Nanomanufacturing – Beyond Silicon

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CNST Center for Nanoscale Science & Technology

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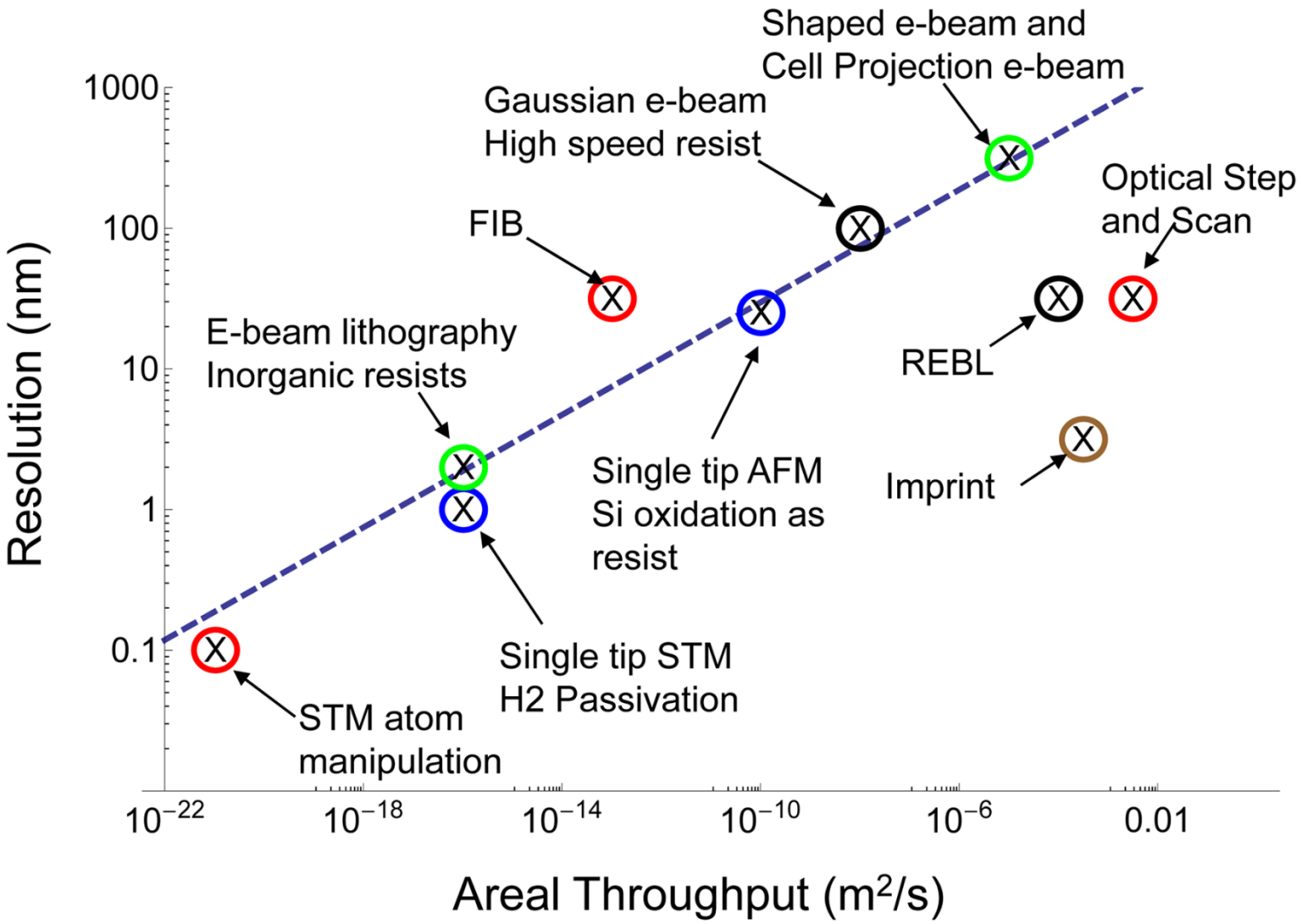
NIST National Institute of Standards and Technology • U.S. Department of Commerce

