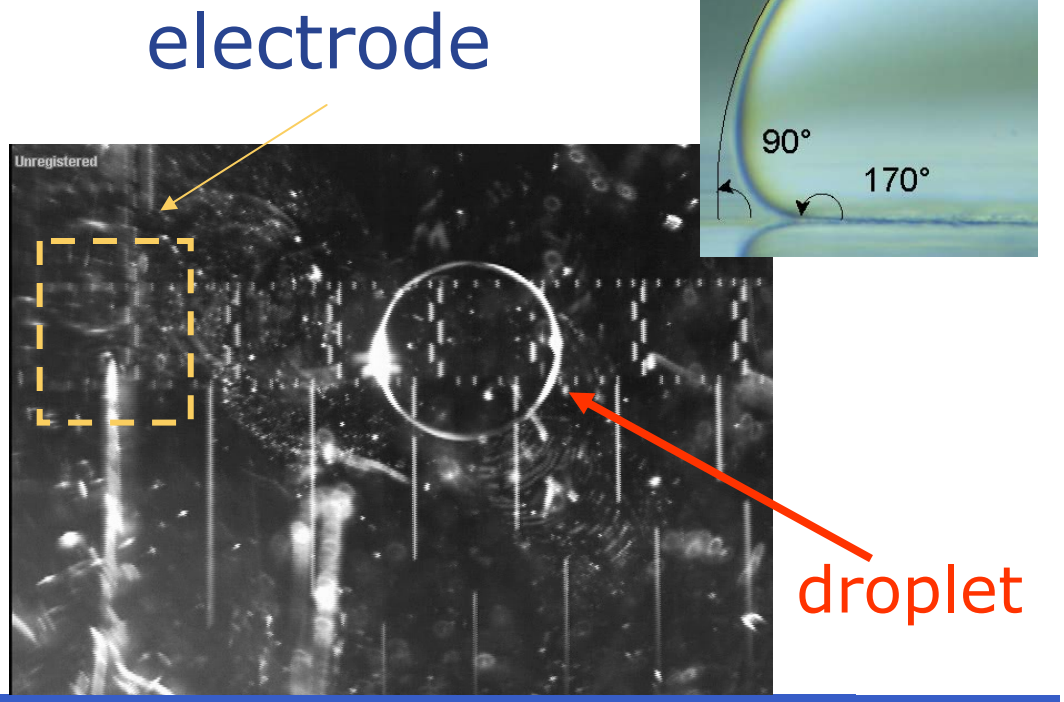
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Digital Microfluidics: EWOD Droplets



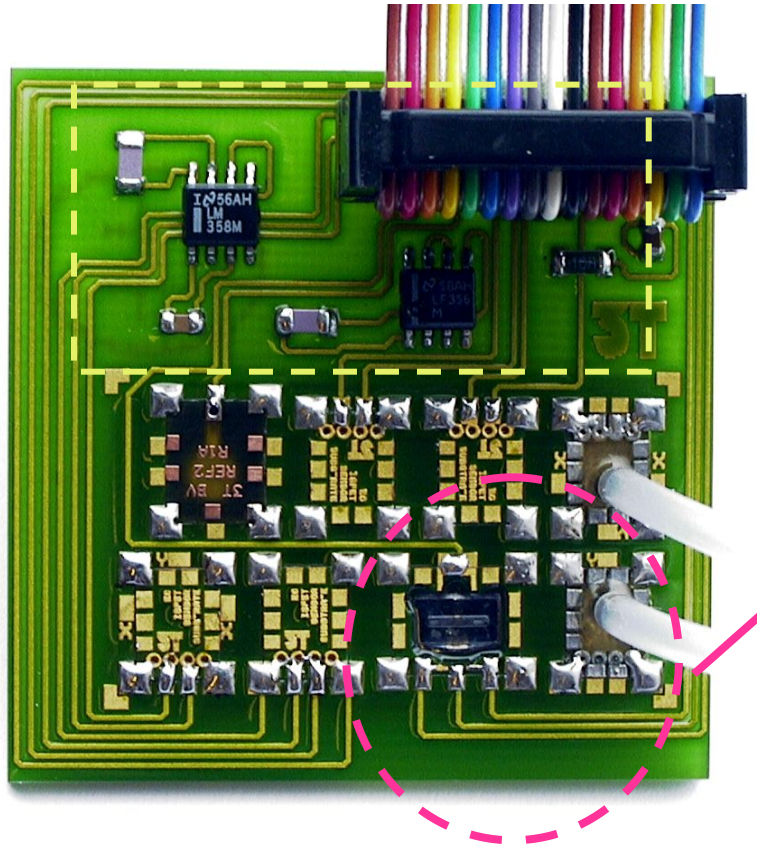
electrowetting equation:

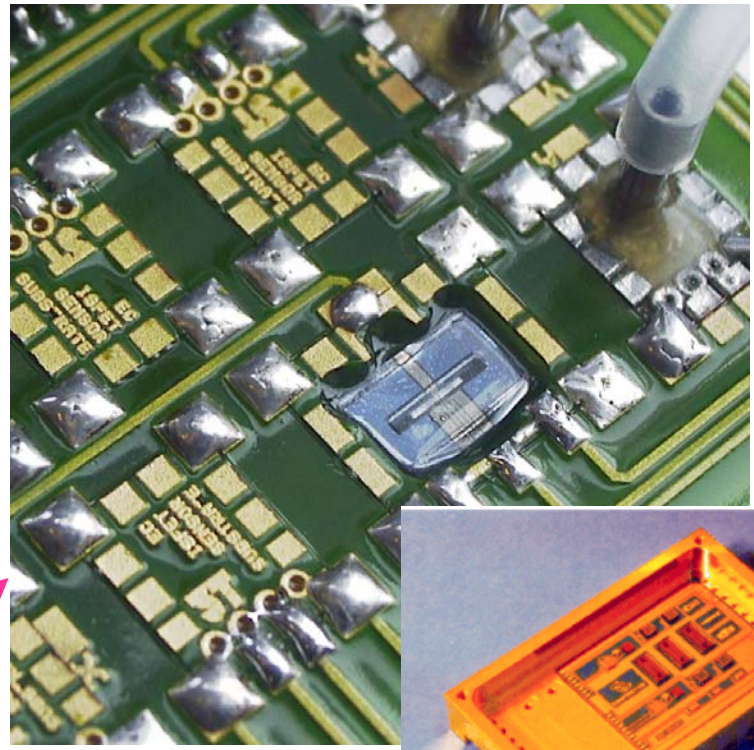
$$\cos(\theta(U)) = \cos\theta_Y + \underbrace{\frac{1}{2}\frac{\varepsilon_0\varepsilon}{d\sigma_{lv}}}_{\eta} U^2$$

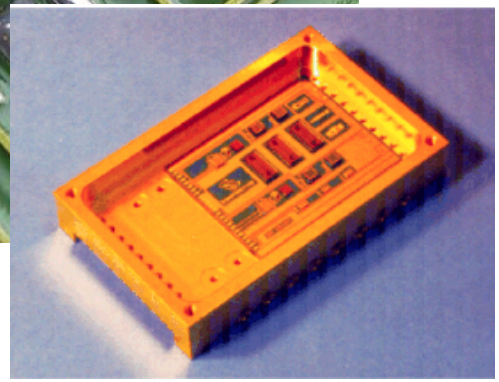


«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Previous „Integrated“ MEF Systems

