



# NanoElectronics Roadmap for Europe: Identification and Dissemination

Athens, April 6/7, 2017

WP6 - Markus Pfeffer (Fraunhofer IISB)



# Outline

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- ❖ Nereid WP6
  - Equipment and materials
  - Manufacturing Science
- ❖ Review of parallel road mapping initiatives
- ❖ NEREID WP6 Roadmap
- ❖ Lessons learned from Domain workshops
- ❖ Summary and Conclusions

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## Task 6.1 Equipment and Materials (imec)

- ❖ **Processing tools and high quality materials** have been the **key enabling factors** in the evolution of Nanoelectronics. One of the major successes of ITRS has been the capability to insure the **timely availability of equipment and materials for the next technology node**, by insuring to manufacturers the long term visibility needed to allocate the R&D investments to guarantee the continuation of the Moore's Law.
- ❖ The objective of this task is to extend this benefit to the increased complexity and variety of technologies developed **not only for 'More than Moore' but also for nanoscale FET and Beyond CMOS**, covered in this European roadmap
- ❖ A close cooperation will be established between device and process developers, on one side, and equipment and materials supplier on the other side.

## Task 6.2 Manufacturing Science (Fraunhofer)

- ❖ The **scaling** down of the MOS transistor has driven the progress in the ICs **performance** and the **cost per function** of the devices has dropped accordingly.
- ❖ For complex devices, the **decrease of the cost per functions** is achieved by the **development of derivative options** on top of the core processes and the **integration of heterogeneous processes**. This leads to increasingly complex line management driven by **many process generations, multiple products with short life cycle and high variability** in terms of demand.
- ❖ The roadmap aims to activate a converging network of experience and competency involving the academic community for the development of new tools and methods for **fab productivity** needed to **increase efficiency** in the fab by managing **cycle time, advancing equipment and process control and yield enhancement** by providing a reference schedule.

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# Review of parallel road mapping initiatives - ITRS

## ITRS 2.0



INTERNATIONAL  
TECHNOLOGY ROADMAP  
FOR  
SEMICONDUCTORS 2.0

2015 EDITION

FACTORY INTEGRATION

THE ITRS IS DEvised AND INTENDED FOR TECHNOLOGY ASSESSMENT ONLY AND IS WITHOUT REGARD TO ANY COMMERCIAL CONSIDERATIONS PERTAINING TO INDIVIDUAL PRODUCTS OR EQUIPMENT.

THE INTERNATIONAL TECHNOLOGY ROADMAP FOR SEMICONDUCTORS 2.0: 2015



INTERNATIONAL  
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2015 EDITION

YIELD ENHANCEMENT

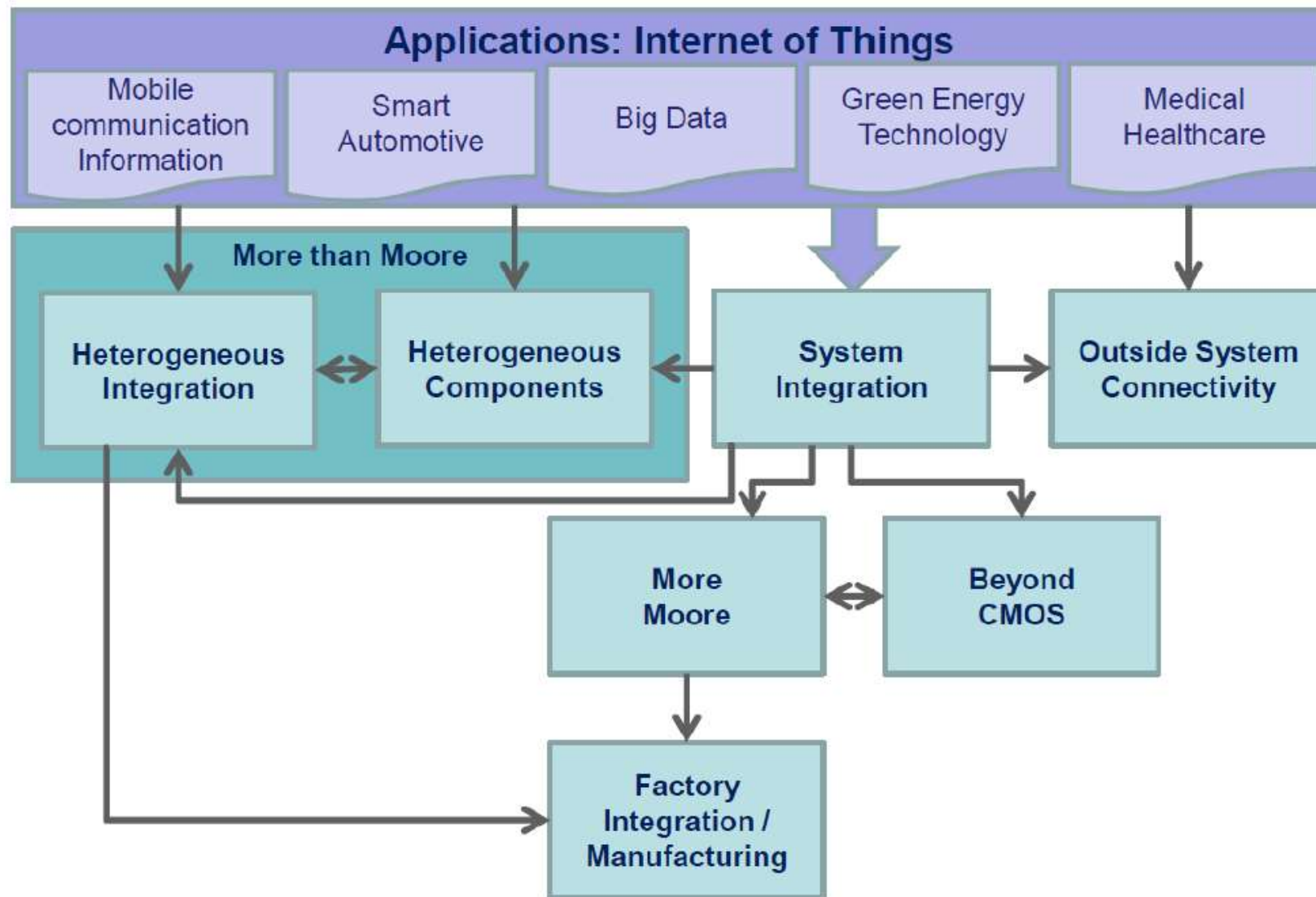
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THE INTERNATIONAL TECHNOLOGY ROADMAP FOR SEMICONDUCTORS 2.0: 2015