Nanofabrication & Nanomanufacturing Today



Liddle & Gallatin, *Nanoscale* – In press

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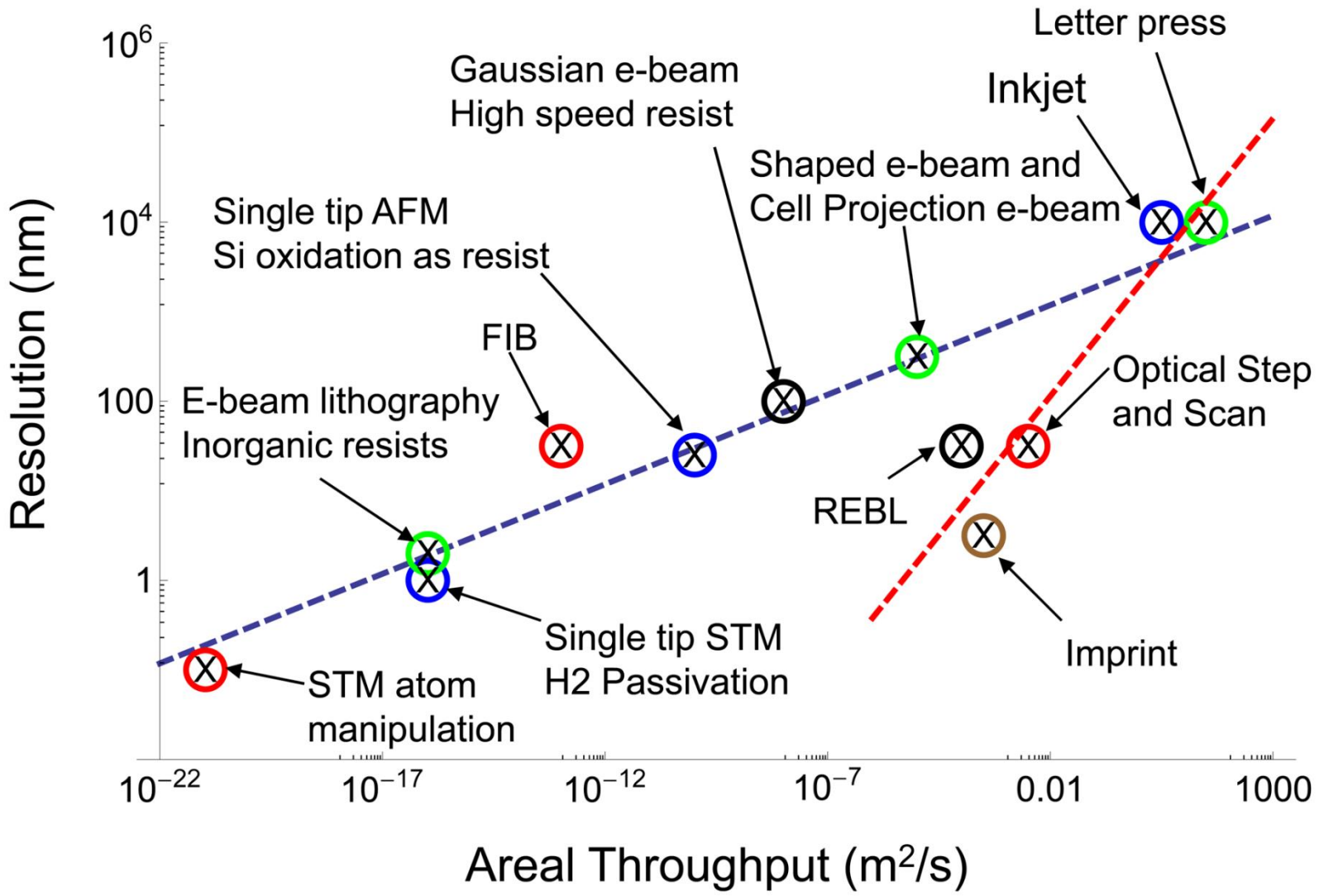