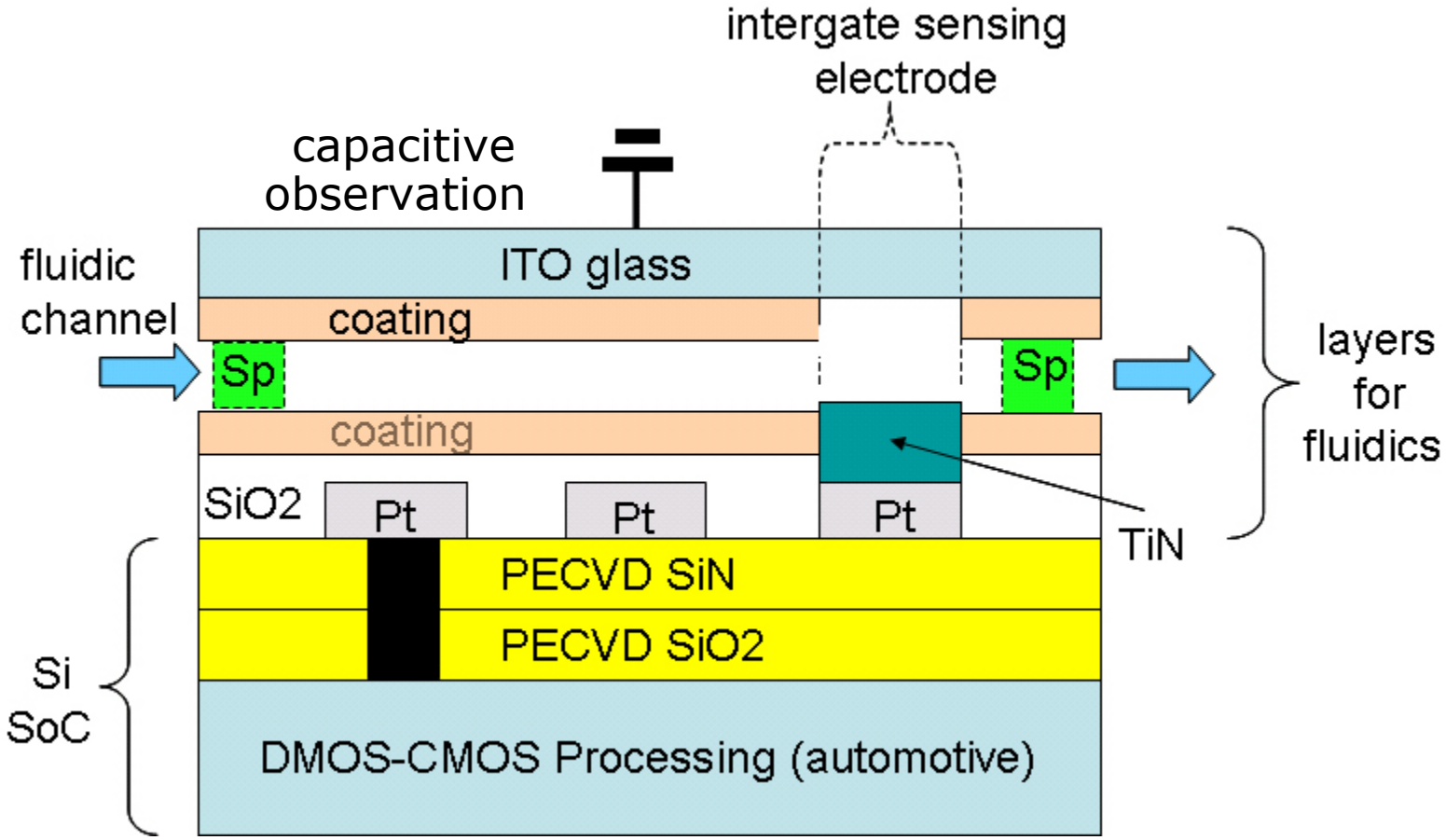






«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Integrated Homogenous MEF Construction



«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Features Heterogenous Integrated System

- Based on mainstream industrial (automotive) process of Philips Semiconductors (A-BCD3)+ BEP
- Uses 90nm CMOS processing capabilities
- Integrates 40V - 120V DMOS transistors for control
- Uses pizza-topping techniques for merging with fluidic parts; electrodes can be contacted with CMOS parts

Peptide Synthesis Fluidic Transport

- Use microfluidic structures for fluidic transport
- More flexibility & less parasitic effects
- Application to peptide synthesis > diseases
- Currently done at macro scale & very expensive

- Enables massive parallel synthesis
- Enables multiple different peptides
- Using e.g. SPOT & Fomoc techniques

- Nice self-testing & repair features

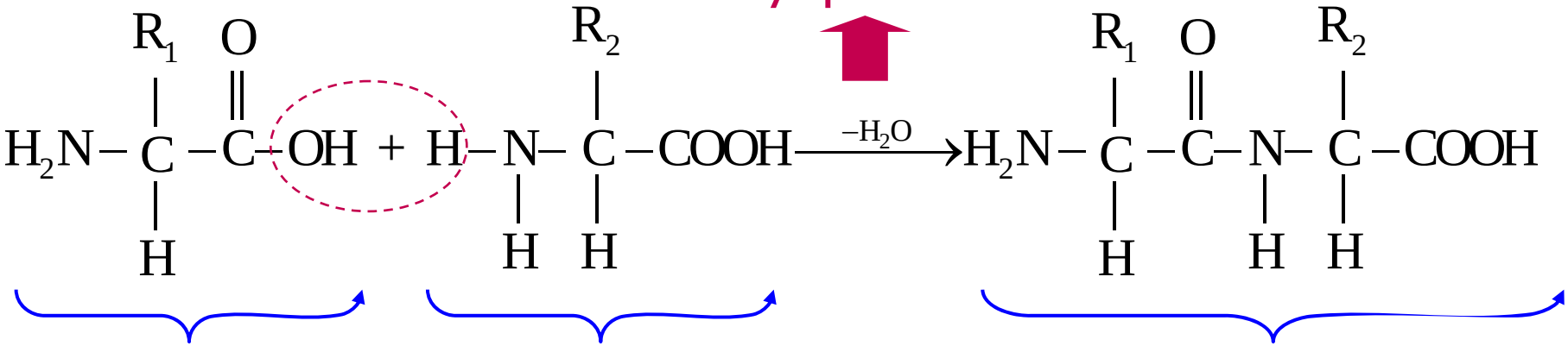
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Peptide Synthesis Principle

