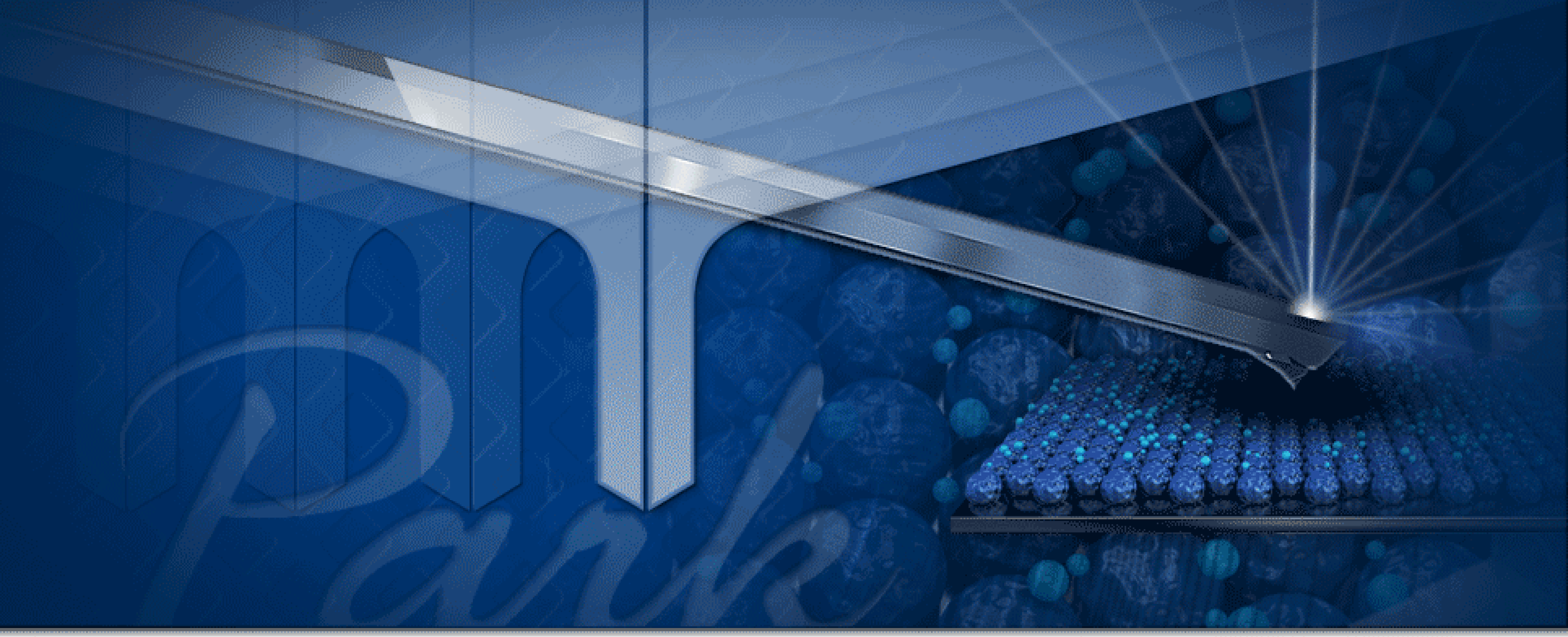

Scanning Probe Lithography Methods for Low-Cost, High-Throughput Lithography

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Lithography

Invented by A. Senefelder in 1798.

State-of-art lithography tool for IC industry

- Enabling technique for modern science and technology
  - ✓ Integrated circuits, Information storage devices, MEMS
  - ✓ Biochips, Microfluidic devices
  - ✓ Photonic bandgap structure, Diffractive optical elements, etc.

Type of Lithography

- **Parallel replication**
  - ✓ **High-throughput and large-area patterning**
  - ✓ Duplicating patterns predefined by serial writing
  - ✓ **Unable to make arbitrary pattern**
  - ✓ Example:
    Photolithography, contact printing, and nano-imprint lithography

- **Serial writing**
  - ✓ **Pattern with high resolution and registration**
  - ✓ **Limited throughput**
  - ✓ Example:
    Electron-beam lithography (EBL), Ion beam lithography, and many scanning probe microscopy (SPM)-based methods

Type of Nano-Lithography

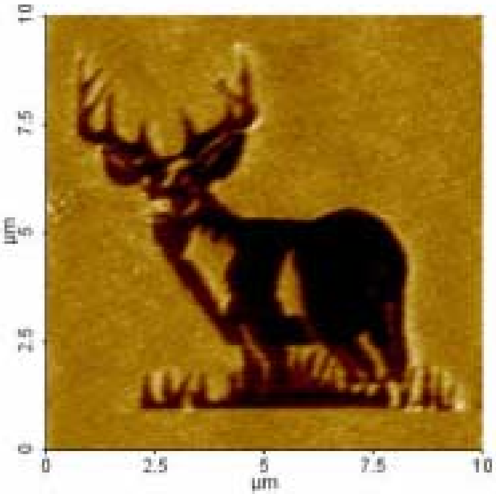
- **Photolithography**
- **E-beam/ion-beam lithography**
- **X-ray lithography**
- **Interference lithography**
- **Scanning Probe**

