NANONICS IMAGING Ltd.

Imaging at the Nanoscale

The Next Evolution in SPM

NANONICS IMAGING FOUNTAIN PEN

NanoLithography Systems

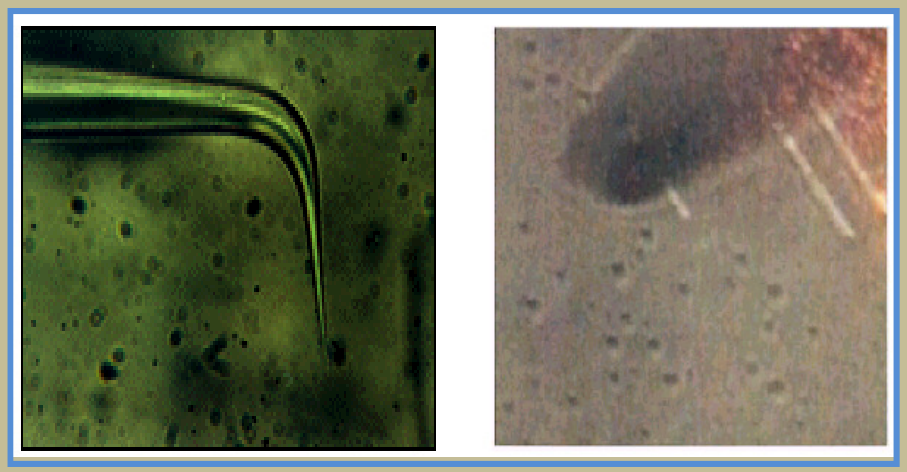
Methods of Nanochemical Lithography

Fountain Pen NanoLithography

A. Lewis et al. Appl. Phys. Lett. 75, 2689 (1999)

FPN controlled etching of chrome.

so far- Impossible with DPN



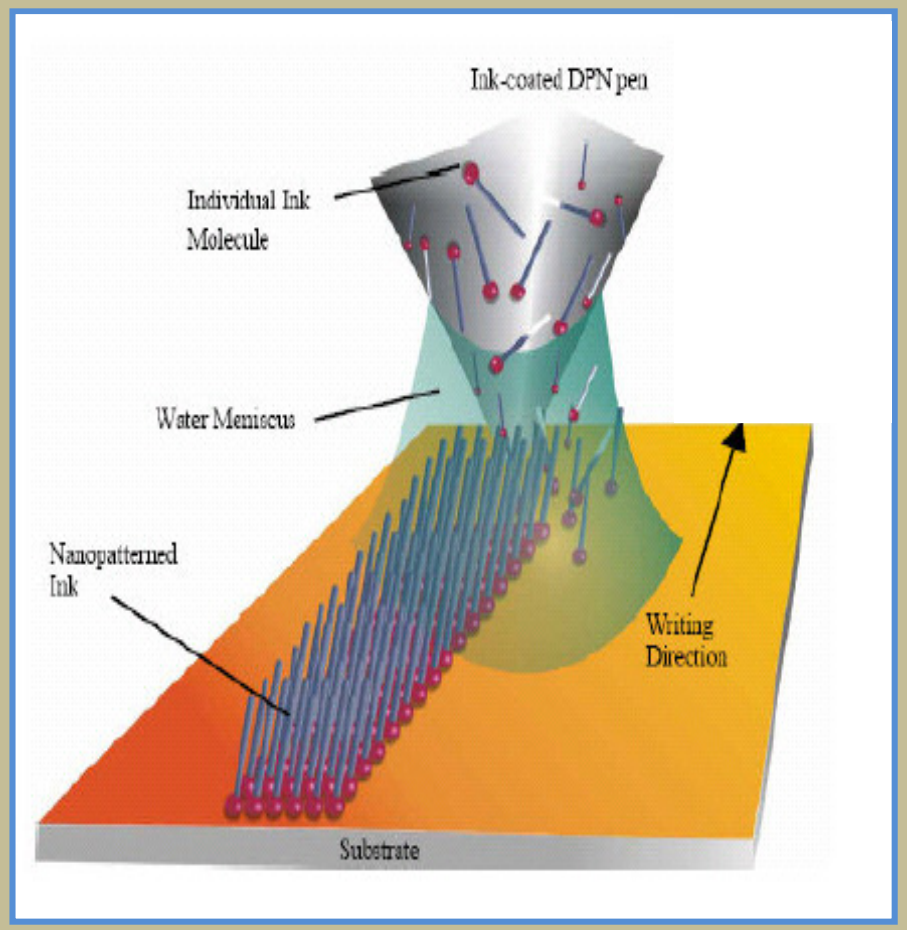
Based on a NanoPipette

- Any surface: flat or rough
- Wide variety of inks
- Reservoir for over a week of writing with no dipping needed
- A NanoTool Kit™ of probes including probes for melting inks on a surface

Methods of Nanochemical Lithography

Dip Pen NanoLithography

R. D. Piner et al. Science 283, 661 (1999)



Based on a meniscus formation with a water layer on the surface to be written

- Requires *very* flat surfaces
- Very limited inks
- Only gold substrate
- Highly limited systems
- Highly limited probes