Now: 7-stage peptides for EB & Pfeifer virus detection

Formation of the peptide bond

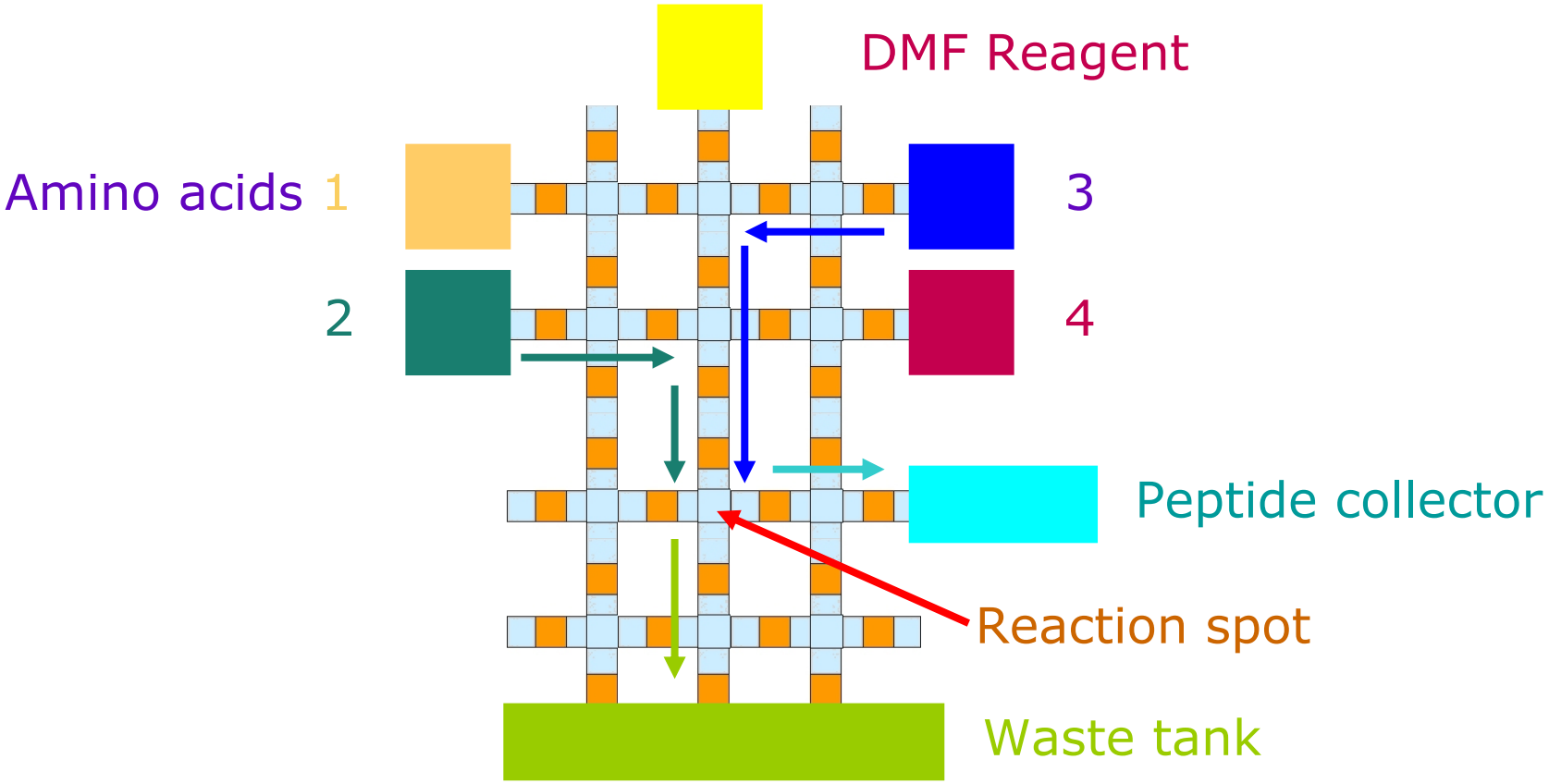
by-product



Amino acid R1 Amino acid R2 Mono Peptide

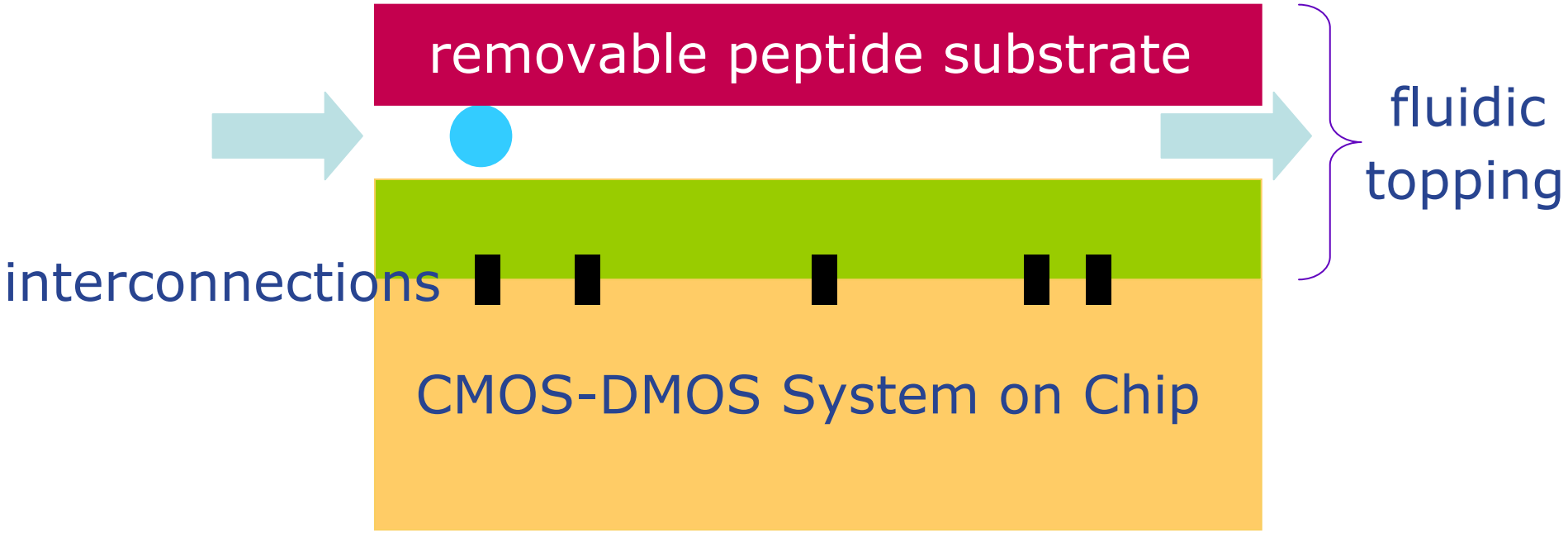
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Symbolic Scheme Peptide Synthesizer

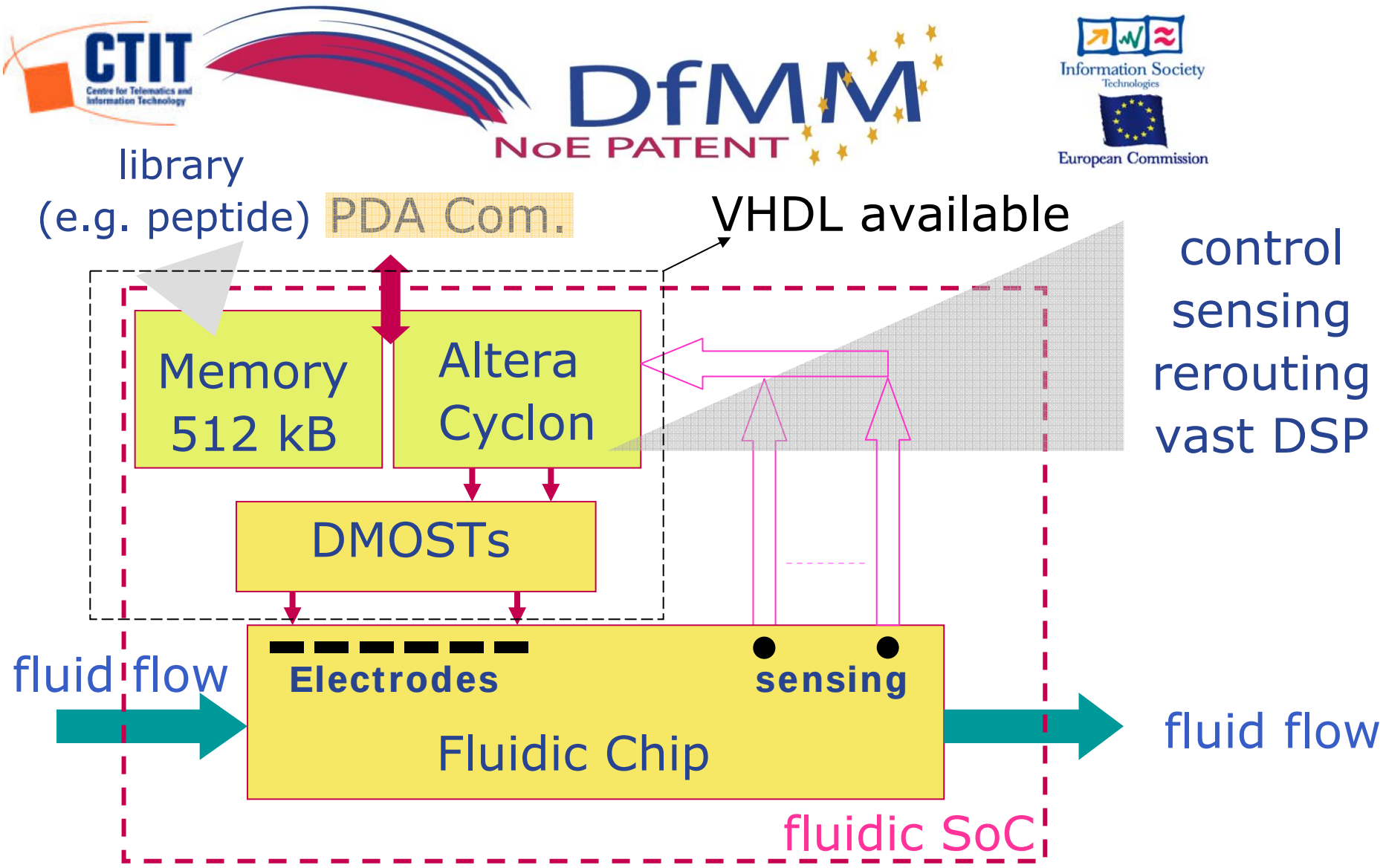


«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Heterogeneous Integrated Fluidic Chip

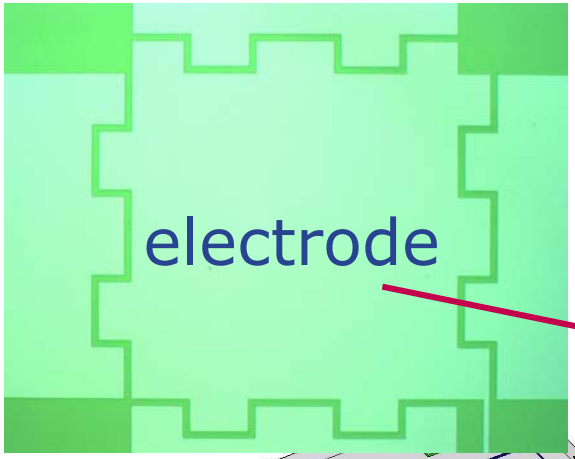


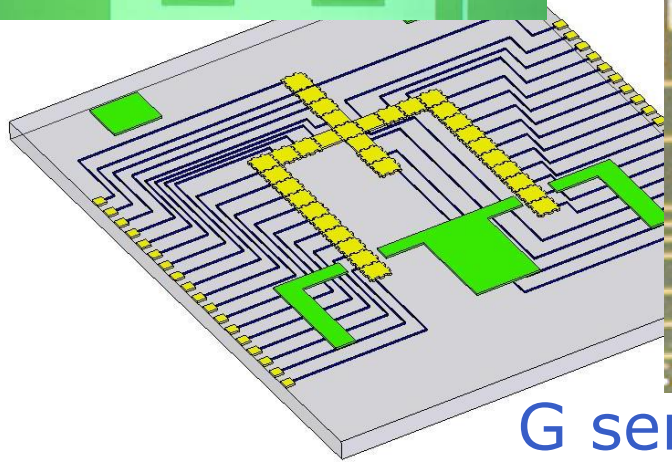
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

