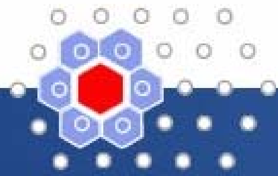

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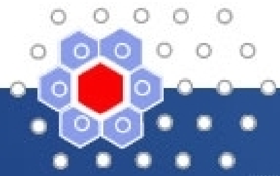
Merging Optics & Nanotechnologies

Equipment for Nanophotonics

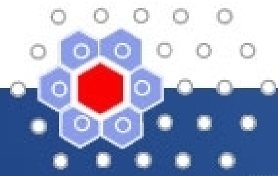
Rainer Beccard
AIXTRON AG

First MONA workshop, April 7th 2006, Strasbourg



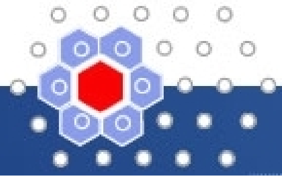
Equipment for Nanophotonics

- Equipment categories to be considered
  - Equipment for bottom up approach
  - Equipment for top down approach
  - Metrology equipment

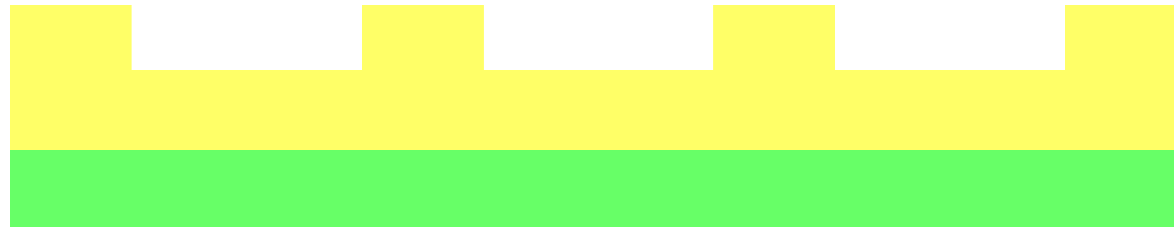


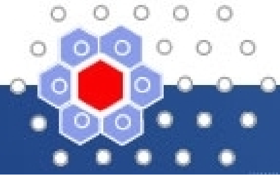
Equipment for Nanophotonics

- Bottom up approach:
  - PVD/MBE (molecular beam epitaxy) →inorganic materials, III-Vs, II-VIs
  - [MO]CVD ([metal organic] chemical vapor deposition) →inorganic materials, III-Vs, II-VIs, Si, Oxides; self assembly
  - Printing (e. g. ink jet printing) → organic materials, polymers
  - OVPD (organic vapor phase deposition) → organic materials, small molecules



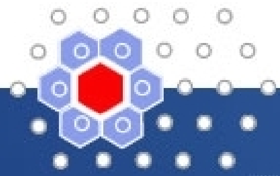
Bottom up approach





Equipment for Nanophotonics

- Top down approach:
  - Optical lithography
  - E-beam / x-ray / ion beam lithography
  - Dry etching
  - Nano imprint / soft lithography



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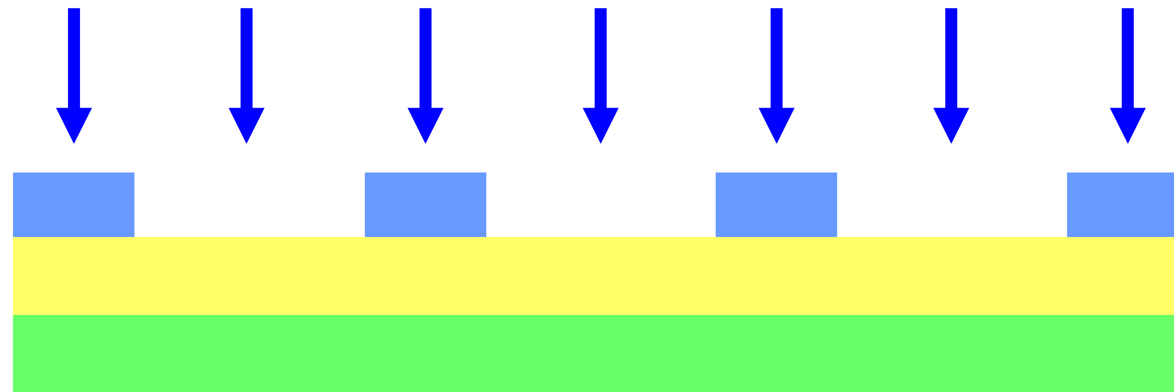
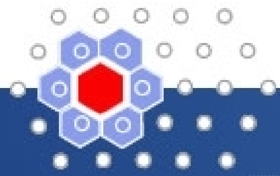
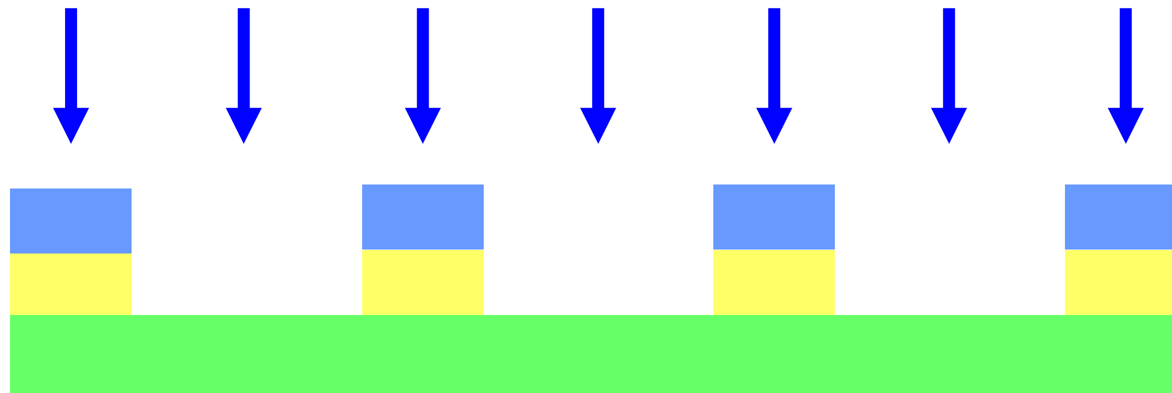
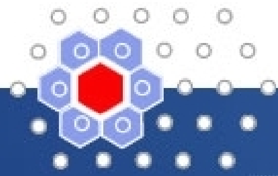
Top down approach