  - Voltage pulse
  - CVD
  - Local electrodeposition
  - Dip-pen

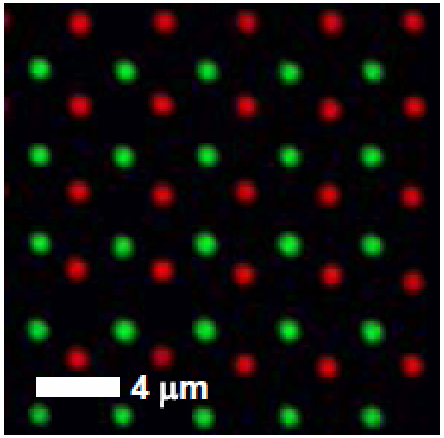
SPM-Based Lithography

Lithography utilizing the physical contact of its probe

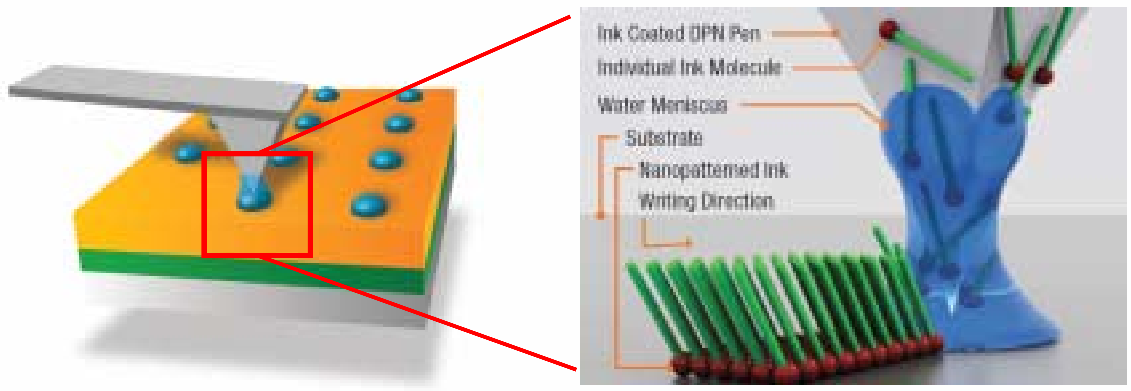
- Type 1: Mechanical lithography
  - ✓ Mechanical deformation of the substrate using the probe
- Type 2: Electrochemical lithography
  - ✓ Oxidation of the substrate using external bias applied to the probe
- Type 3: Dip-Pen Nanolithography
  - ✓ Delivering/depositing chemical through the probe