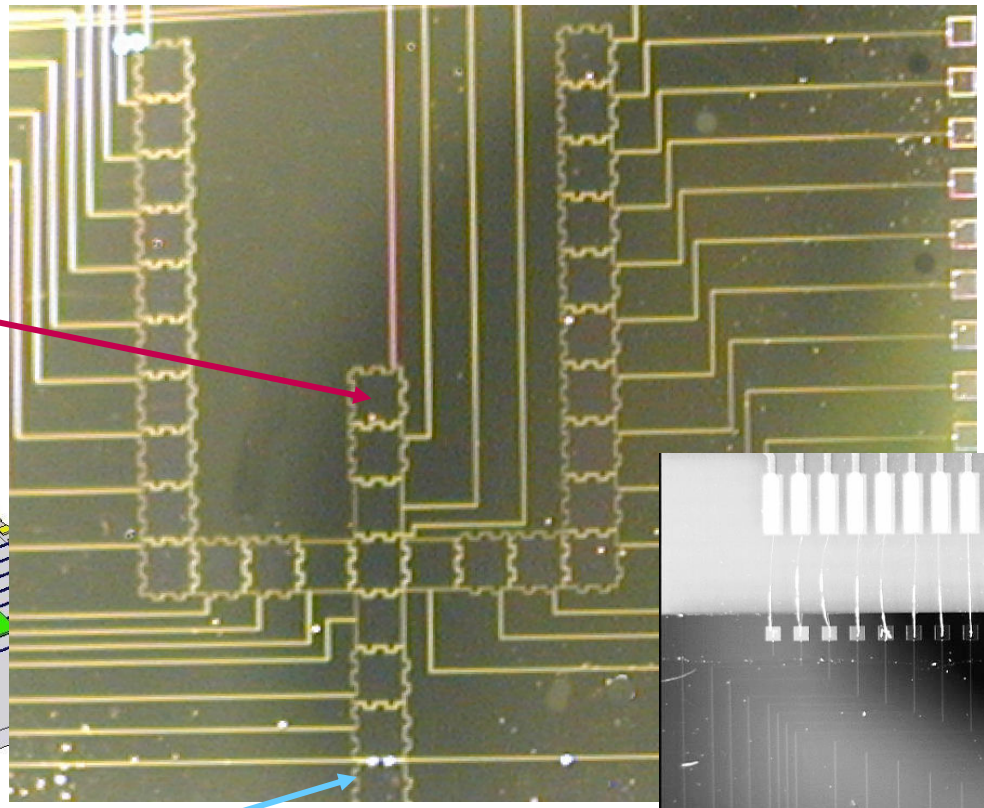


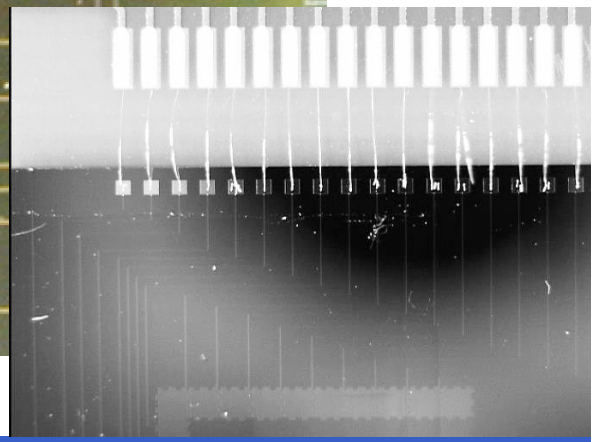
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Layout / Implementation of Fluidic A-BCD3 Chip