Top down approach





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Equipment for Nanophotonics

- Metrology
  - SEM
  - AFM
  - TEM
  - Reflectometry
  - Ellipsometry
  - In situ metrology for bottom up techniques

Equipment for bottom up approach

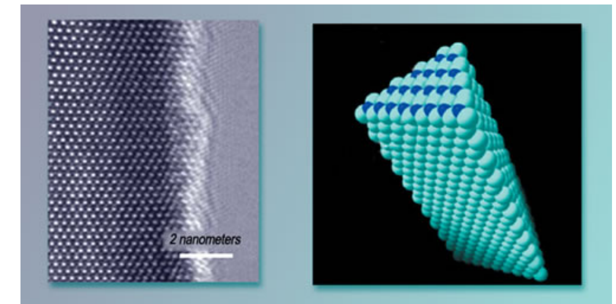
- MBE
  - Current status: Multi 6 inch MBE available
  - Standard equipment used for nano applications
  - QD growth (III-V) established (lasers / amplifiers)
  - Early stage of commercialization
  - Future: more sophisticated nano devices → gas source or solid source MBE might be required

Source: Riber

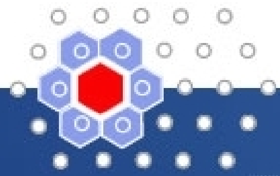
Equipment for Nanophotonics

- Equipment for bottom up approach
  - MOCVD
    - Current status: Multi 8 inch MOCVD available
    - Standard equipment used for nano applications
    - Self-assembled growth of low dimensional structures established for GaAs, InP, GaN, ZnO and related materials
    - Catalyst induced growth of nano structures
    - Very precise control of thin layers in one dimension is possible
    - Customized solutions for nano applications available
    - Future: Improve reproducibility
    - In situ metrology will become much more important (reflectometry, RAS,...)
    - Transformation of promising R&D results into industry

Source: AIXTRON



Source: Berkeley Labs

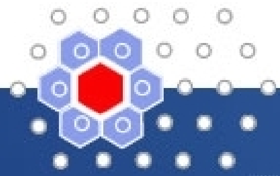


Equipment for Nanophotonics

- Equipment for bottom up approach
  - other CVD: PECVD, ALD,...
    - Current status: Standard and modified equipment is used for SiN, TiN, SiO, SiC, oxides (HfO, Al_2O_3), metals
    - No dedicated equipment available for nanophotonics
    - Nanophotonics do not play any important role today
    - Future: some potential?

Source: ASM

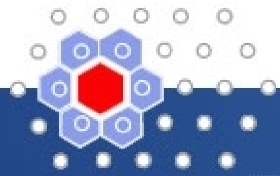
Source: Genus



Equipment for bottom up approach

- Printing
  - Current status: Ink jet printing for full color displays (polymer OLEDs)
  - Non-standard equipment used
  - Screen printing: not working on nano scale, but used to deposit nano materials
  - Future: dedicated equipment for nano applications
  - Structuring / modification of deposited layers on nano scale

Source: Litrex



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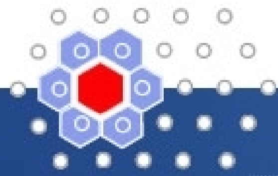
Equipment for bottom up approach