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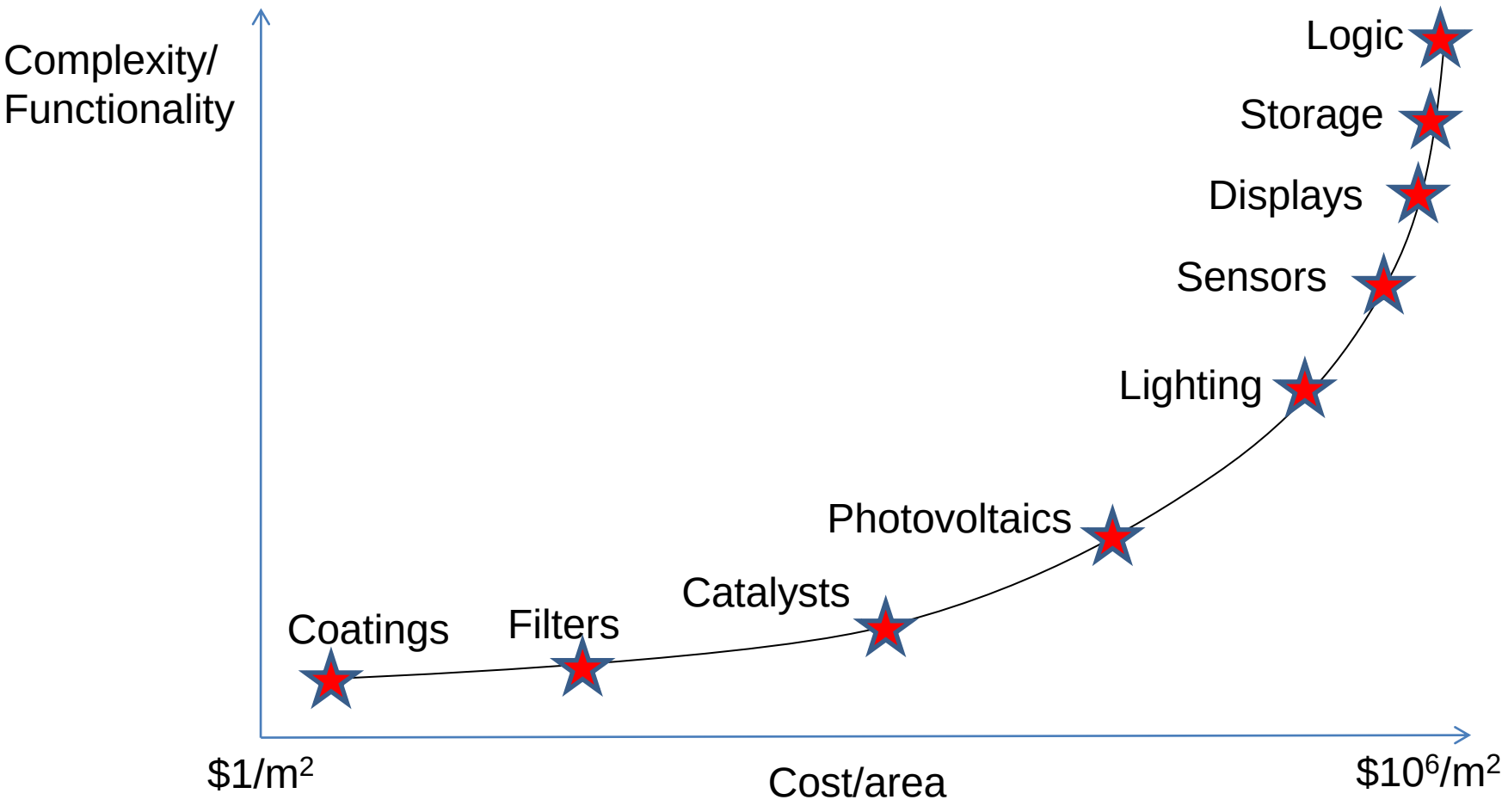
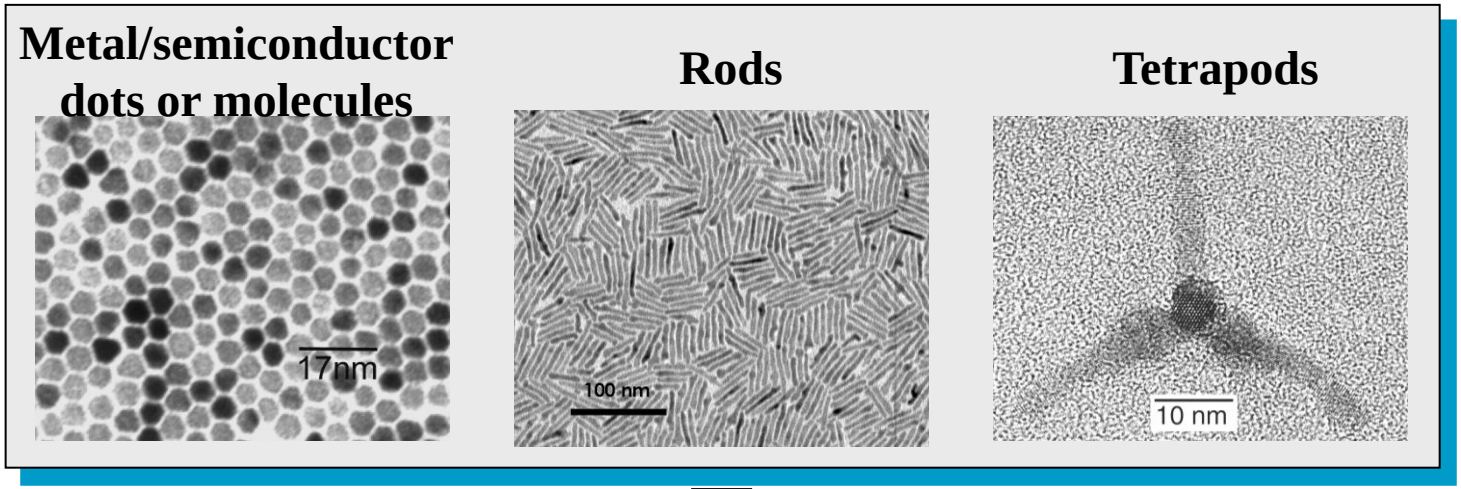
The Cost of Complexity



Some Assembly Required



Some assembly required!