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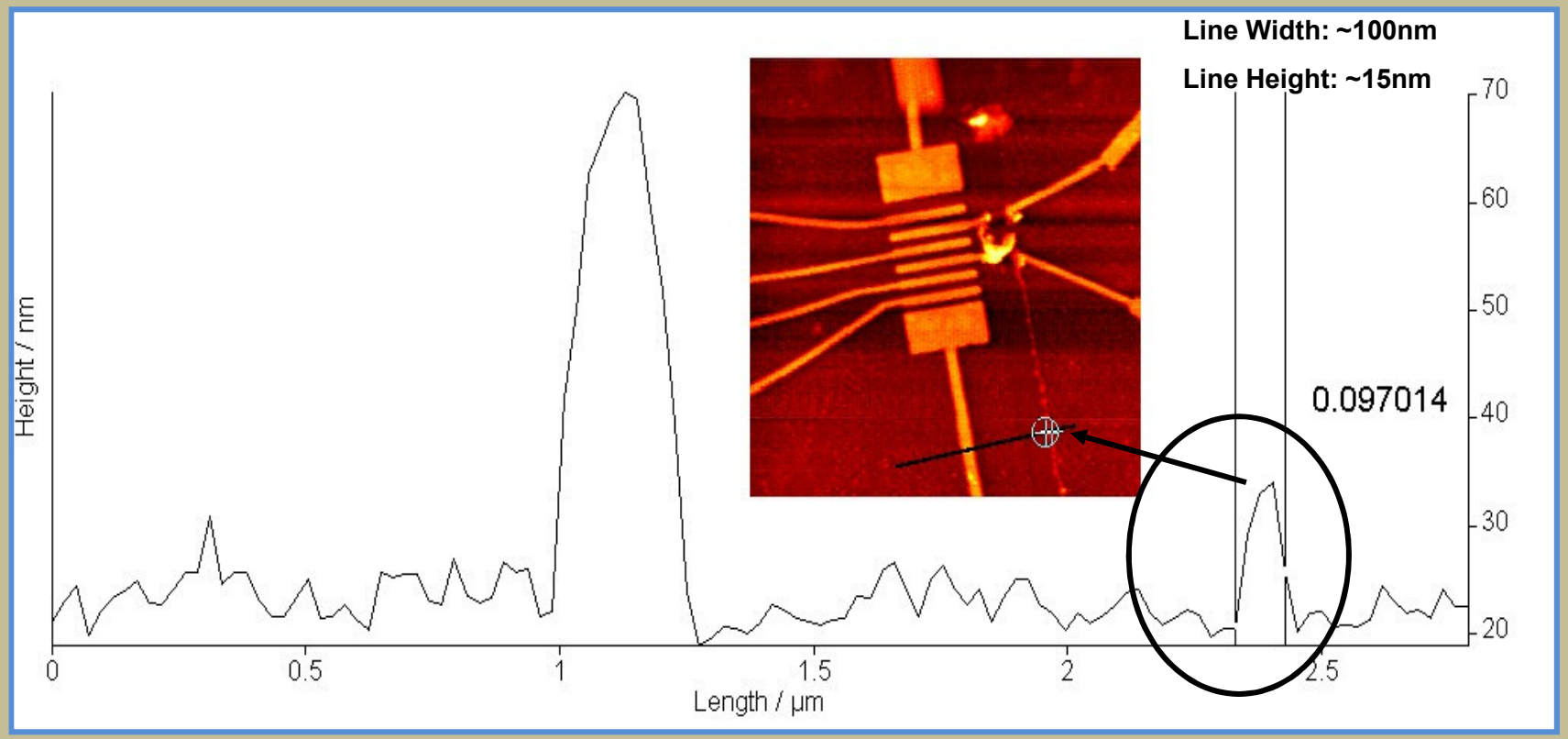
Nanonics Unique FPN Systems

- Any solvent
  - Organic
  - Aqueous
- Any surface
  - Smooth surface
  - Rough surface
  - Any material surface: Silicon; Glass; Metal
- Any ink
  - Gold nanoparticles
  - Gases
  - Proteins
  - Nanotubes
  - Rods
- Any Problem
  - Etching
  - Printing conducting patterns
  - Gas deposition
  - Protein chips
  - Hydrophobic polymer nanoparticles
  - Circuit edit
  - Photonic circuits
- Ultimate control- Voltage Controlled Electrophoretic & Dielectrophoretic Deposition
- Any view
  - Above
  - Below
  - Both
  - True independent MultiProbe operation
- On-line spectroscopic characterization
  - Fluorescence
  - Raman
  - Near-Field optical

Nanoparticle Deposition

Gold Nanoparticles in Methanol Deposited on Silicon



Registration of a gold nanoparticle line (100 nm wide & 15 nm high) to a gold line (250 nm wide & 50 nm high) patterned by electron beam lithography