- Organic Vapor Phase Deposition (OVPD)
  - Current status: Technology exists for large area deposition of small molecule OLEDs on large area glasses
  - Nano resolution easily achieved in one dimension
  - Future: Lateral definition of nano structures

Source: AIXTRON



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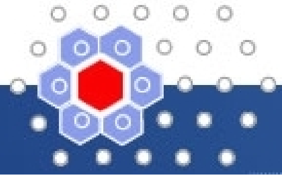
Equipment for Nanophotonics

Equipment for bottom up approach

- Others:
  - Laser ablation / pulsed laser deposition (oxides)
  - CNT deposition (CVD, hot wall CVD)
  - Sputtering techniques
  - Spin coating
  - Sol-gel processes
- Issues / future development:
  - Reproducibility
  - Scalability
  - No dedicated nano equipment available yet

Source: AIXTRON

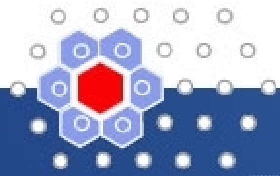


Equipment for top down approach

Optical lithography

- Current status: well established technology down to 65 nm / 45 nm node (193 nm wavelength, immersion technology)
- Holographic lithography allows low cost production of periodic patterns
- Future: EUV required for definition of smaller structures (plasma or synchrotron UV sources); wavelength 13.4 nm

Source: ASML



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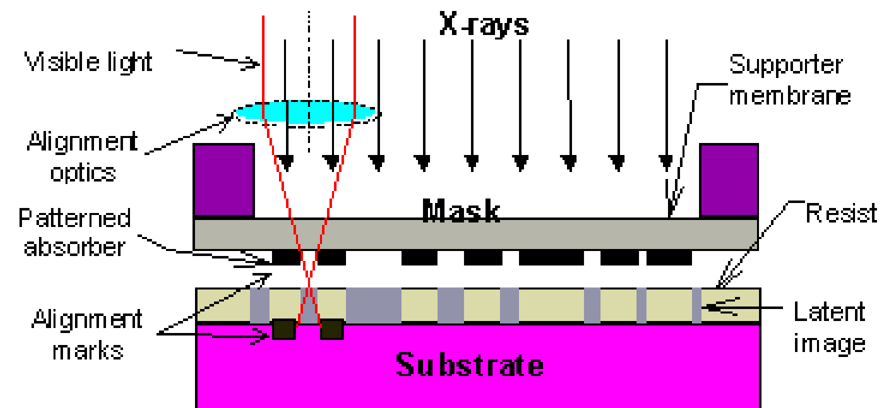
Equipment for Nanophotonics

- Equipment for top down approach
  - E-beam lithography
    - Current status: allows definition of very small structures; not limited by wavelength but by various other effects
    - SEM type equipment; not suited for volume production
    - Future: E-beam projection lithography (higher throughput)

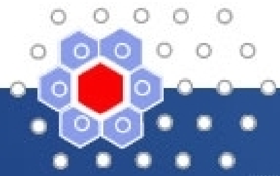
Equipment for top down approach

X-ray lithography

- Very short wavelength (0.01 – 1 nm)
- Tough requirements for masks
- X-ray generation by synchrotron required
- No industrial scale use so far



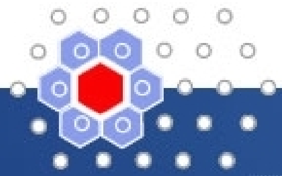
Source: Maxlab



Equipment for Nanophotonics

- Equipment for top down approach
  - Ion beam lithography
    - Resolution down to 30 nm
    - Focused ion beam (scanning principle, no mask) or
    - Ion projection lithography (using masks)

Source: ASML



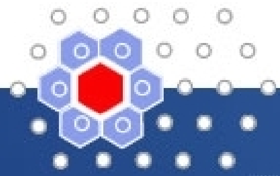
Equipment for top down approach

Dry etching

- Current status: Reactive ion etching and ion beam etching well established
- Standard equipment currently used for nano applications
- Dry etching techniques used for nano applications in R&D scale
- Nano applications not limited by equipment
- Future: Reproducibility of dry etching in combination with masks and materials is critical

Source: STS

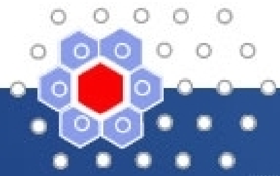
Source: Oxford Instruments



Equipment for top down approach

- Nano imprint / soft lithography
  - Current status: Technology is available for Si, III-Vs
  - Part of ITRS roadmap
  - Structure size down to 50 nm (R&D stage)
  - Future: Improvements on accuracy, defects, reproducibility
  - Throughput to be increased to meet industrial needs

Source: Molecular Imprints



Equipment for Nanophotonics

- Metrology equipment
  - Current issues:
    - Reliability
    - Standardization
    - Calibration
    - In situ metrology: Transfer from R&D stage to industrial scale; choice of suited in situ methods

Source: Laytec