Photovoltaics

Catalysis

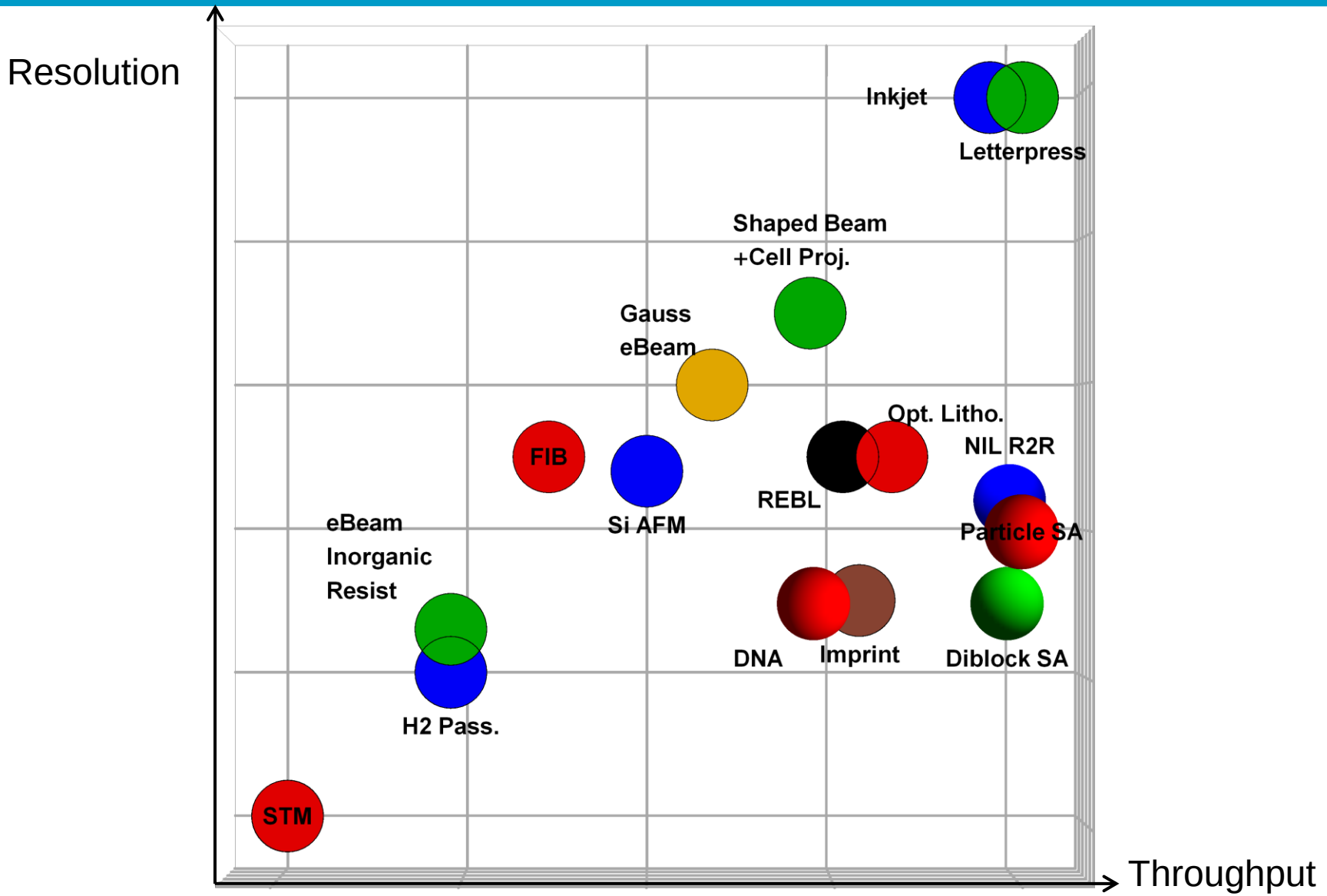
Water Purification & Photolysis

Multifunctional Coatings

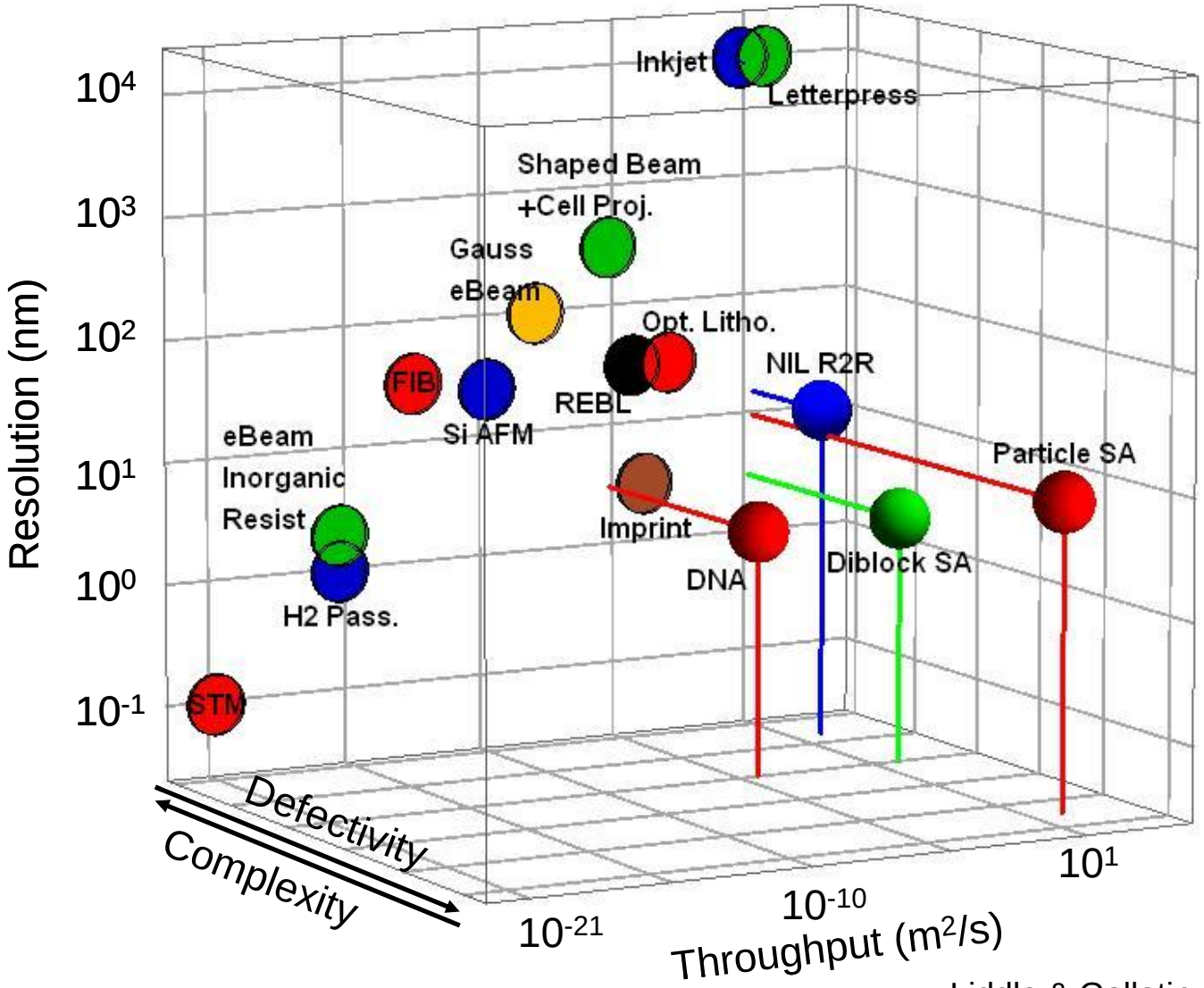
Sensors

Electronics