# Review of parallel road mapping initiatives - ITRS

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# Review of parallel road mapping initiatives - IRDS



WP6 - Athens, April 7, 2017

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## NEREID WP6 Roadmap - The start

Concepts/Technologies	Medium term: 5+	Long term: 10+
<b>i) Concept 1: More Moore</b>		
a) Key research questions or issues		
<i>nanoscale FET CMOS</i>		
- Si based technology	X	
- Si(Ge) to Ge	X	X
- III/V		X
<i>Interconnects</i>		
- Advanced low-k to airgap	X	
- Cu based (including liner / barrier)	X	
- Beyond Cu metallization		X

## NEREID WP6 Roadmap - The start

Concepts/Technologies	Medium term: 5+	Long term: 10+
<b>i) Concept 1: More Moore</b>		
a) Key research questions or issues		
<i>emerging devices beyond CMOS</i>		
- Tunneling FET (conventional materials)	X	
- tunneling FET (2D materials)		X
- from charge based to spin based		X
<i>computing paradigms</i>		
- Quantum computing		X
- Neuromorphic		X

## NEREID WP6 Roadmap - The start

Concepts/Technologies	Medium term: 5+	Long term: 10+
<b>i) Concept 1: More Moore</b>		
b) Potential for application or Application needs and Impact for Europe		
<i>The feeling exist that with the worldwide effort on materials, processes and manufacturing in the domain of More Moore, the imminent needs of European application domains is covered – but in certain domains (e.g. litho) Europe is playing leading role)</i>	X	X

## NEREID WP6 Roadmap - The start

Concepts/Technologies	Medium term: 5+	Long term: 10+
<b>i) Concept 1: More Moore</b>		
c) Technology and design challenges --> Material and Process Technology Challenges	X	X
<i>Advanced Surface Passivation / defect passivation (new materials, scaled technologies)</i>		
<i>Material / thin film growth</i>		
- Conventional semiconductor technologies	X	
- 2D materials		X
- Spin based materials / stacking		X
<i>Patterning</i>		
- Area Selective Deposition	X	
- Area Selective Etching	X	
- EUVL	X	
- DSA based litho	X	

## NEREID WP6 Roadmap - The start

Concepts/Technologies	Medium term: 5+	Long term: 10+
<b>i) Concept 1: More Moore</b>		
d) Definition of FoMs (quantative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)		
e) Other issues and challenges, and interaction with other Tasks/WPs.		

➔ Lessons learned from Domain workshops

## NEREID WP6 Roadmap - The current work

Concepts/Technologies	Medium term: 5+	Long term: 10+
<b>ii) Concept 2: More than Moore</b>		
a) Key research questions or issues		
<i>Sensors</i>		
<i>Energy</i>		
b) Potential for application or Application needs and Impact for Europe		
c) Technology and design challenges --> Material and Process Technology Challenges		
d) Definition of FoMs (quantative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)		
e) Other issues and challenges, and interaction with other Tasks/WPs.		

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# Lessons learned from Domain workshops (1/2)

After consultation with technical experts of WP6, we came to the following intermediate conclusions:

- ❖ Concurrent WP's should analyze their domain in view of the presented applications and derive **immediate and long term requirements in terms of materials, processes and manufacturing needs**. WP's should provide a SWOT analysis of their domain in view of needs / opportunities for materials, processes and manufacturing to serve their application domains.
- ❖ The feeling exist that with the worldwide effort on materials, processes and manufacturing in the domain of More Moore, the imminent needs of European application domains is covered. However, more **specific needs in the other NEREID domains** need to be identified.

# Lessons learned from Domain workshops (2/2)

WP6 presented a first summary table of materials and processes. Important is to rank / evaluate the content in view of 'impact for Europe', as well as current 'position for applications' in Europe.

- ❖ Cover activities in WP6 roadmap where Europe is leading in terms of materials, processes and manufacturing, but where the demand from application side is stronger outside of Europe (e.g. EUV litho)
- ❖ Cover activities in WP6 where application wise Europe is leading, but where specific needs for materials, process and manufacturing require continued attention (e.g. OLED)

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# Summary and Conclusions

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Based on the aforementioned learnings, WP6 can proceed as WP 6 is not an autonomous work package.

- ❖ The application specific requirements for materials, processes and manufacturing are best covered within the roadmap of the WP's
- ❖ The WP6 roadmap should / will concentrate on the domains not covered – but relevant for Europe