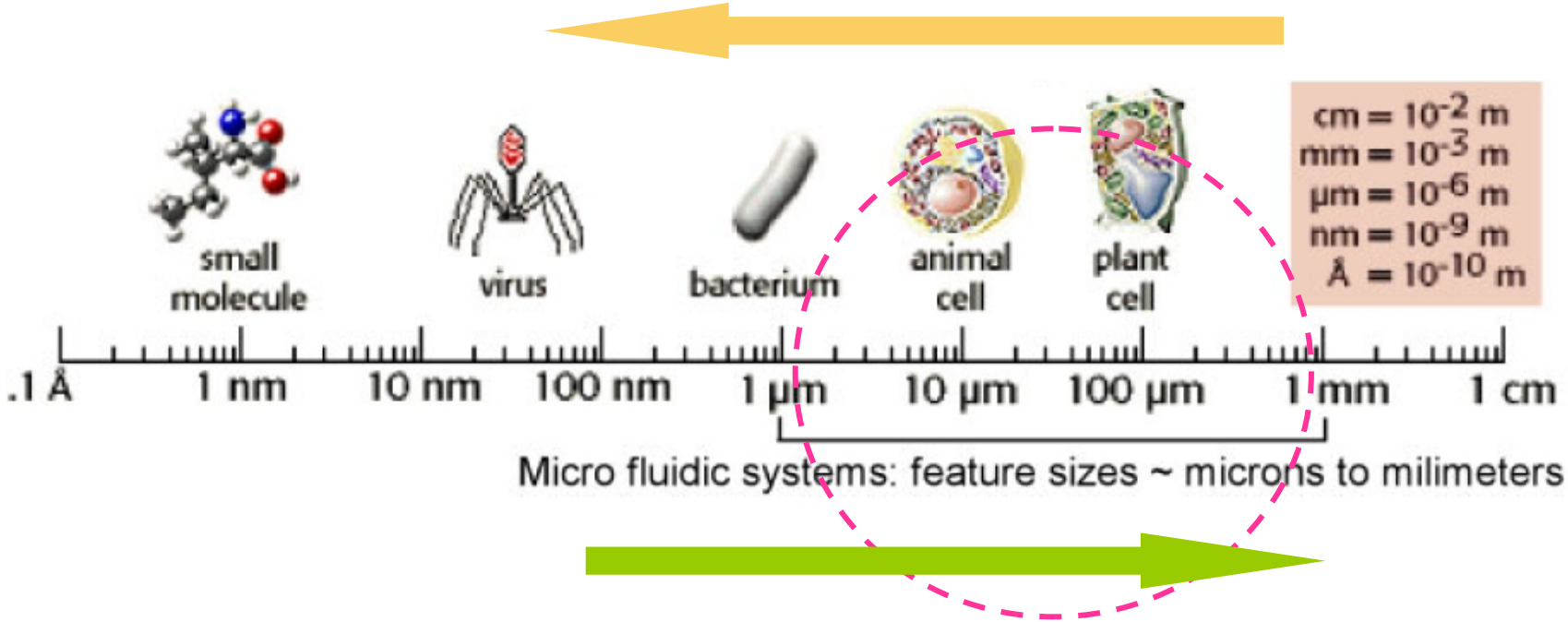






«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

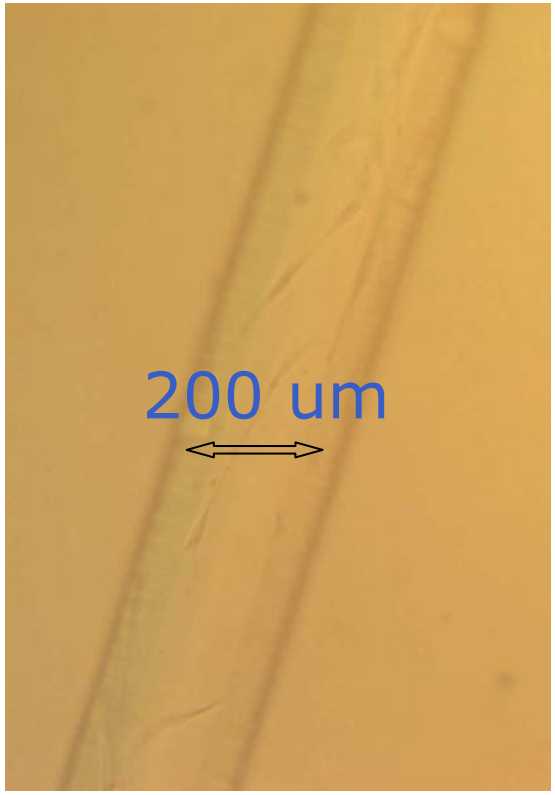
Different Sizes in Bio Systems

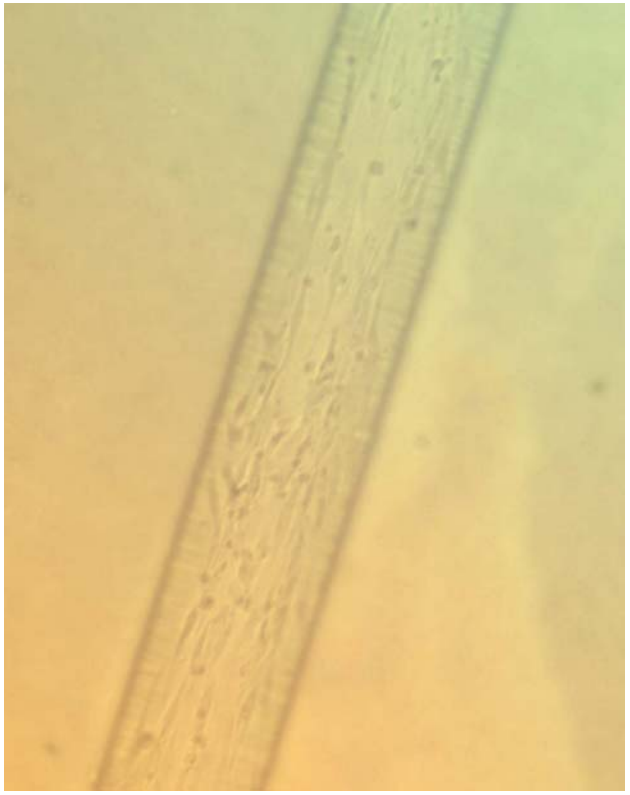


Contamination in biomaterial -> clog

«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Time-Dependent Faults in Bio Systems

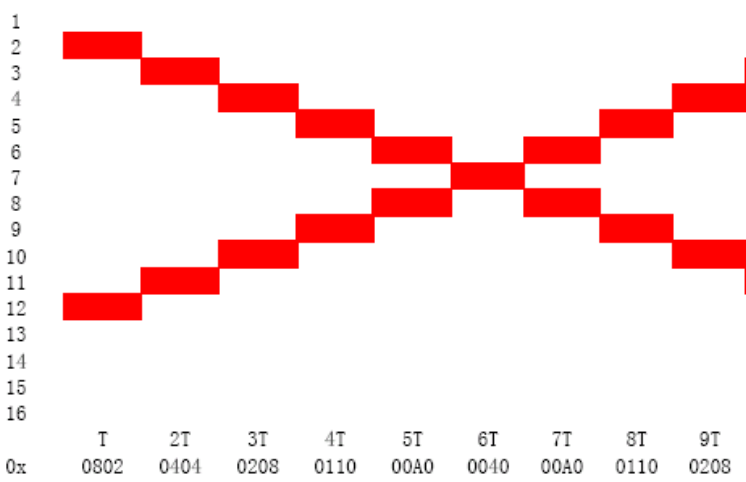




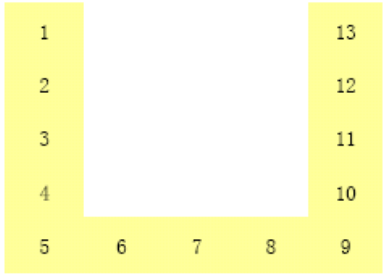
Contamination in biomaterial -> clog

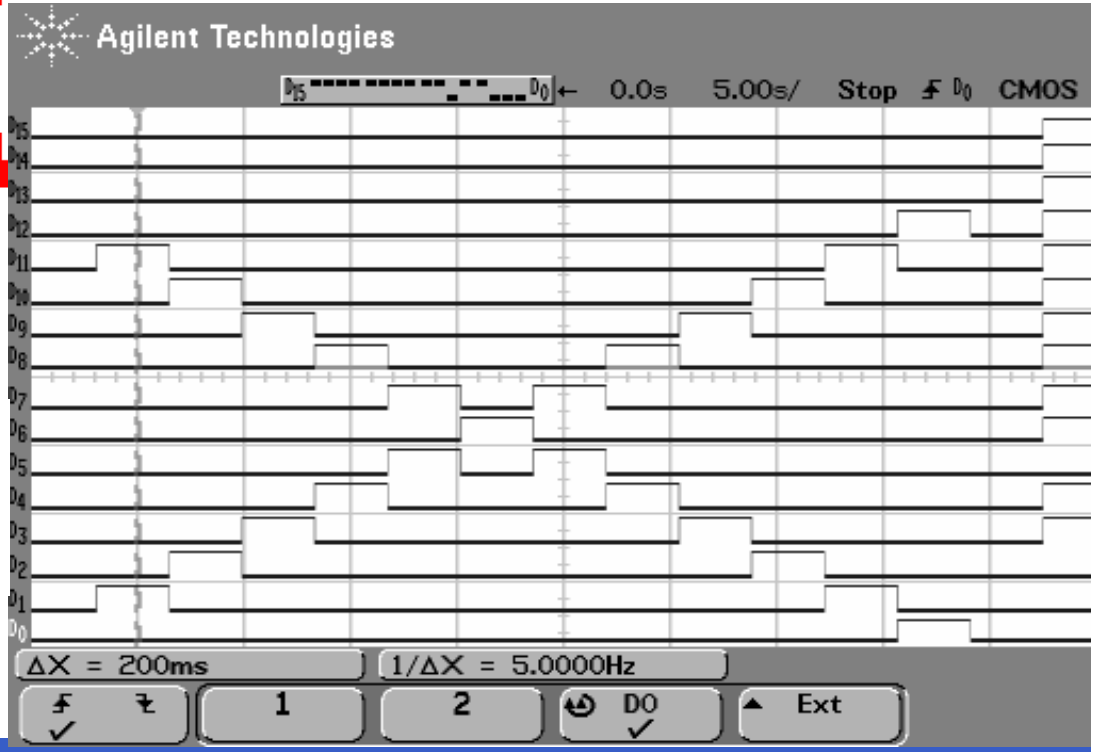
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Testing Scheme Cycle of MEF System



