MONA
Merging Optics & Nanotechnologies

EU MONA Project – Merging Optics and Nanotechnologies: Report on 5-10 years roadmap on equipment and processes

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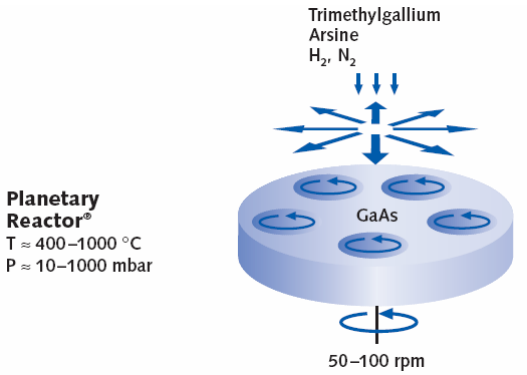
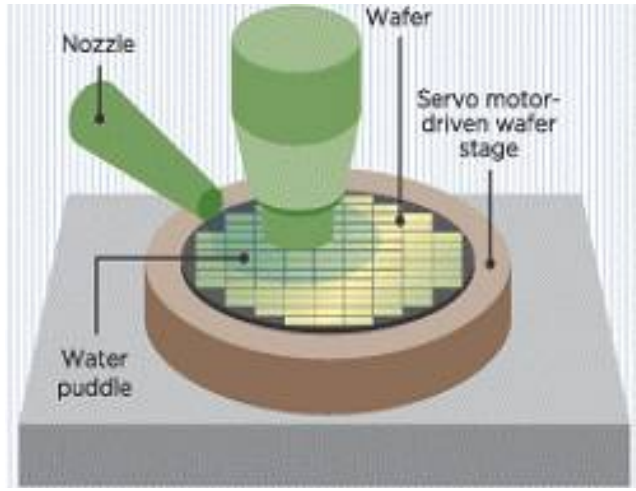
Outline

- Some examples of nanostructuring techniques
- Key issues related to manufacturing of nanophotonic devices
- Applications requiring specific bottom up equipment/processes
- Applications requiring specific top down equipment/processes
- Equipment maturity and potential for mass production
- Roadmaps
- Summary

Examples of Nanostructuring Techniques

- Top-Down
  - Lithography
  - Nanoimprint & Soft Lithography
  - Etching





- Bottom-Up
  - Thin films (MOCVD, MBE, ALD etc.)
  - Self Assembly
  - Printing

Key issues - manufacturing

- How could the fabrication of photonics devices converge with CMOS fabrication?
- How could specific photonics devices fabrication processes reach mass production?
- How to mix bottom-up and top-down approaches for the fabrication of nanostructures?
- Bridging the micro-nano gap: connecting the microworld to the nanoworld

Basis of Data to be Presented

- The data in this presentation has been extracted from the materials, applications and equpiment sub-roadmaps.

Applications Requiring Specific Bottom-up Equipment/Processes

	Telecom/ datacom	Sensors/ detectors	Optical interc.	Lighting	Photo-voltaics	Displays	Instr./ metrology	Data storage
MOCVD	X	X	X	X	X			X
MBE	X	X	X	X	X			X
CNT CVD						X		
SiOx CVD			X					
HVPE				X				
Direct nanoparticle deposition	X							
Colloidal chemical synthesis	X	X	X	X	X	X	X	X
Laser ablation CNT	X							
Nanophosphor fabrication				X				
Sol-gel synthesis						X		
II-IV Pyrolysis						X		
TiO_2 nanoparticle formation					X			
Electrodeposition ZnO				X				
VPD of ZnO				X				
Spin coating					X			
Ink jet printing						X		
OVPD				X	X			
Pulsed laser ablation		X						