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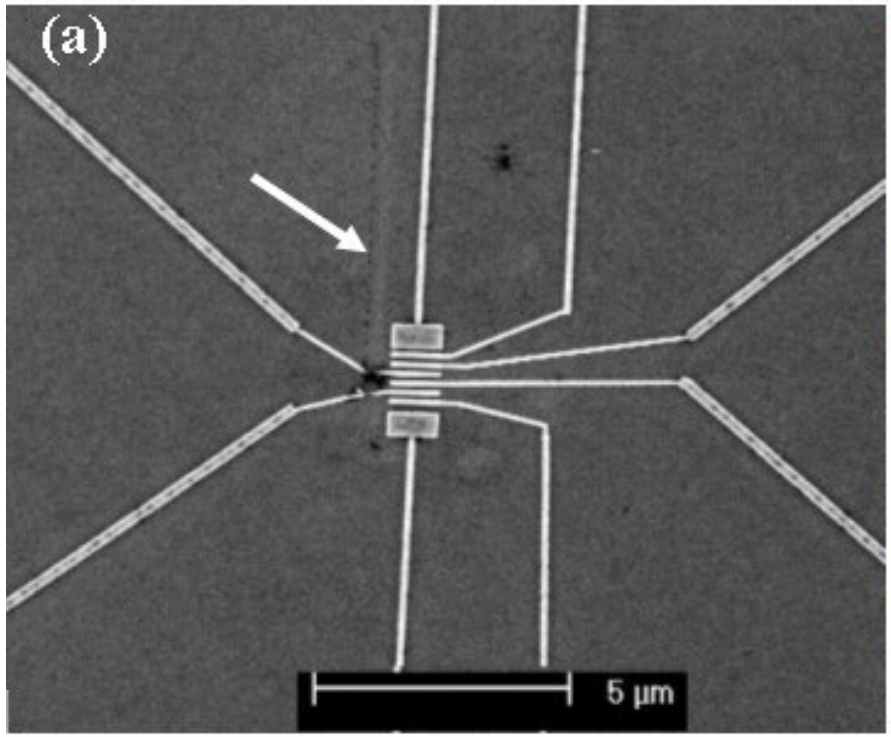
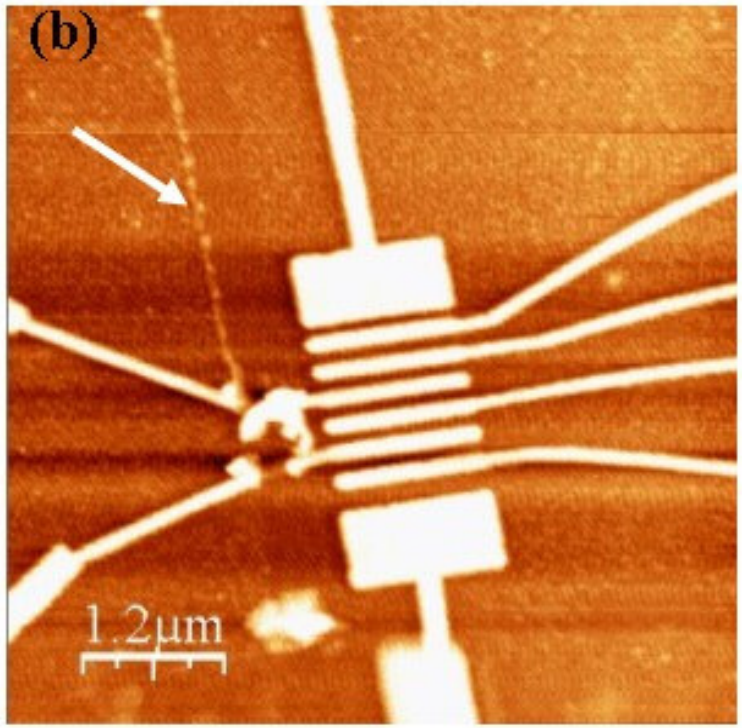
FPN gold NanoLine- full view

SEM Image

AFM Image

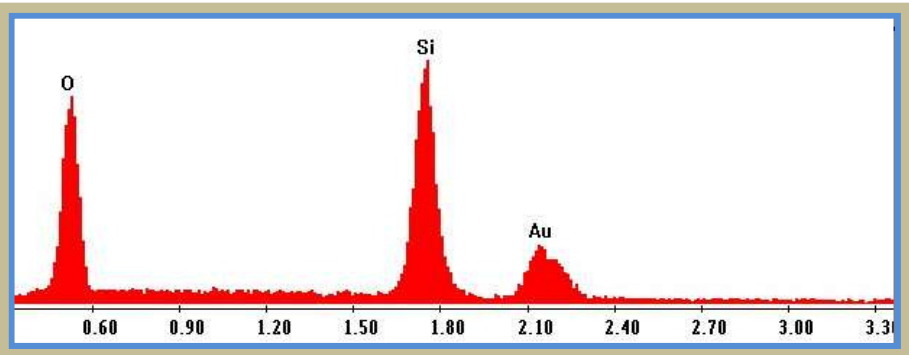




SEM imaging of the FPN deposited gold showing conductivity of the line

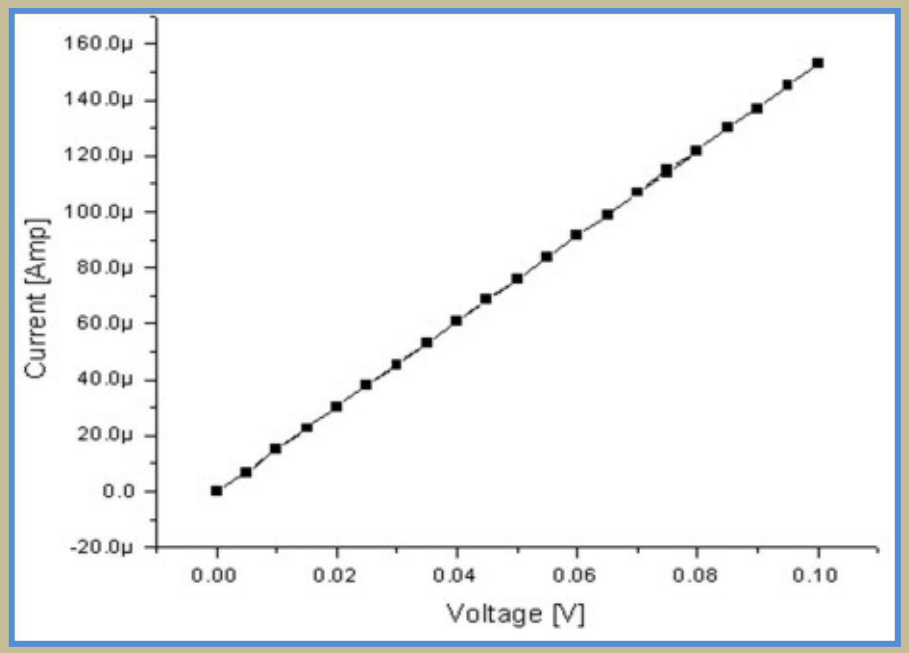
Characterization of the FPN written gold line

EDS measurement of the gold line:



I-V Characterization of the gold line without annealing, i.e. gold nanoparticle ink not melted together

The line slope shows Ohmic behavior with resistance of ~ 650 ohms.