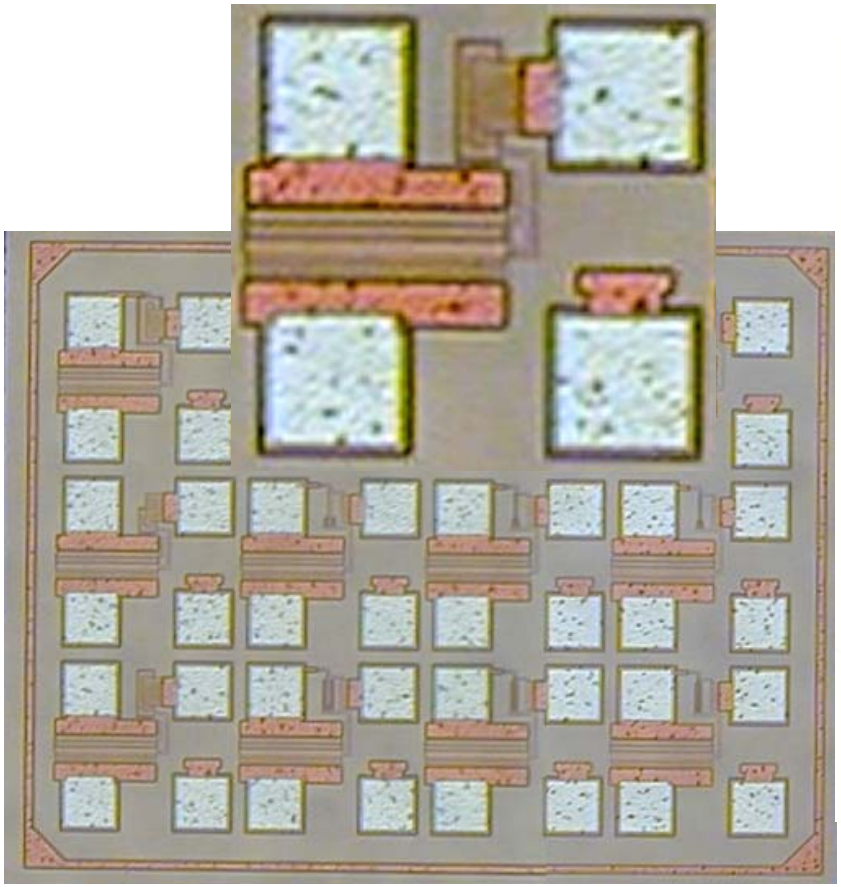
Electrode layout

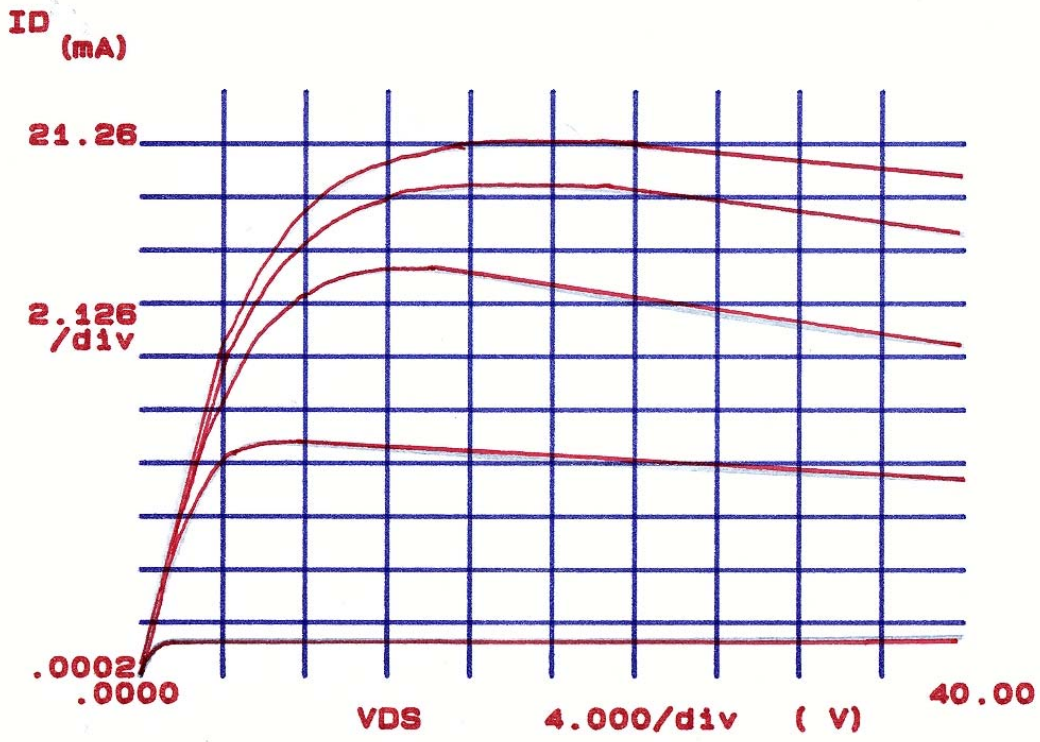




«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

The Used DMOS A-BCD3 Transistors

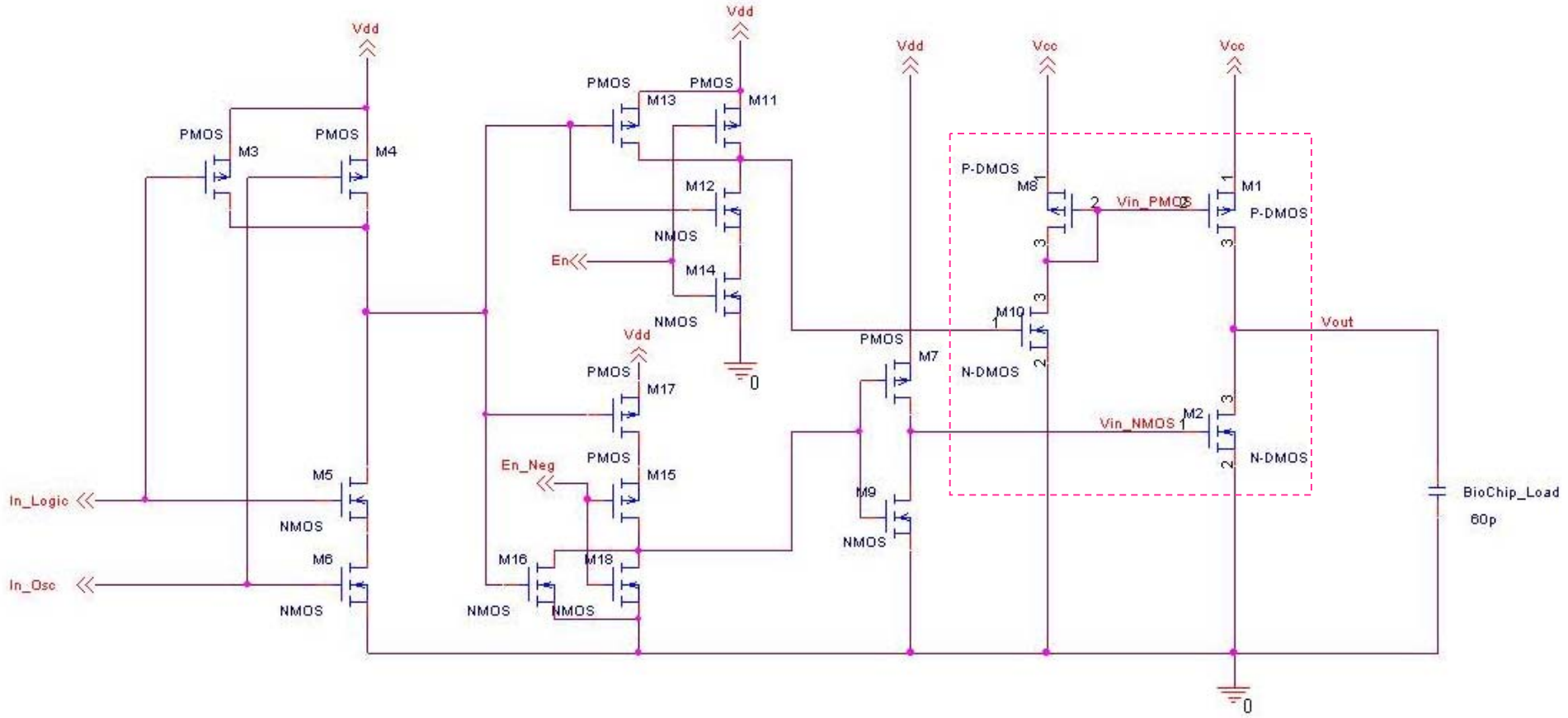




Courtesy of
Philips Semiconductors