Applications Requiring Specific Top-Down Equipment/Processes

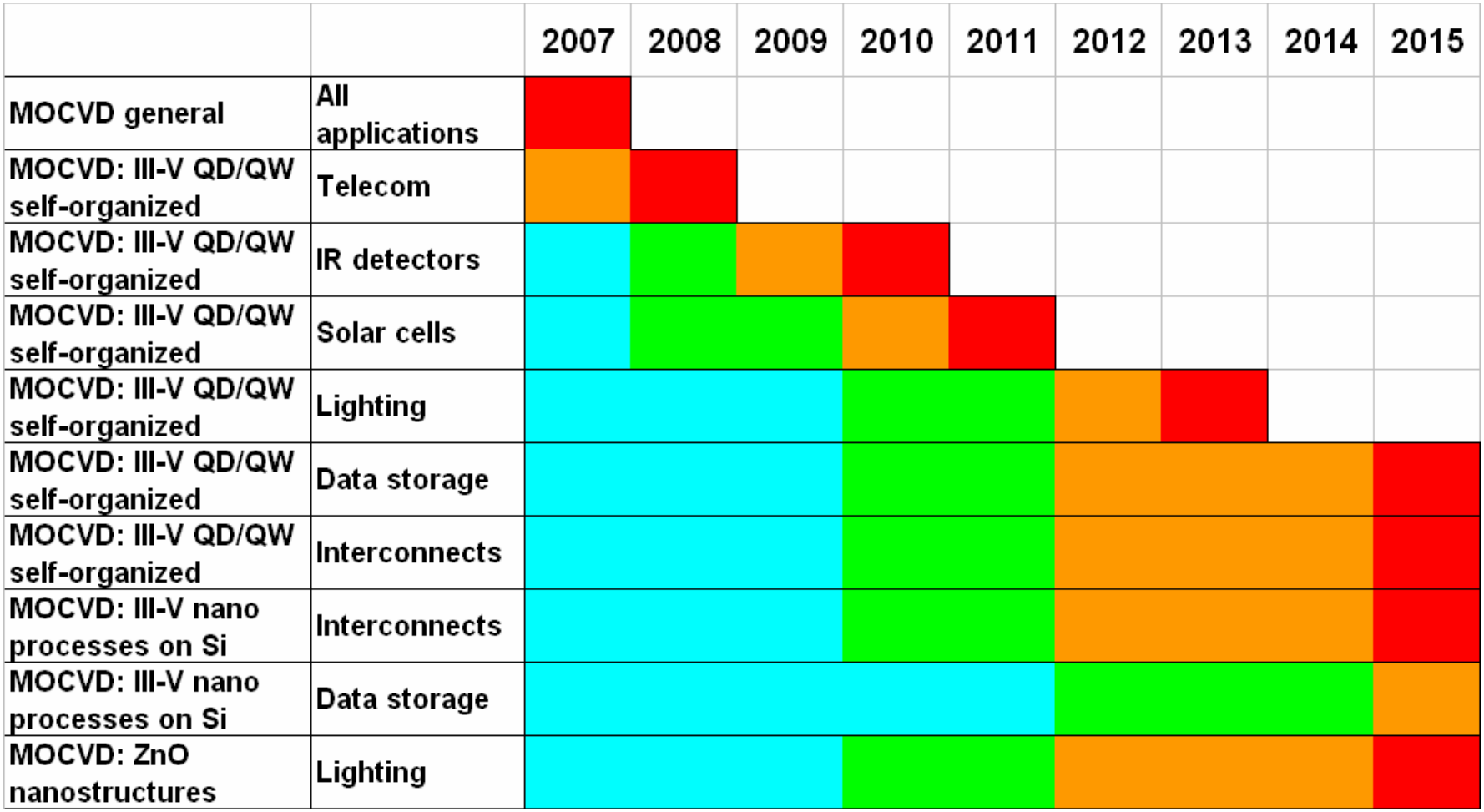
	Telecom/ datacom	Sensors/ detectors	Optical interc.	Lighting	Photo-voltaics	Displays	Instr./ metrology	Data storage
UV litho	X	X		X				
X-ray litho	X	X	X	X	X			X
E-beam						X		
Nanoimprint litho			X					
FIB litho				X				
Etching	X							

Equipment Maturity and Potential for Mass Production

	Equipment/process	General maturity 2007	Maturity for nanophonic applications 2007	Effort required to come mature	Impact on performance of nanophotonic devices	Potential for mass production	
Bottom up	MOCVD	++	+	+	++	++	⇦
	MBE	+	+	++	++	o	
	CNT CVD	o	+	o	++	+	⇦
	SiOx CVD	++	+	o	+	+	
	Si nanowire CVD	o	o	++	++	o	
	HVPE	o	o	+	+	+	
	Direct nanoparticle deposition	+	+	o	+	+	
	Colloidal chemical synthesis	+	+	+	++	++	⇦
	Laser ablation	+	+	o	+	+	
	Nanophosphor fabrication	+	+	o	++	++	⇦
	Sol-gel synthesis	+	+	o	+	++	⇦
	Pyrolysis	+	o	o	+	+	
	TiO_2 nanoparticle formation	+	+	o	+	+	
	Electrodeposition	o	o	o	+	o	
	VPD of ZnO	o	o	o	o	o	
	Spin coating	+	-	+	-	+	
	Ink jet printing	+	-	+	-	+	
	OVPD	+	o	+	+	++	⇦
	PECVD	++	+	o	o	++	
	Pulsed laser ablation	+	+	o	+	+	
Top down	Deep UV/EUV	o	+	+	++	+	⇦
	X-ray lithography	o	++	+	++	o	
	E-beam lithography	+	++	+	++	o	
	Nanoimprint lithography	-	++	++	++	++	⇦
	FIB lithography	o	+	+	++	o	
	Etching	++	+	o	+	++	⇦