Emerging Nanomanufacturing Methods



Emerging Nanomanufacturing Methods



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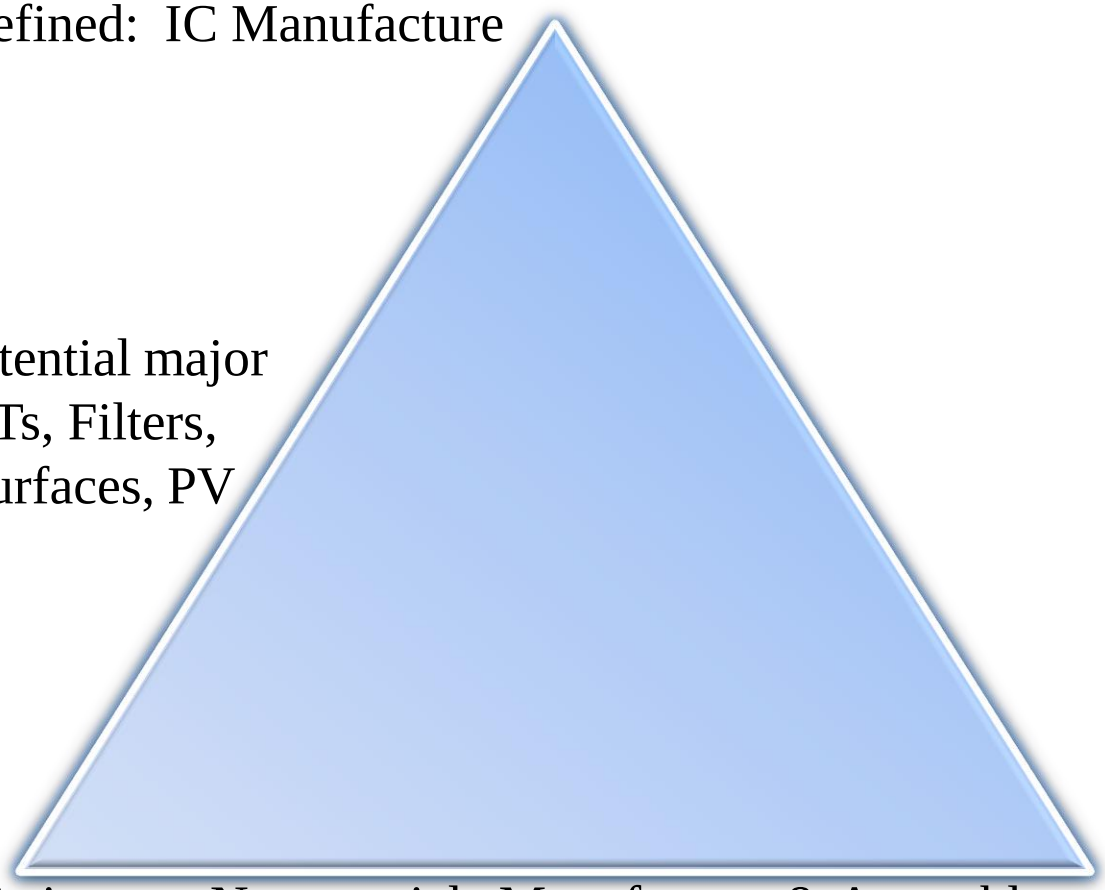
Nanomanufacturing Characteristics