«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

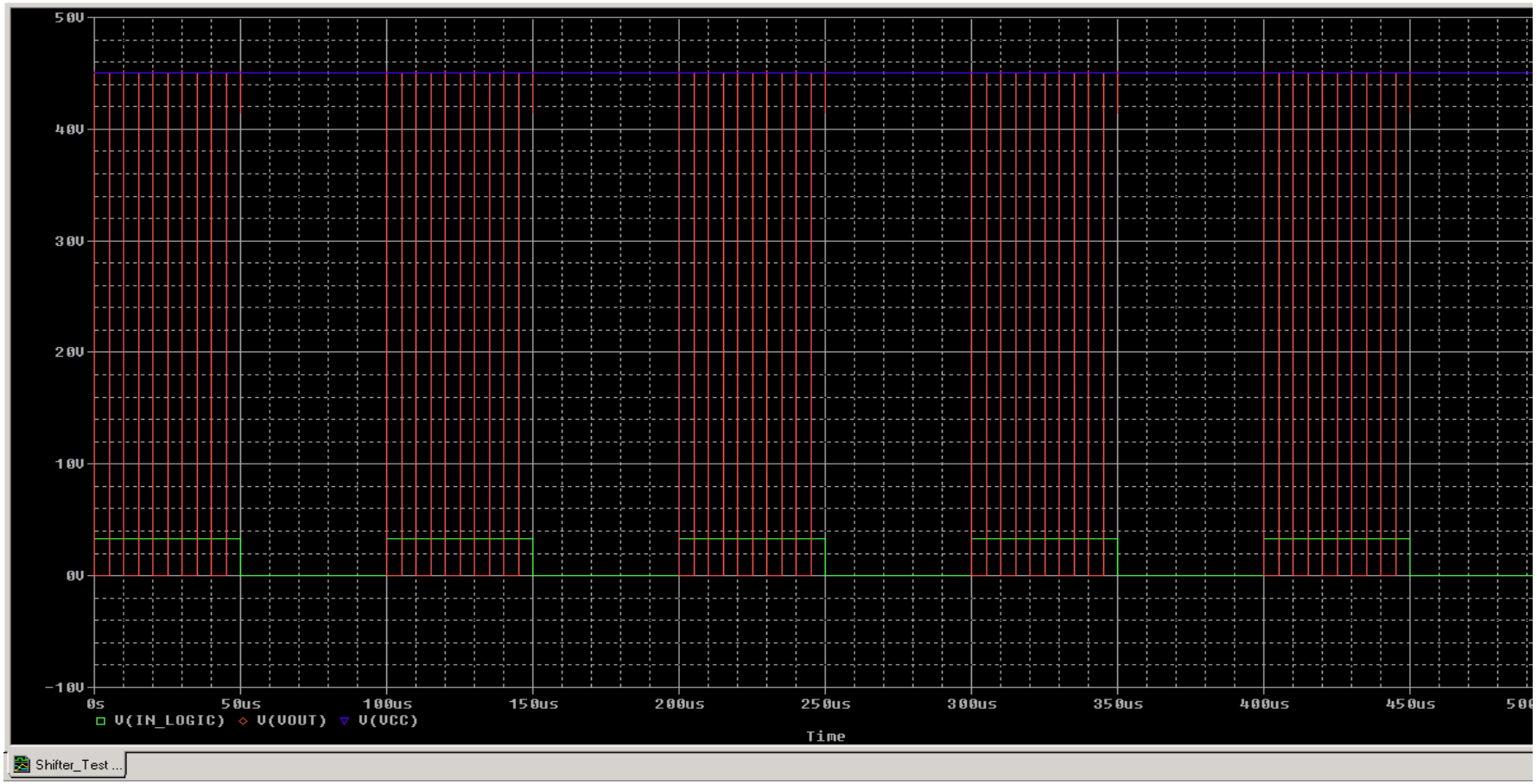
DMOS Tristate Fluidic Control Scheme



«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»

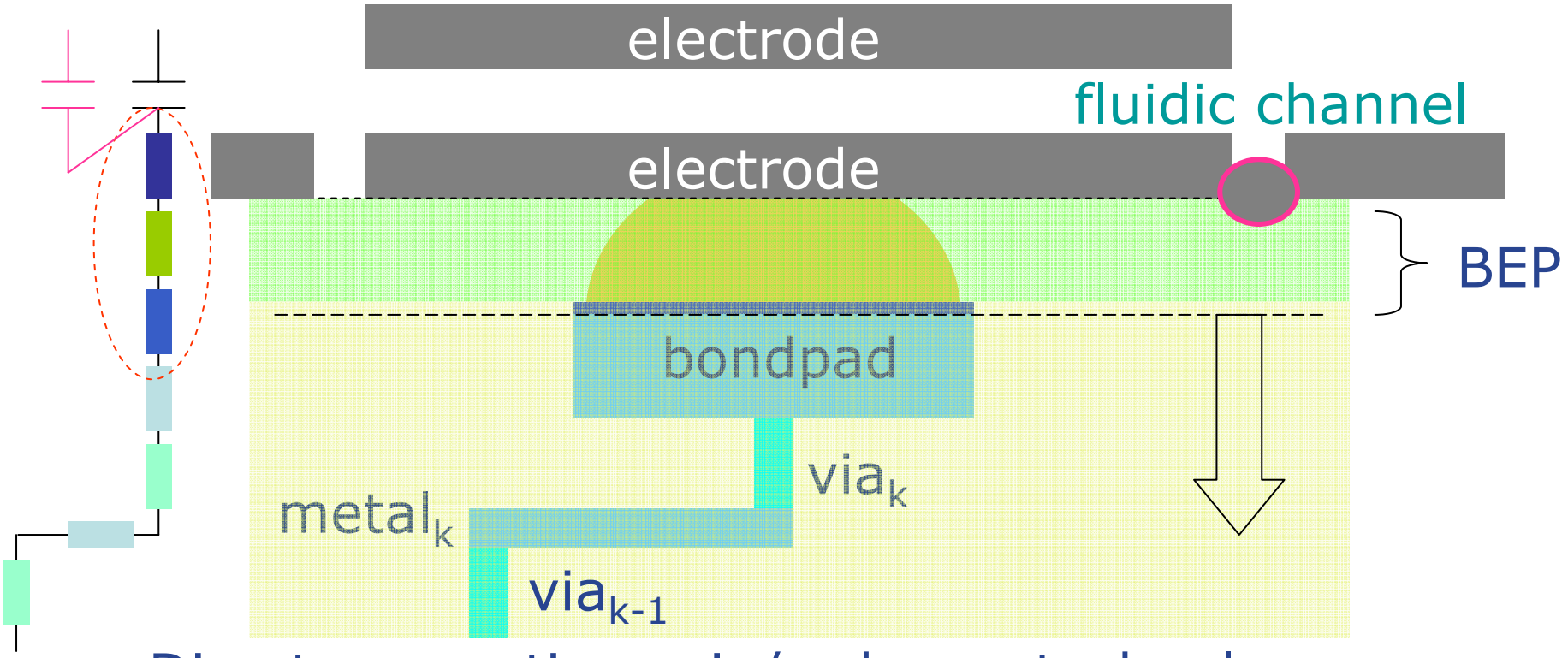
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