MOCVD Roadmap

Basic R&D | Applied R&D | First Applications | Mass production



		2007	2008	2009	2010	2011	2012	2013	2014	2015
MOCVD general	All applications									
MOCVD: III-V QD/QW self-organized	Telecom									
MOCVD: III-V QD/QW self-organized	IR detectors									
MOCVD: III-V QD/QW self-organized	Solar cells									
MOCVD: III-V QD/QW self-organized	Lighting									
MOCVD: III-V QD/QW self-organized	Data storage									
MOCVD: III-V QD/QW self-organized	Interconnects									
MOCVD: III-V nano processes on Si	Interconnects									
MOCVD: III-V nano processes on Si	Data storage									
MOCVD: ZnO nanostructures	Lighting									

MBE Roadmap

Basic R&D | Applied R&D | First Applications | Mass production

		2007	2008	2009	2010	2011	2012	2013	2014	2015
MBE: general	All applications									
MBE: III-V QD/QW self-organized	Telecom									
MBE: III-V QD/QW self-organized	IR detectors									
MBE: III-V QD/QW self-organized	Solar cells							??	??	??
MBE: III-V QD/QW self-organized	Lighting							??	??	??
MBE: III-V QD/QW self-organized	Data storage									
MBE: III-V QD/QW self-organized	Interconnects									
MBE: III-V nano processes on Si	Interconnects									
MBE: III-V nano processes on Si	Data storage									

Other CVD Roadmap

Basic R&D | Applied R&D | First Applications | Mass production

		2007	2008	2009	2010	2011	2012	2013	2014	2015
HVPE: III-V QDs	Lighting									
CVD: Si nanowires	n.a.							??	??	??
CVD: SiOx	Interconnects									
CVD: CNT	Displays									

UV and E-beam Lithography Roadmaps

Basic R&D | Applied R&D | First Applications | Mass production

		2007	2008	2009	2010	2011	2012	2013	2014	2015
UV lithography: integration in ICs	Telecom									
UV lithography: plasmonics/metalic	Lighting									
UV lithography: III-V QDs	Telecom									
UV lithography: photonic crystals III-V	Telecom									
UV lithography: nanostr. in Si	Telecom									

		2007	2008	2009	2010	2011	2012	2013	2014	2015
e-beam lithography: photonic crystals III-V	Lighting							??	??	??
e-beam lithography: III-V QDs	Telecom									
e-beam lithography: nanostr. in Si	Telecom									
e-beam lithography: photonic crystals III-V	Telecom									
e-beam lithography: left-handed mater.	Metrology									

Nanoimprint Lithography, FIB and Dry Etching Roadmaps

Basic R&D | Applied R&D | First Applications | Mass production

		2007	2008	2009	2010	2011	2012	2013	2014	2015
Nanoimprint: photonic crystals III-V	Lighting									
Nanoimprint: photonic crystals III-V	Telecom									
Nanoimprint: nanostr. in Si	Telecom									

		2007	2008	2009	2010	2011	2012	2013	2014	2015
FIB lithography: left-handed mat.	Metrology									

		2007	2008	2009	2010	2011	2012	2013	2014	2015
Dry etching: photonic crystals III-V	Lighting									
Dry etching: photonic crystals III-V	Telecom									
Dry etching: nanostr. in Si	Telecom									

Summary

- In this overview the equipment and process types were ranked with respect to their maturity, their potential to enter into mass production of nanophotonic devices and the broadness of application fields
  - The technologies that have the highest potential impact on nanophotonics and at the same time have potential for mass production are the following: **MOCVD, CNT CVD, colloidal synthesis, nanophosphor fabrication, sol-gel synthesis, OVPD, UV lithography, nanoimprint and etching.**
  - The equipment and process types with the broadest field of applications are the following: **MOCVD, MBE and colloidal chemistry as bottom up technologies and UV litho, e-beam and nanoimprint as top down technologies**