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Gas Phase Delivery & Nanochemistry Only With FPN

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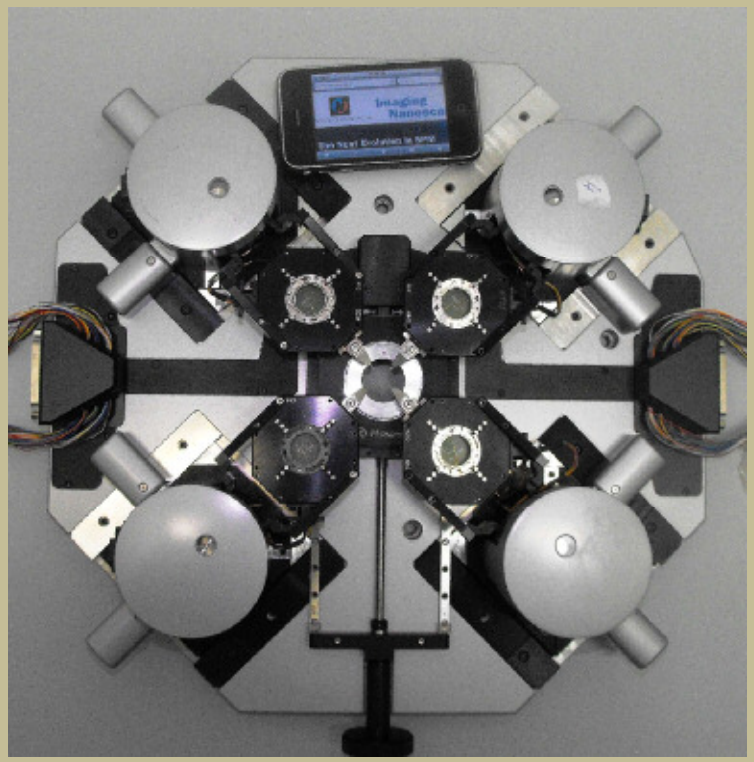
The Nanonics Multiprobe MultiView FPN System



Only Nanonics has Independently Controlled MultiProbes

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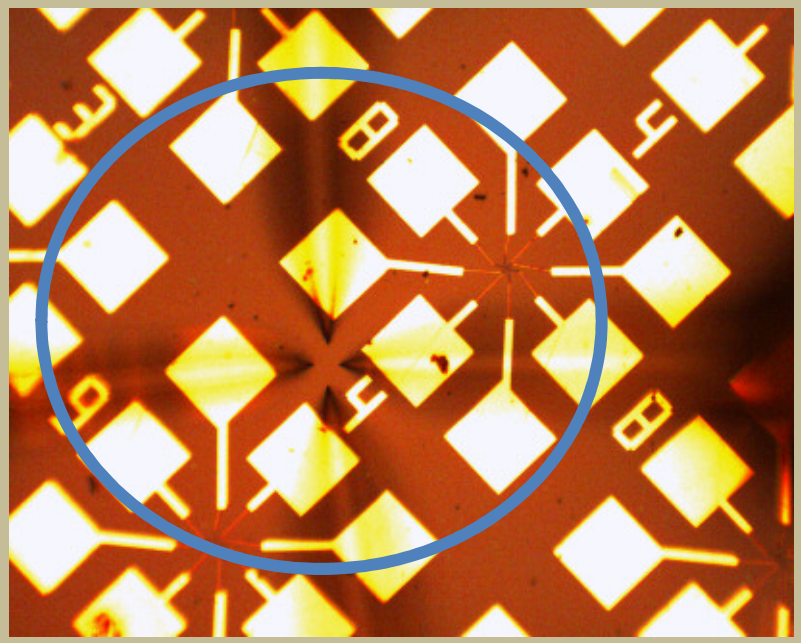
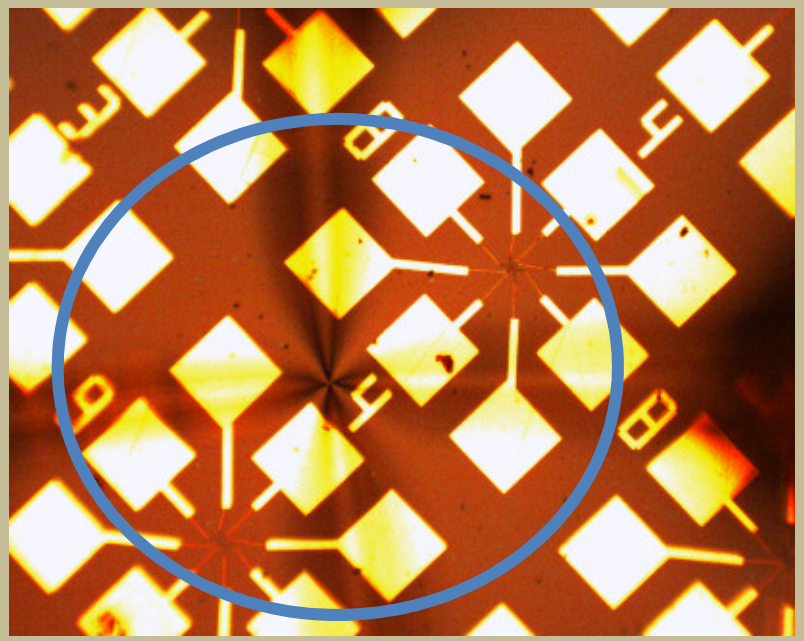
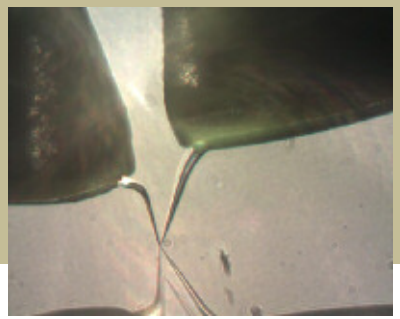
The Nanonics Multiprobe MultiView Full View FPN System





An upright microscope view of four probes approaching an opaque sample in close proximity.