Specific, well-defined: IC Manufacture

Developing, potential major industries: CNTs, Filters, Self-cleaning surfaces, PV



Broad, generic issues: Nanoparticle Manufacture & Assembly

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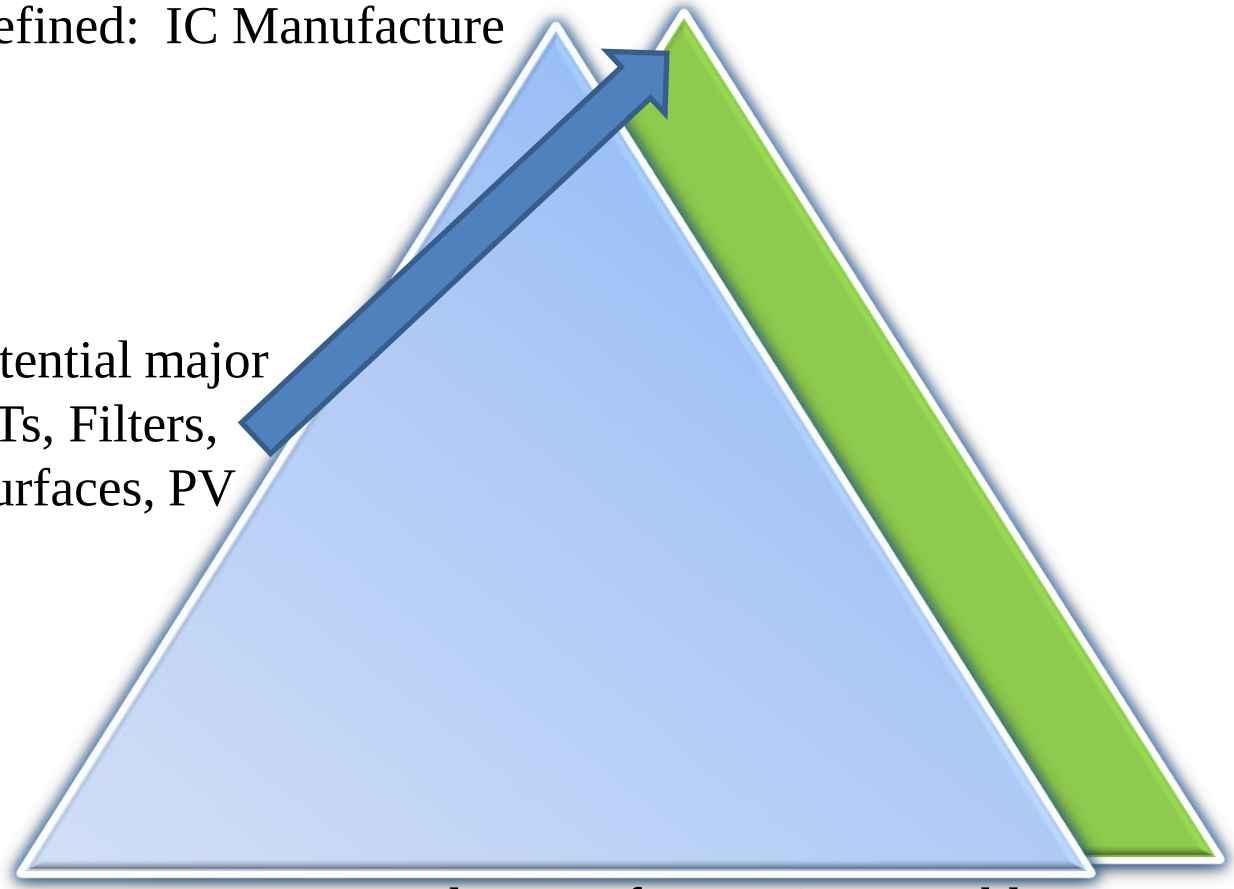
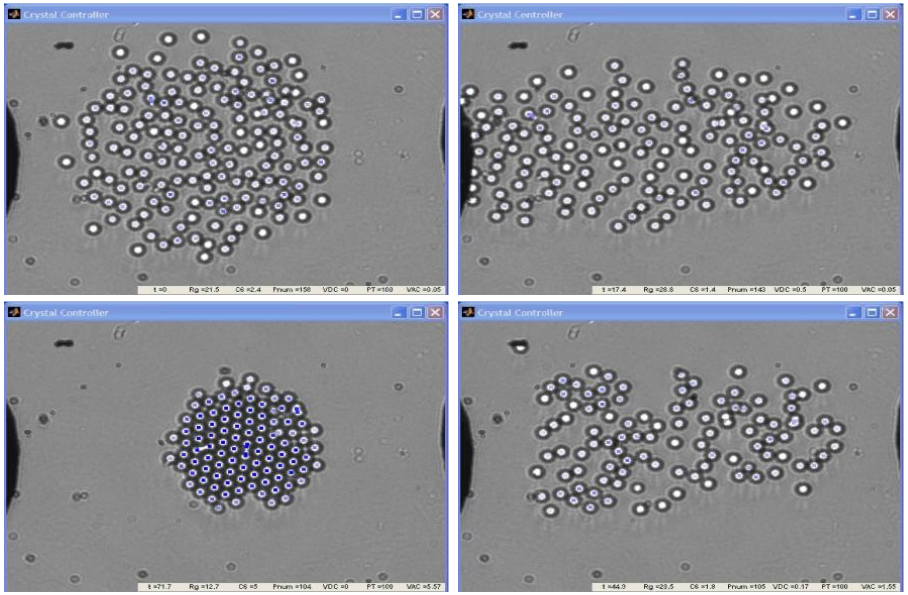