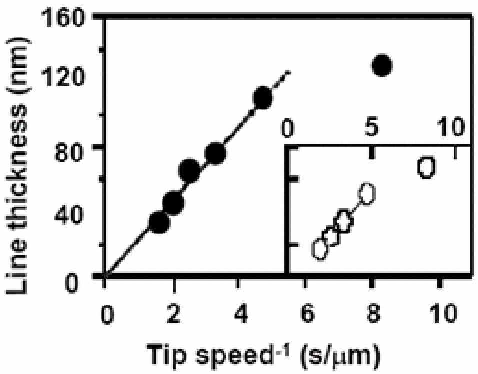


Optical Microscopy w/ Fluorophore Probes



Dip-Pen Nanolithography

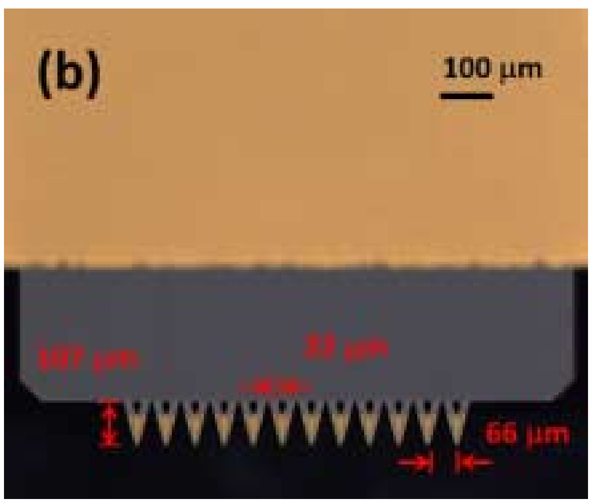




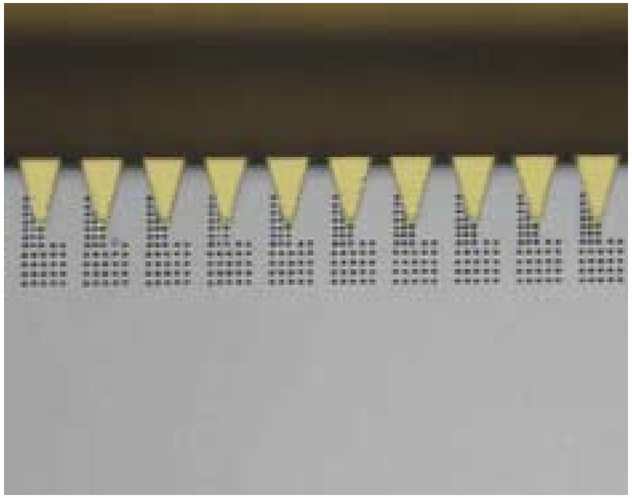
- Inking the probe with desired chemical/protein/precursors
- Pattern formed by the diffusion of the ink
- Feature size controlled by the contact time of the probe
- Making patterns by various methods:
  - 1) Force, 2) Electric bias, and 3) Chemicals

Combination of Two Strength
Dip-Pen Nanolithography with Cantilever Arrays

- ✓ SPM-based lithography method (Serial writing)
  - High resolution and registration (in sub-nanometer scale)
  - Arbitrary patterning
- ✓ 1D/2D array of cantilevers (Parallel replication)
  - Increased throughput
- ✓ Making patterns by various methods:
  - 1) Force, 2) Electric bias, and 3) Chemicals
- ✓ Developed by Prof. Chad Mirkin at Northwestern Univ.