Unique optical and multiprobe friendly probe structure enables imaging all probes in NanoToolKit™



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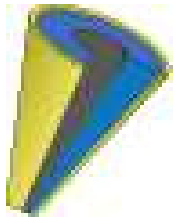
NanoToolKit™

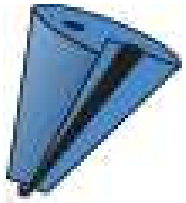
Unique exposed tip-optically & multiprobe friendly probes

NanoOptical Light Source

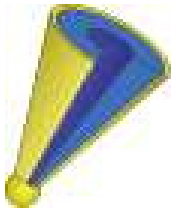


Nanopipettes for:

- Ionic Conductance
- NanoFountain Pens for
  - Liquid & Gas Delivery
- NanoEvacuation



NanoHeaters combined with Differential Scanning Calorimetry

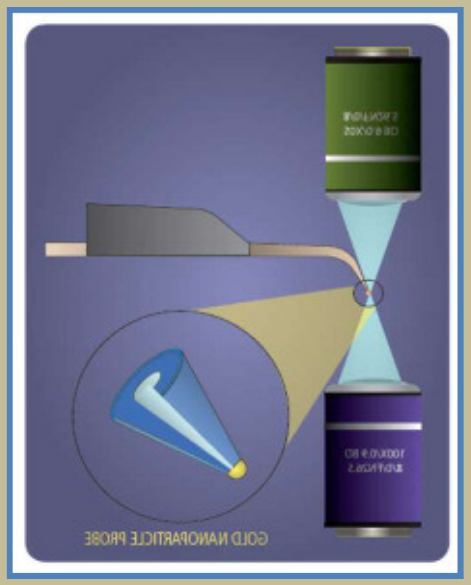


Plasmonic NanoProbes with Single Gold NanoParticles

Glass Insulated Coaxial NanoElectrical & Cantilevered NanoElectrochemical Probes

General probe properties:

MultiProbe Friendly



Optically Friendly:

- Non-Obscuring Non-Interfering Cantilevers
- Probe Tips Exposed To The Optical Axis

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Nanonics FPN System versus DPN System

DPN System:

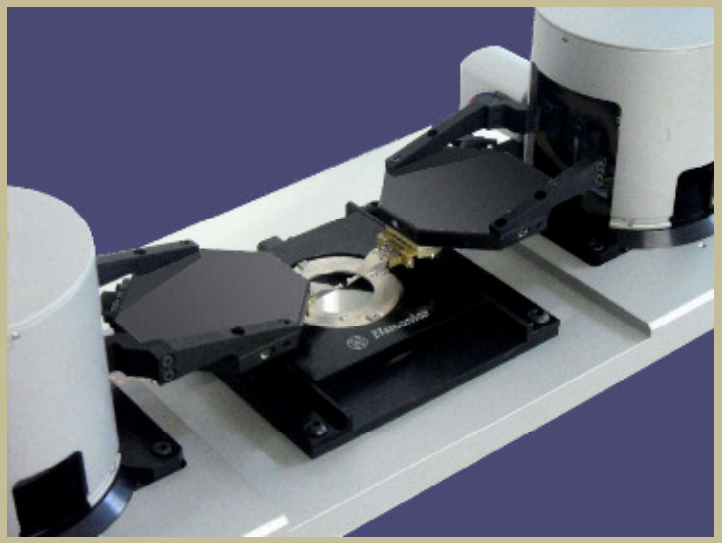
Restricted View-

blocked from above

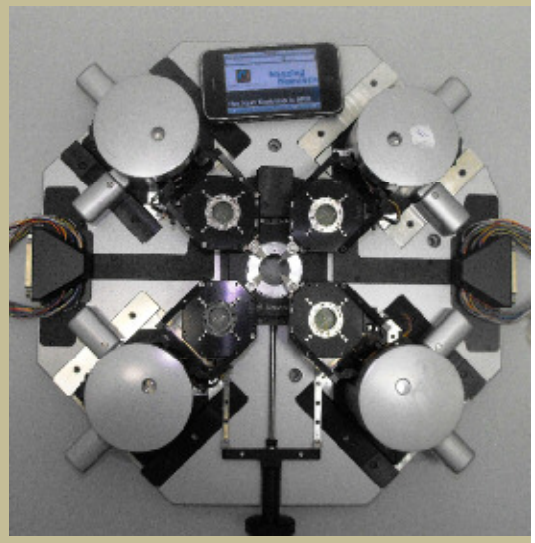
Nanonics Full View FPN Systems:

- All are accessible from above and beneath

Single Probe



Two Probe



Four Probe

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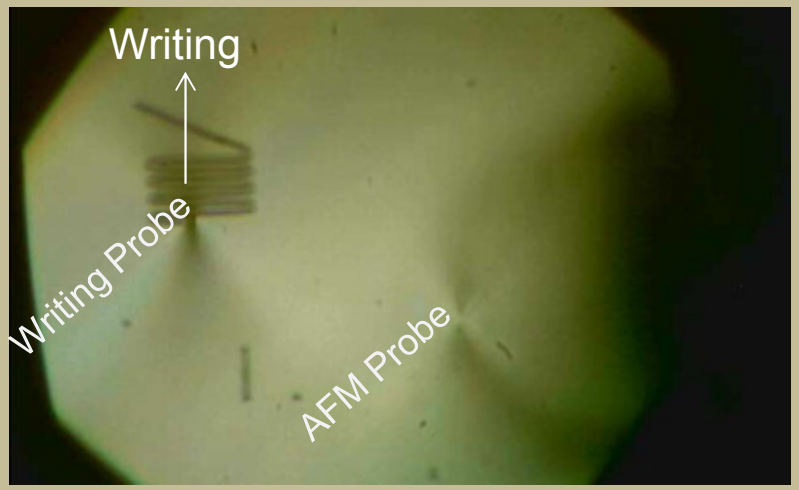
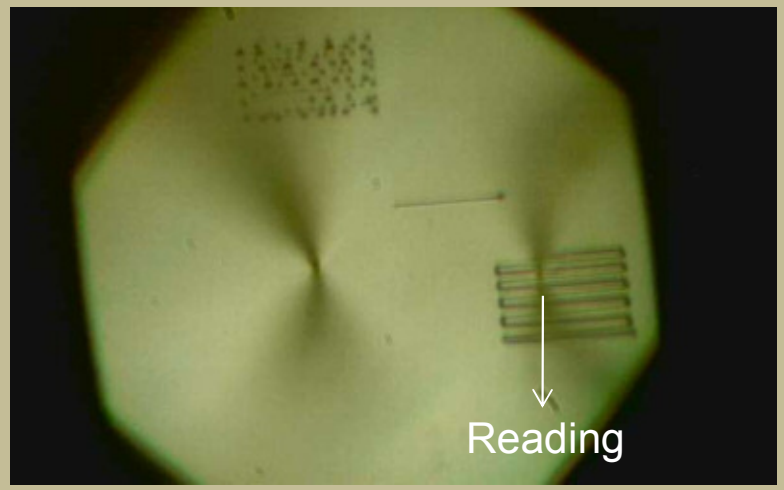
MultiProbe Writing & Imaging

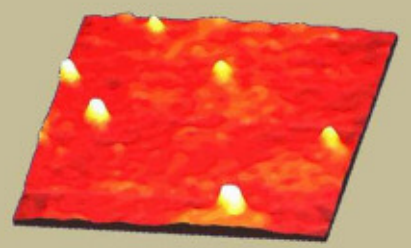
Protein Bovine Serum Albumin On Conventional Protein Spotting Glass Substrates





Protein Spotting on standard Superoxide or Superaldehde protein macrospotting substrates.

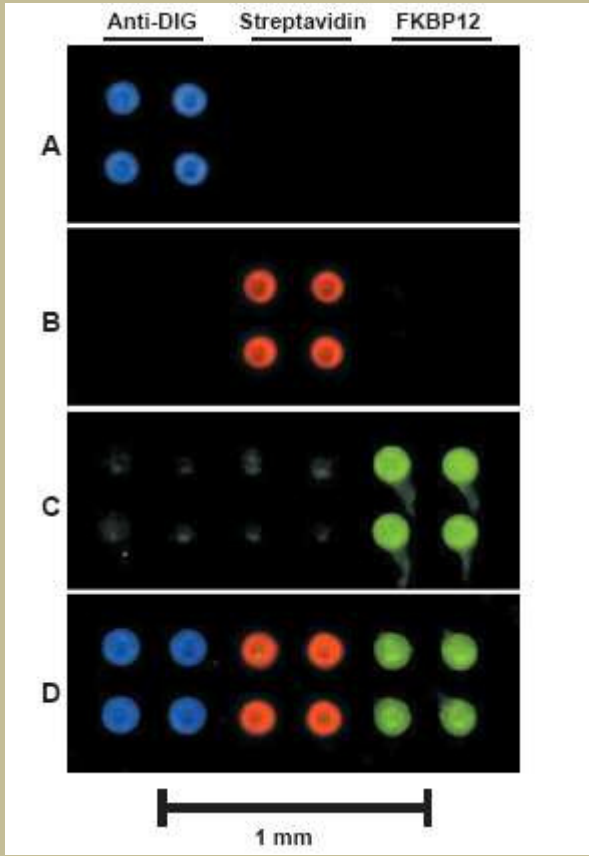
- No need for protein modification as in DPN
- Full protein activity for binding studies



NANONICS IMAGING

Standard Macro Spotting of Proteins On Conventional Protein Spotting Glass Substrates