DMOS Control Behaviour



«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

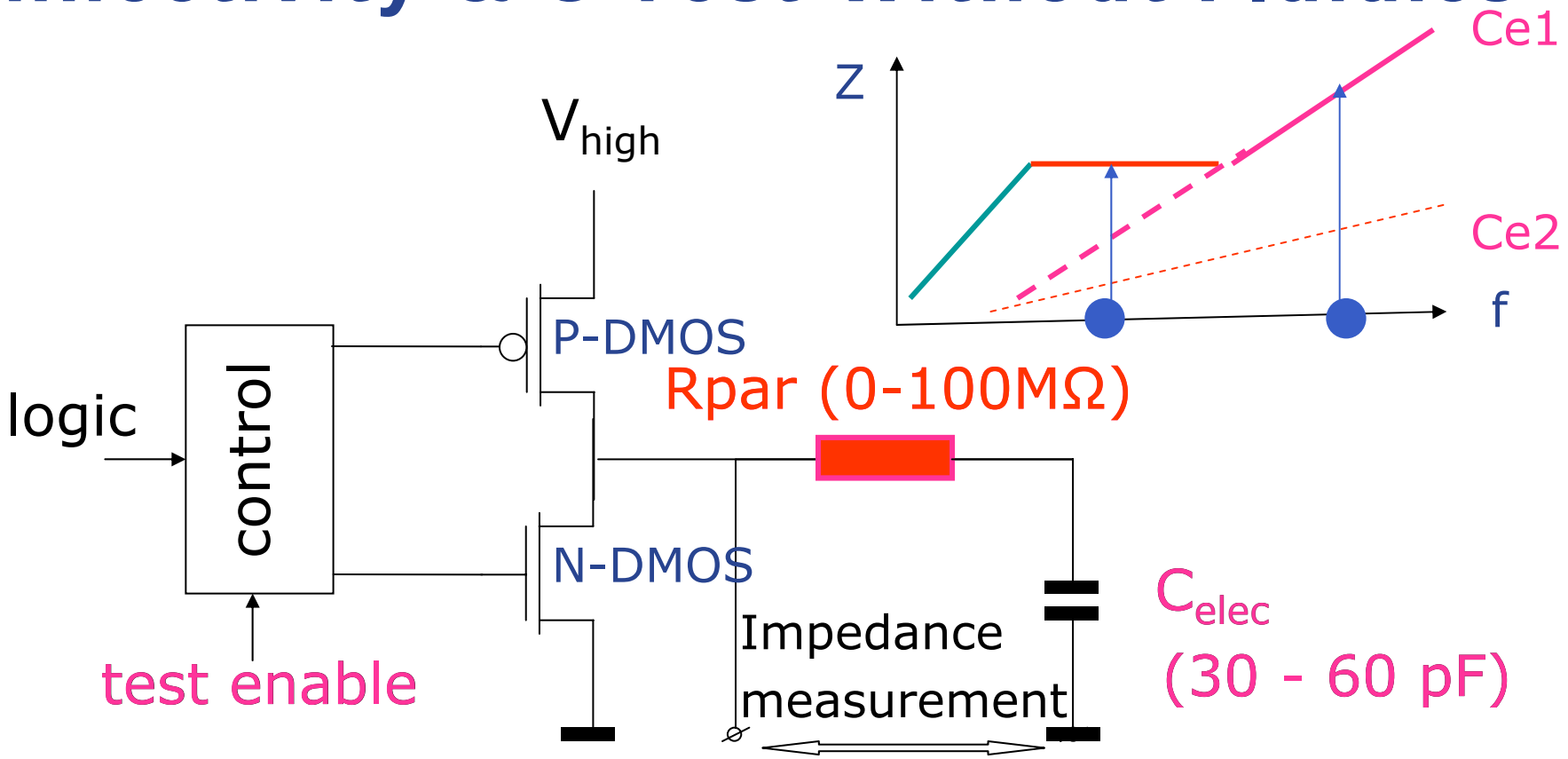
Critical: SoC to Fluidic Connections



Direct connections via/or bump technology

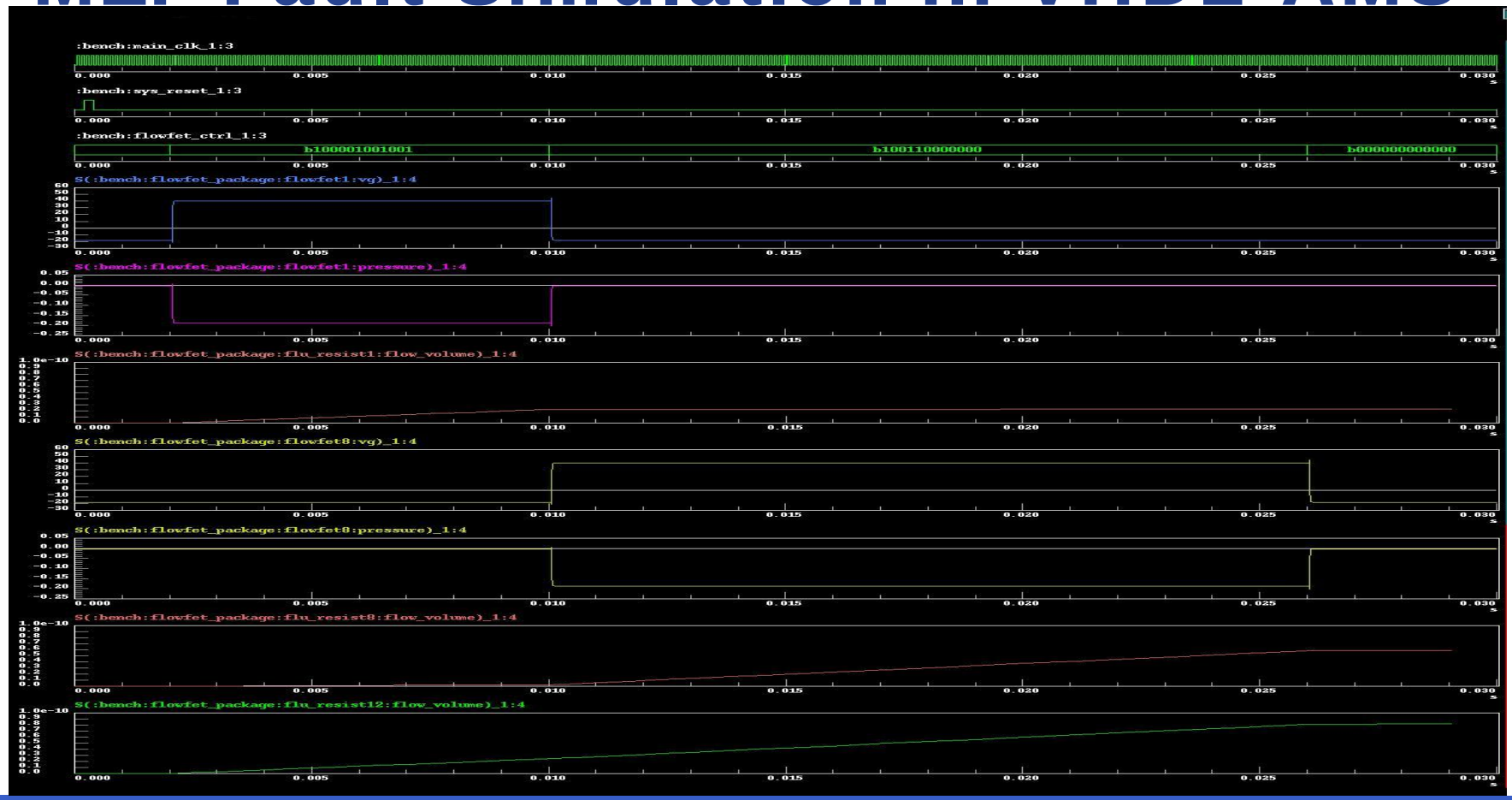
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Connectivity & C Test Without Fluidics



«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

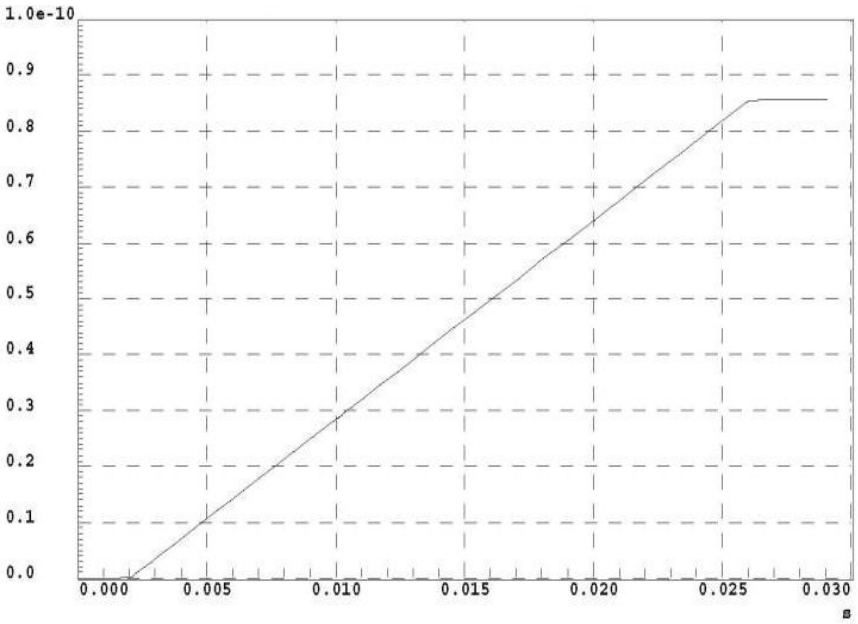
MEF Fault Simulation in VHDL-AMS



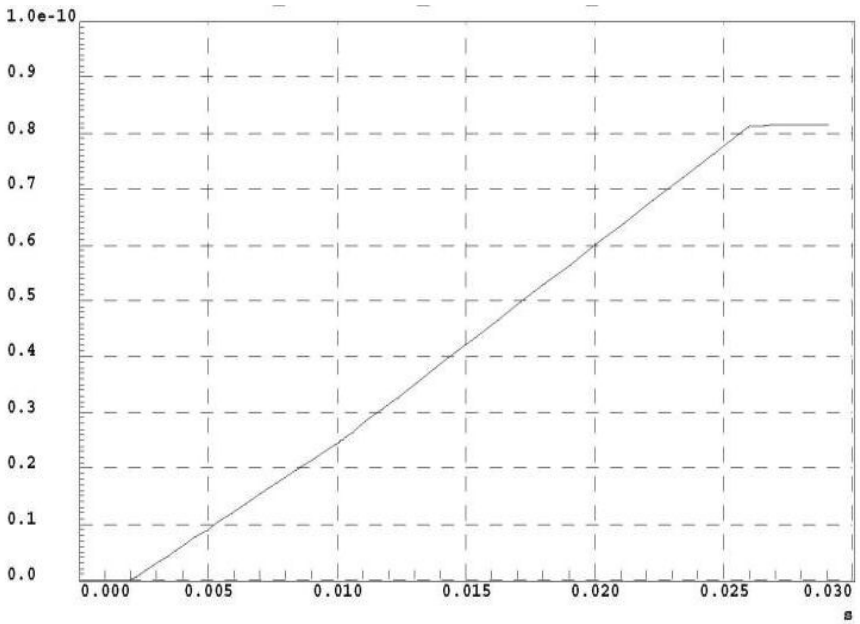
«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»

Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Differences Due to Bio Clog in VHDL-AMS



Fault-free



Faulty

«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

Conclusions

- Designed, implemented and tested a programmable Micro-Electronic Fluidic array, proven for bio applications and ready for heterogeneous integration
- Used fluidic FEM & HDL modelling, simulation and System-on-Chip tools for joint fault simulation
- Helps to find the influence of defects in both domains
- New detection and control electronics are being developed for testing and the system itself
- Promising, innovative industrial applications

Questions ?

«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)