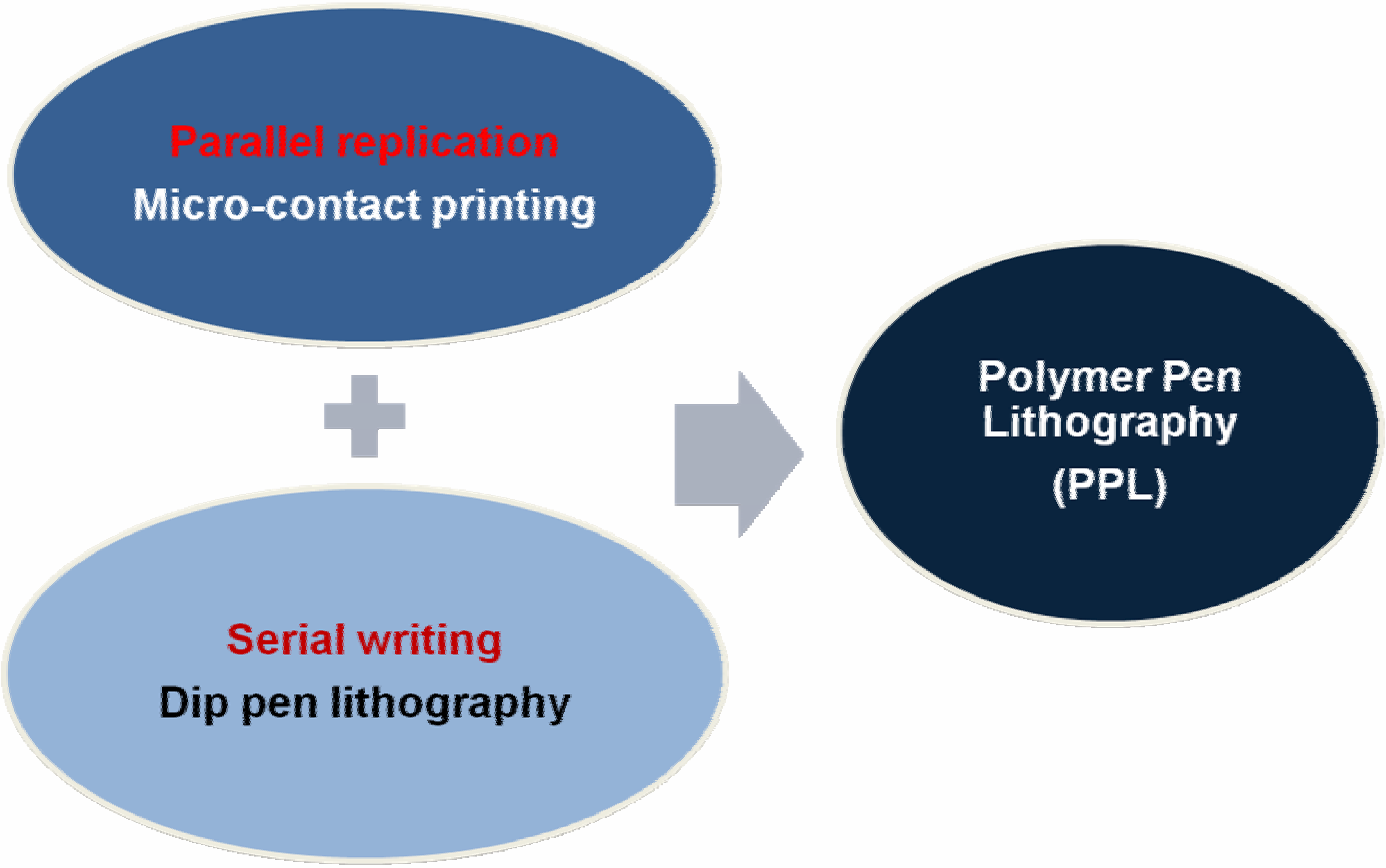
Cantilever array for DPN



Parallel replication using a cantilever array

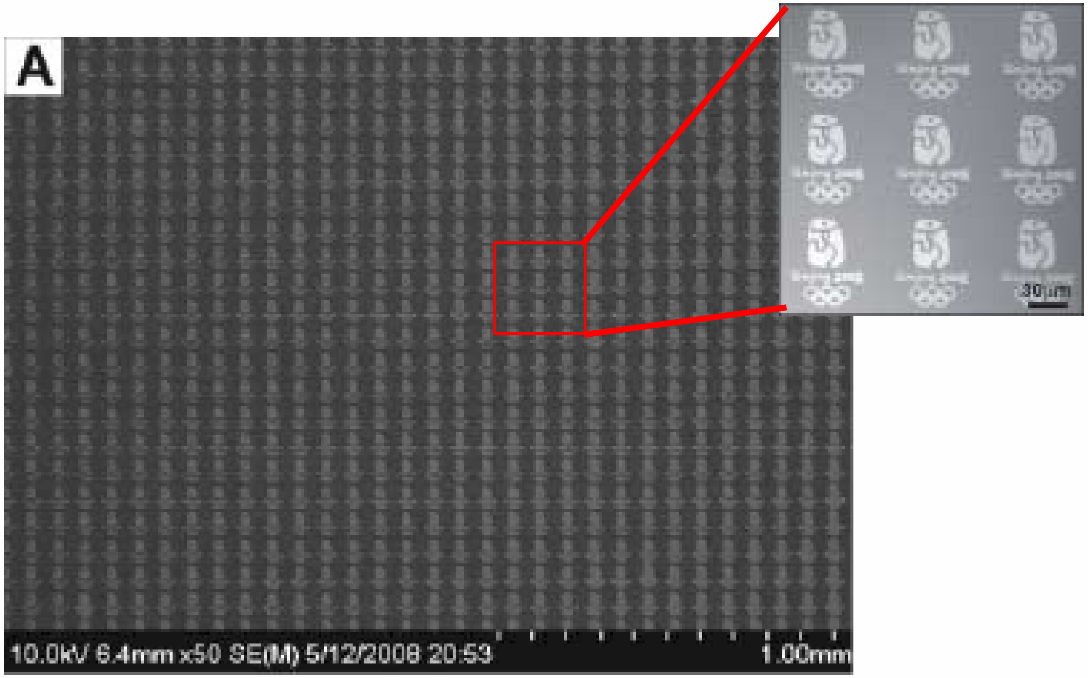
Polymer Pen Lithography (PPL)

Polymer Pen Lithography (PPL)