from Telechem International

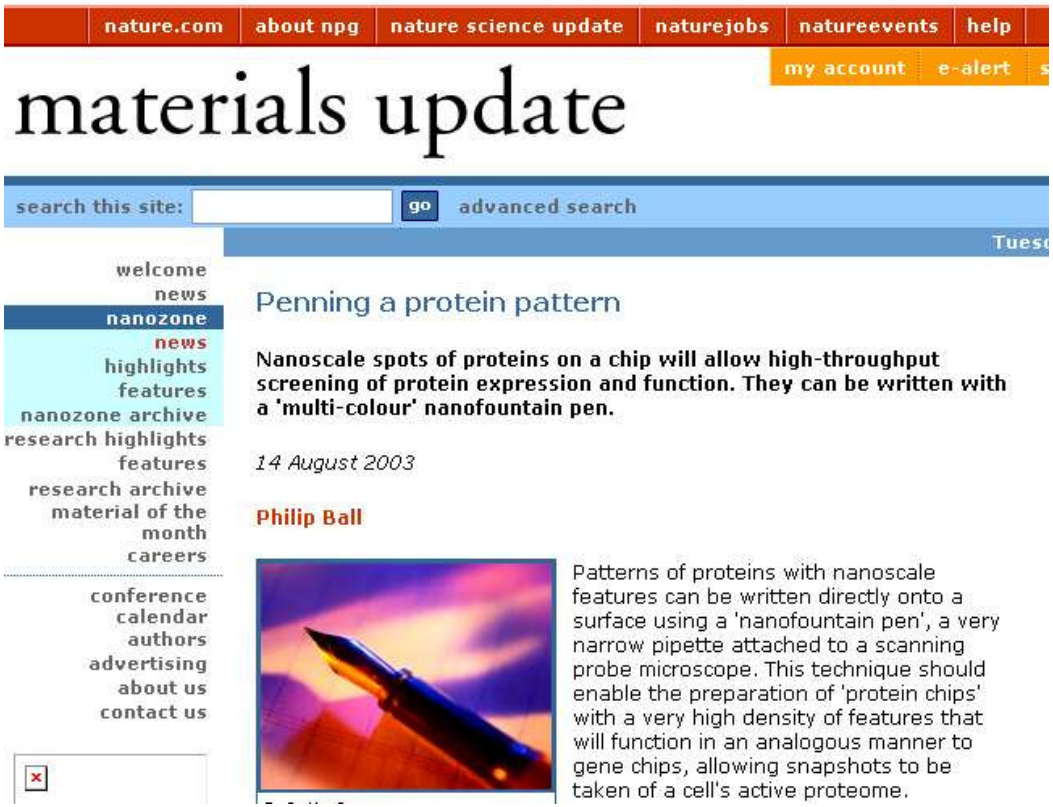


- G. MacBeath & S. L. Schreiber, Science 289, 1760 (2000)
- Aldehyde slides were purchased from TeleChem International (Cupertino, CA) under the trade name SuperAldehyde or Superepoxide Substrates
- Spotted using a GMS 417 Arrayer (Affymetrix, Santa Clara, CA) for Fig. 2, proteins were spotted using a split pin arrayer

The Inspiration

NanoFountain Pen Protein Printing: Indpendent Comparison with Dip-Pen

Phillip Ball in Nature Materials



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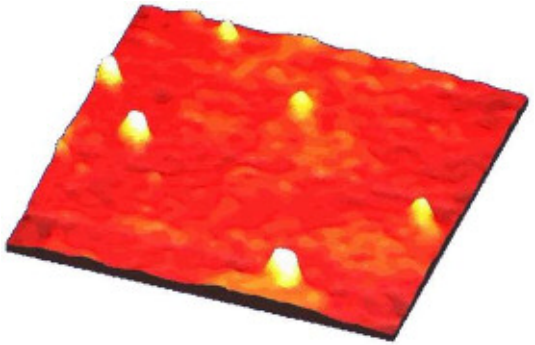
Penning a protein pattern

Nanoscale spots of proteins on a chip will allow high-throughput screening of protein expression and function. They can be written with a 'multi-colour' nanofountain pen.

14 August 2003

Philip Ball

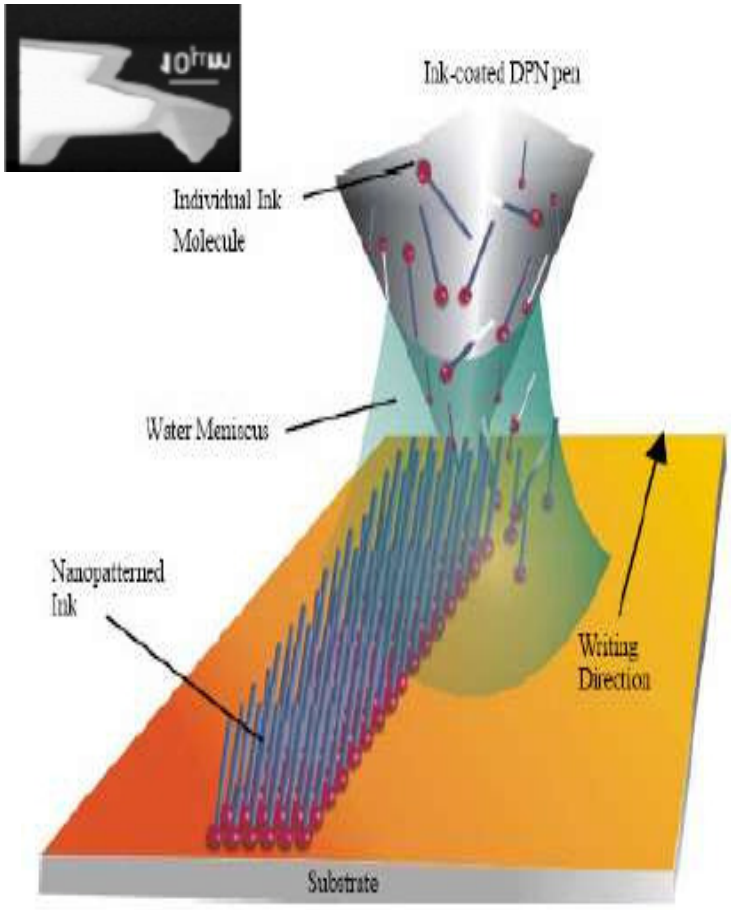
Patterns of proteins with nanoscale features can be written directly onto a surface using a 'nanofountain pen', a very narrow pipette attached to a scanning probe microscope. This technique should enable the preparation of 'protein chips' with a very high density of features that will function in an analogous manner to gene chips, allowing snapshots to be taken of a cell's active proteome.