Broad, generic issues: Nanoparticle Manufacture & Assembly

Control

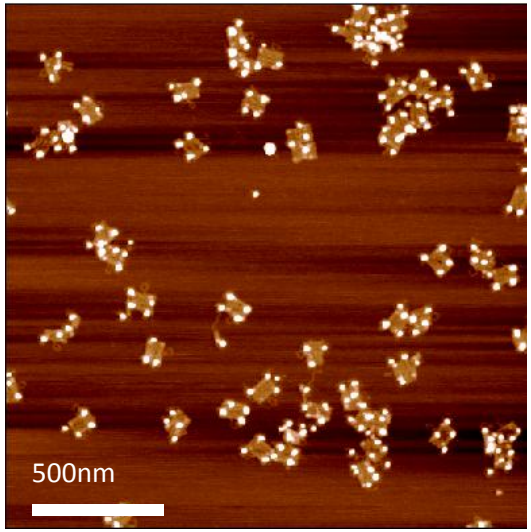
- Nanosystem fabrication involves assembly of 10^9 components
  - Top-down – reliable, slow, expensive
  - Bottom-up –fast, cheap & out of control
    - How do we bring such processes under control when we can't see or touch the individual pieces
  - Need to develop stochastic control methods
    - Control boundary conditions
      - Energy landscapes
    - Meaningful feedback parameters

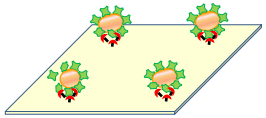


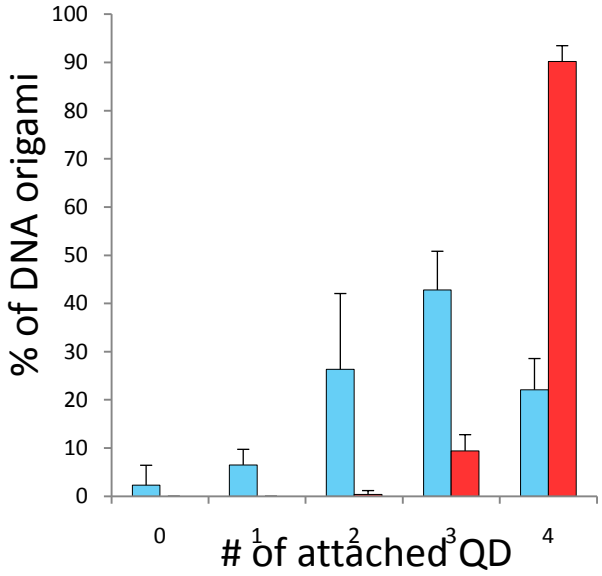
Controlled formation of colloidal crystals using video microscopy and combined multiple actuation methods Juarez, Mathai, Bevan, Liddle, *in preparation*

Standard Interfaces

- Standard interfaces enable modular design
  - Performance is sacrificed
  - Manufacturability, reliability and design turnaround speed are gained
    - How do we do this for nanosystems?