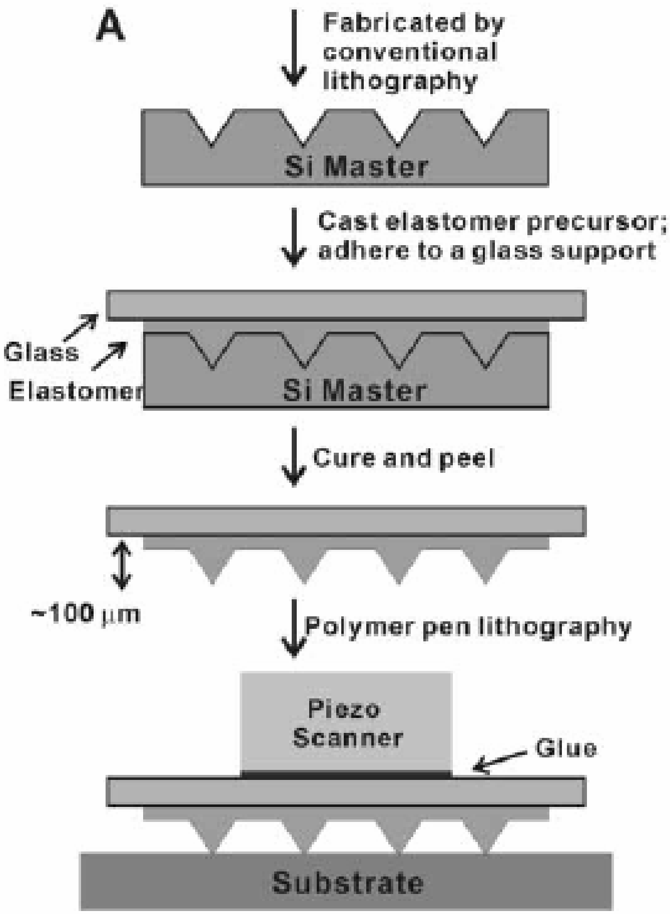
Polymer Pen Lithography

- Direct patterning method in nanoscale
  - Invented by Prof. Chad Mirkin who invented Dip Pen Nanolithography
  - Low-cost, high-throughput method to generate micro- and nanoarrays
  - Applicable to fabricate high-density protein microarrays

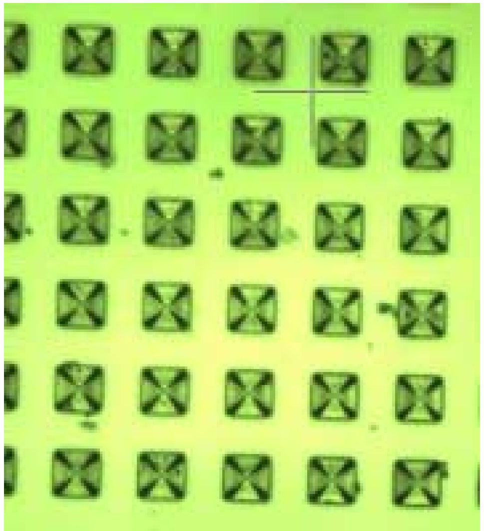


Science 321, 1658-1660 (2008)

Polymer Pen Chip for Pattern Generation



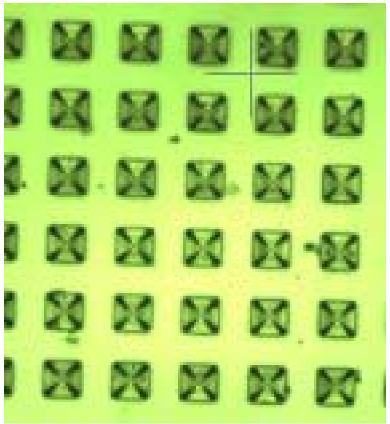
- **Array of soft elastomer pyramids**
  - Casting elastomer (PDMS) to form the chip
  - Template made by conventional photolithography
  - Easy and low-cost production



Optical view of the polymer pen

Polymer pen Lithography (PPL)

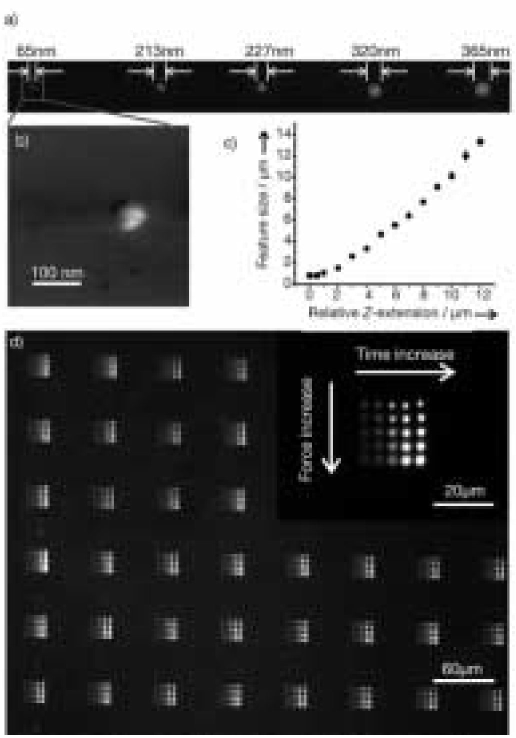
- **Enabling easy pattern control**
  - Pattern size controlled by the pressure
  - Pattern intensity controlled by the contact time
  - Features on the nanometer, micrometer, and macroscopic length scales can be formed with the same tip array
  - Produce features with diameters ranging from 80nm to >10µm in a single writing step using massively parallel (>10^7 pens) arrays of pyramidal, elastomeric pens



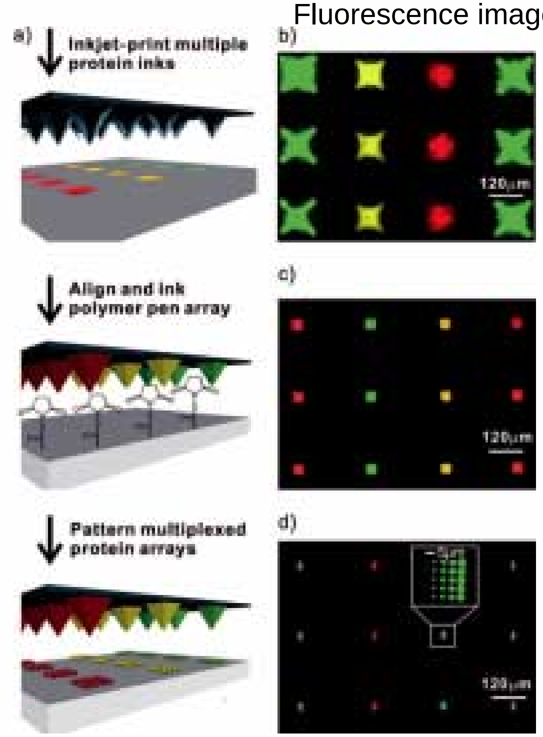
- **Multiplexed inking**
  - Tips can be inked with different inks
  - Each tip works as a reservoir of ink

Features of Polymer Pen Lithography

- **Precise control on the size/strength of the single dot pattern**
  - Controlling both Contact time and Contact force
- **Delivering multiple compositions at the same time**
  - Inking each pen with different chemicals



Fluorescence image



Si mould inked with three proteins

Polymer pen array dipped into the mould

Multiplexed proteins arrays made by PPL

Zheng et al., Angew. Chem Int. Ed., 48, 7626 (2009).

Enabling Technologies for PPL

Enabling PPL technology

- Planarity over Wide Patterning Area
- Orthogonal Scanning Structure
- Wide, and High Resolution Optical View
- Long Range Z Movement

Planarity over Wide Patterning Area

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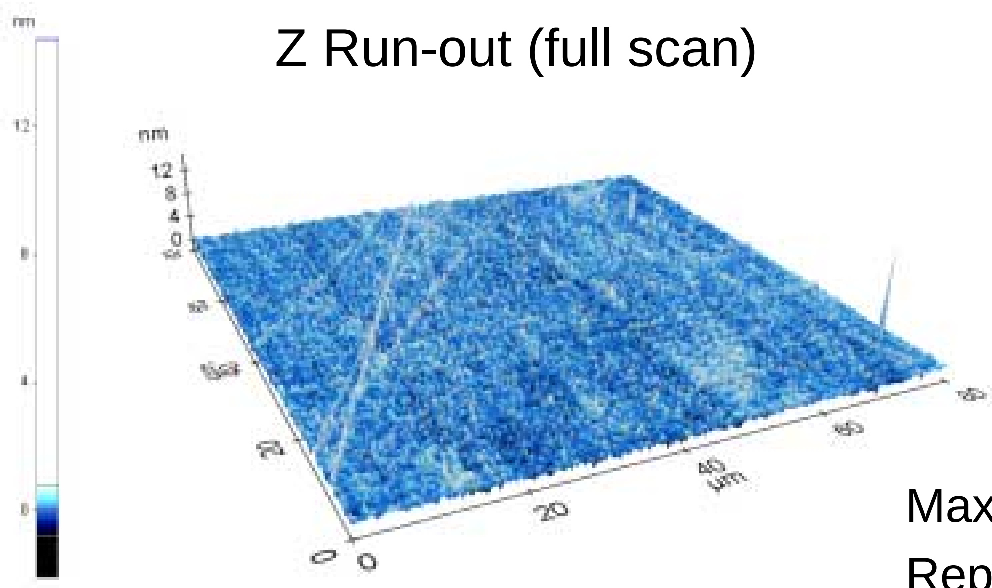
- Uniform contact of the polymer pen array

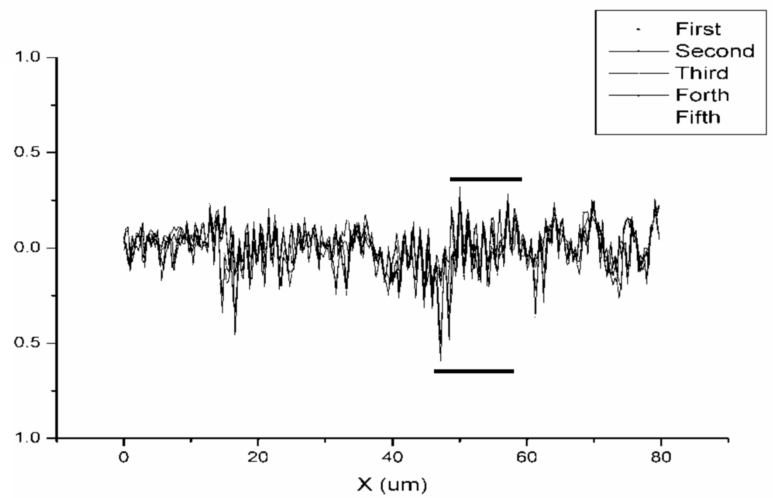
  : Flat XY scan surface realized uniform contact