Assembly based on DNA origami – factors controlling speed & yield
Ko, Gallatin, Liddle, submitted

Diblock Copolymer Line-Edge Roughness by Resonant X-ray Scattering

Objective

•Develop methods to measure the intrinsic line-edge roughness in self-assembled diblock copolymers to quantify their behavior in lithographic applications

Method

•Use directed self-assembly of diblock on nanolithographic template on SiN membrane to create effective diffraction grating

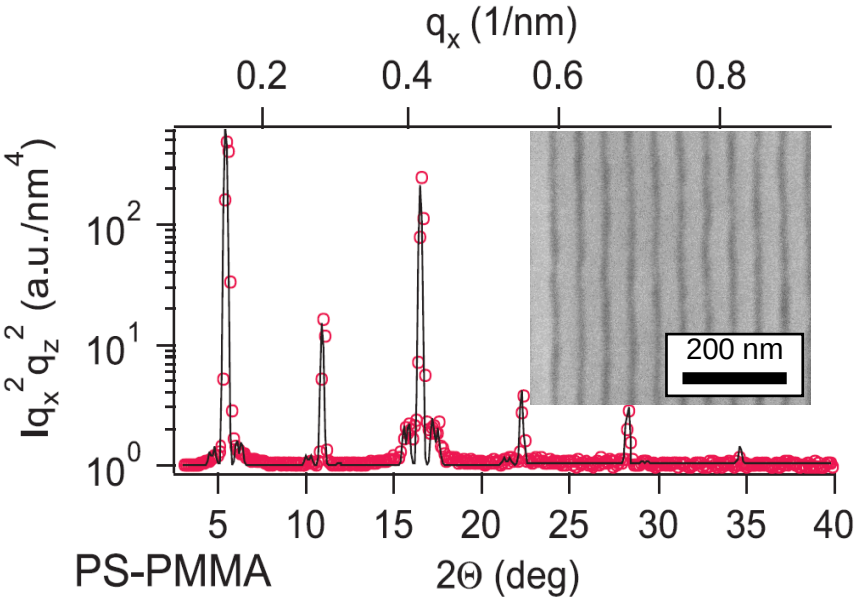
•Use x-ray energy tuned to specific chemical bond to achieve high contrast between phases

Results and Impact

•Detailed measurements of diblock morphology from 50 nm thick films in transmission

•Patterned nanostructure produces high quality diffraction pattern enabling detailed parameter extraction

•"Scattering from pattern" concept applicable to many different nanotechnology problems



Diffraction from assembled diblock

G. Stein, J. A. Liddle, A. Aquila, E. M. Gullikson, *Macromolecules,* **43** 433 (2010)

Real Time Roll-2-Roll (R2R) Metrology for NanoManufacturing

G. Gallatin, J.A. Liddle & J. Watkins (CHM-UMass. Amherst)

Objective

•Develop "good, fast, cheap" metrology solutions for real time measurement of short and long range nano-pattern fidelity.

•R2R goal is to produce coherent nano-scale patterns on ~1 meter wide substrates moving at ~1m/s

➔Need nanoscale accuracy and precision at GHz rates over meter length scales.

➔Needs to be cost effective

Method

•Metrology solution must be "keyed" to the desired nano-pattern

•Cheap → Use off-the-shelf technology

•Hard disk flying height sensor technology

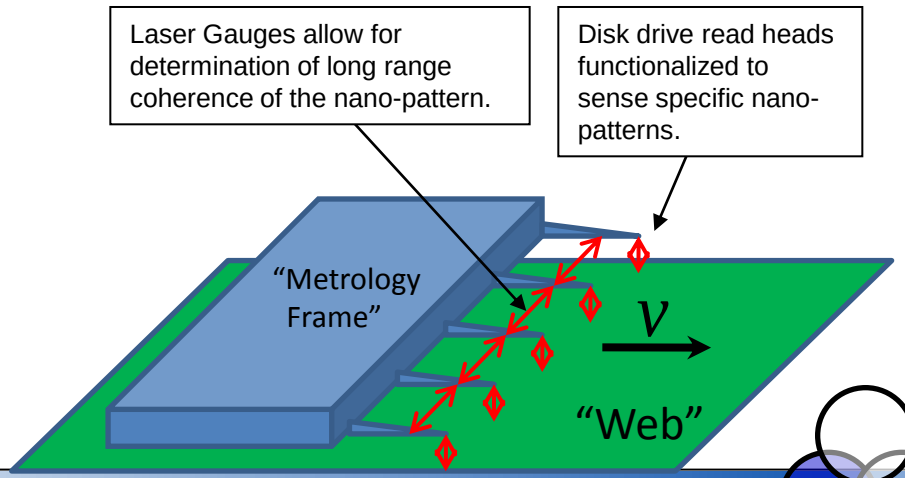
•Laser interferometry for long range coherence

•Near field metrology for short range coherence.

Results and Impact

• For R2R to become a cost effective revenue generating nanomanufacturing technology it requires metrology that is:

- •Cheap
- •Accurate
- •Real-time
- •Online



Measurement Needs

Two classes of measurements:

- Detailed, extensive
  - Develop understanding of basic processes
    - E.g. *In situ* observations of CNT growth for process window optimization
- On-line, fast
  - Enable process control during manufacture
    - E.g. Nanoscale structured-mask plasmonic devices for massively parallel interrogation of photomasks
- We’re pretty good at the first, but the second need work!

Summary

- High-throughput, top-down techniques exist
  - Need to match volumes and price points
- Bottom-up techniques are emerging
  - Need new control methods
  - Need to develop more modular approaches
- Measurements of basic phenomena available
- Measurements for process control lacking