  : < 10 nm Z run-out over 400 µm movement

  : < 2 nm over 100 µm movement

Z Run-out (full scan)





Maximum peak-to-peak = 0.871 nm

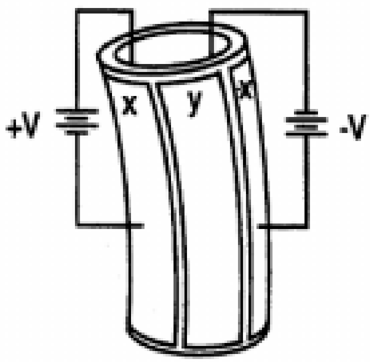
Repeatability = 0.481 nm

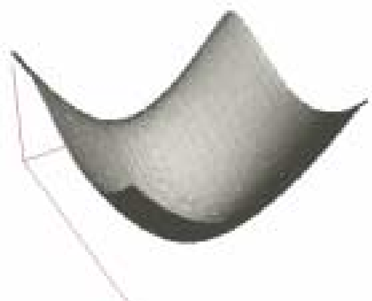
Orthogonal Scanning Structure

- Precise Z movement control

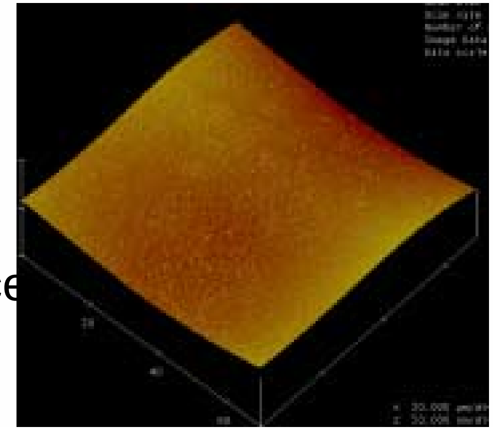
  : Elimination of XY/Z movement crosstalk

Conventional Tubs Scanning Structure

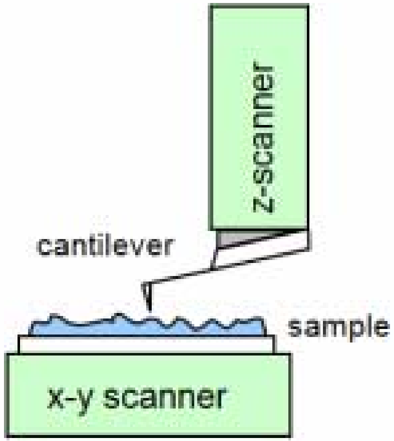


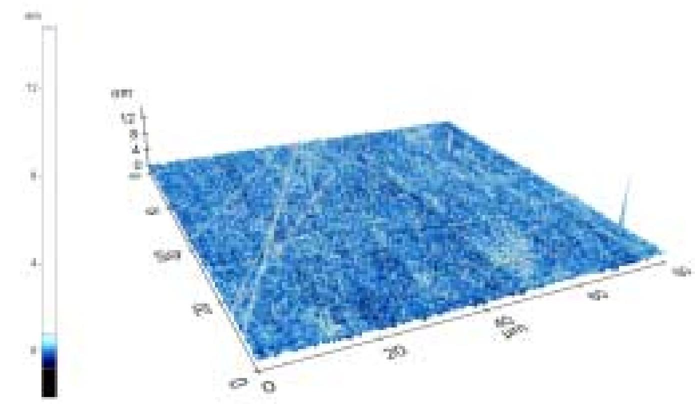


Even after software flattening, flat surface does not "look" flat.



Decoupled XY/Z Structure



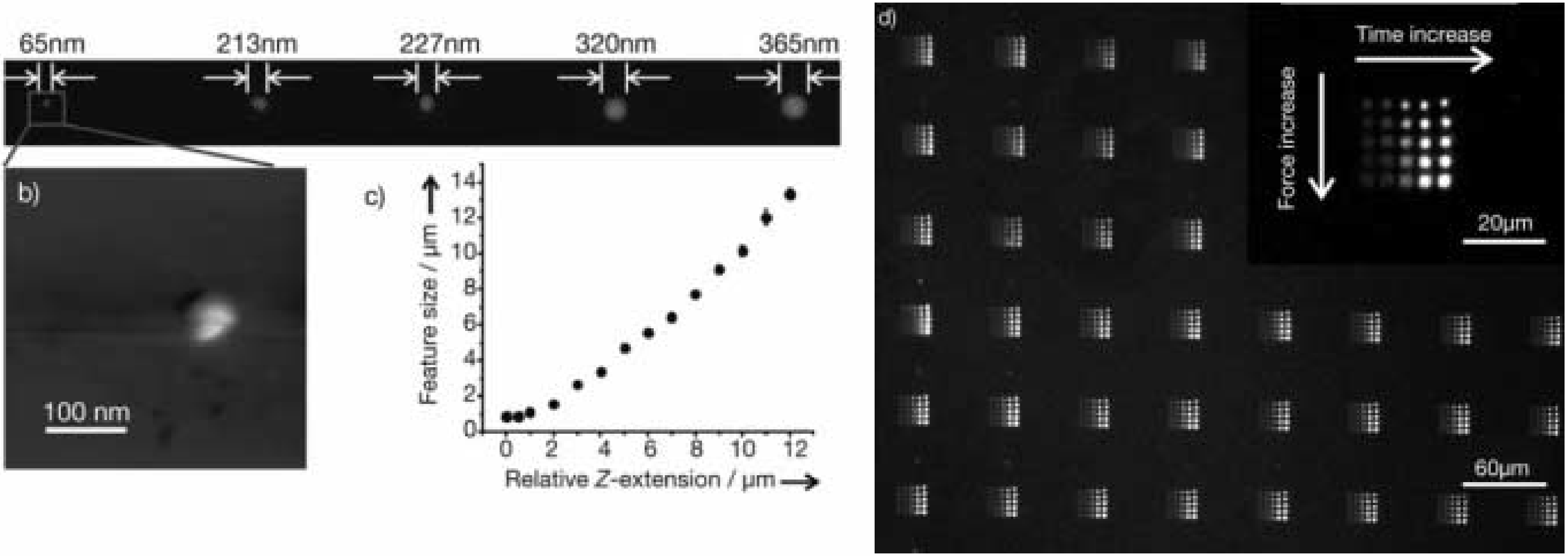


Wide, and High Resolution Optical View

- High resolution view to align Polymer pen chip (< 1μm)
- Vision with wide field-of-view (~ 1 mm x 0.75 mm)
- Panning feature to monitor whole pen array (~ 10 mm)

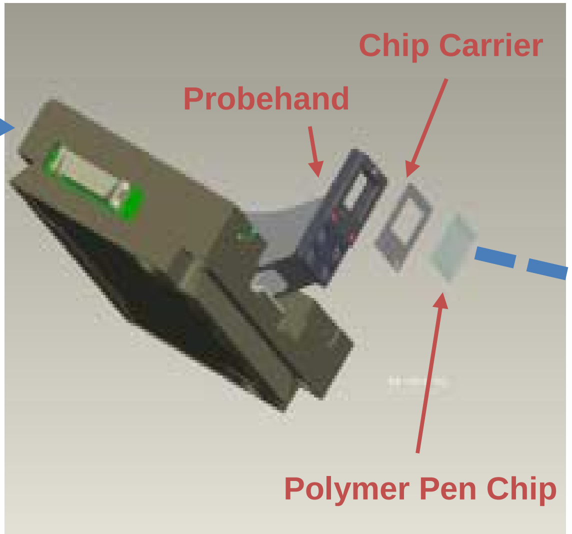
Long Range Z Movement

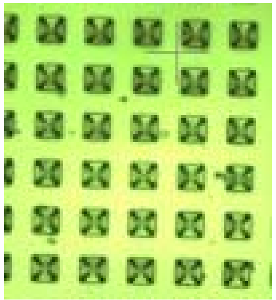
- **Wide dynamic range in pattern size (from 50 nm to 25 µm)**
  : Pattern size depends on the pressure (i.e., the Z movement)
  : 25 µm pattern size from 25 µm indentation



PPL System Enabled by XE AFM

- **Decoupled XY/Z scanner structure**
  : Uniform printing over entire area (< 2 nm run-out over 100 µm)
  : Precise control of contact force and contact time
- **User-oriented design**
  : Easy and accurate align of the polymer pen and substrate
  : Clear and intuitive view to the operating area





Conclusion

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- PPL technique takes advantages of parallel patterning and serial writing, and it provides better throughput with low cost.

- Park Systems XE-150 system enable PPL technology with scanner flatness, scan orthogonality, wide view penning and long range Z movement .

Thank you for your attention!!

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www.parkafm.com