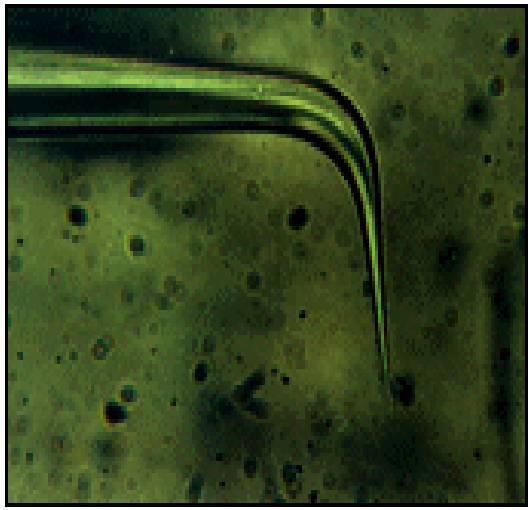
'fountain pen' can have different inks channelled into it automatically, simply by connecting it up to standard high-performance liquid chromatography instrumentation. This should make writing a multi-protein nanoarray much easier than by using DPN, and *without the need for any complex pre-treatment of the substrate.*

Both FPN & DPN Have No Control of the Writing in Contact

DPN Probe



FPN Probe With Its Reservoir & Inherent Writing Capabilites, Multiprobe & Spectral Transparency Advantages & Its Long Reach Into Deep Trenches

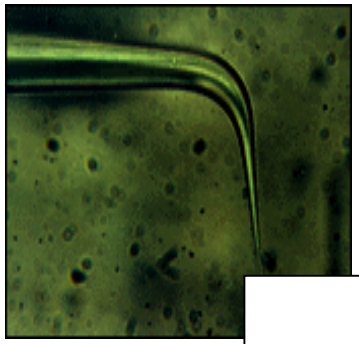


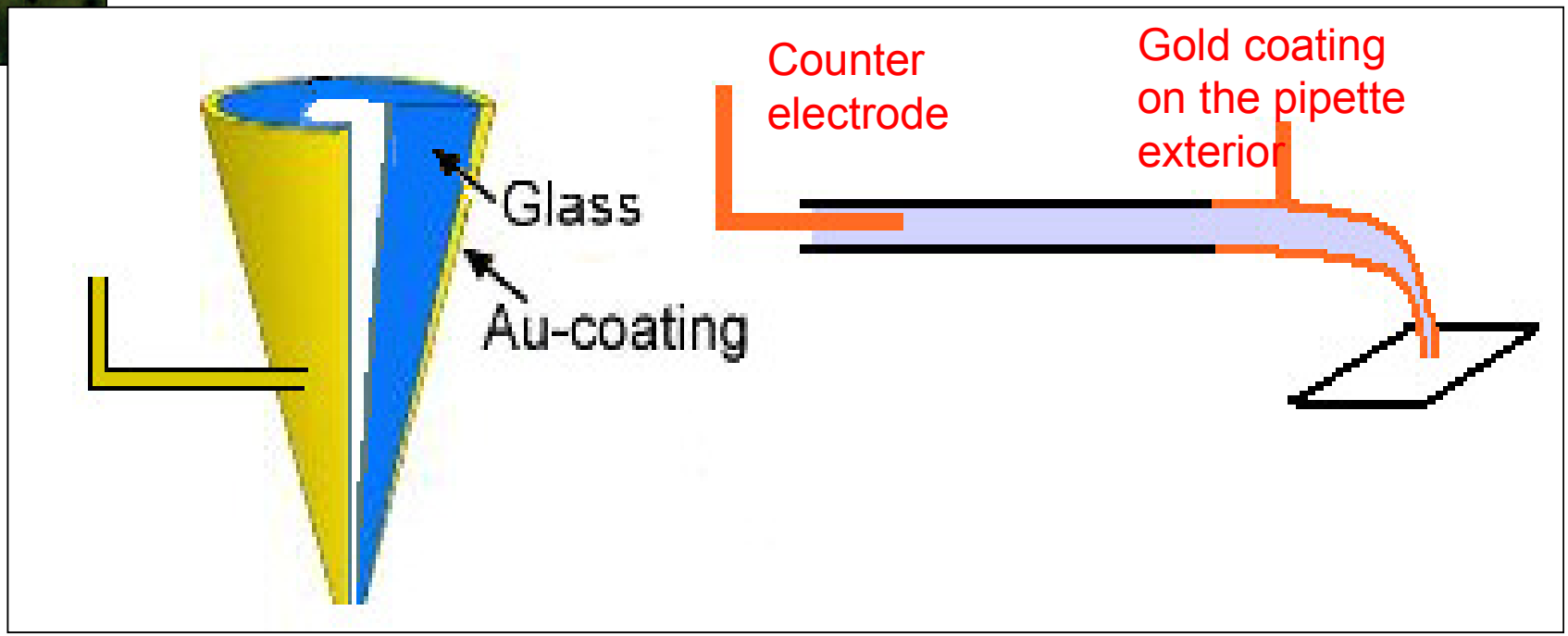
Both Dip Pen Lithography & Fountain Pen Lithography Suffer From
A Lack Of Control
When The Probe Touch They Write.

Nanonics Offers
The Ultimate in Control With
Voltage Controlled Liquid Deposition or
Gas Phase Chemical NanoDelivery with
the Ultimate in Resolution

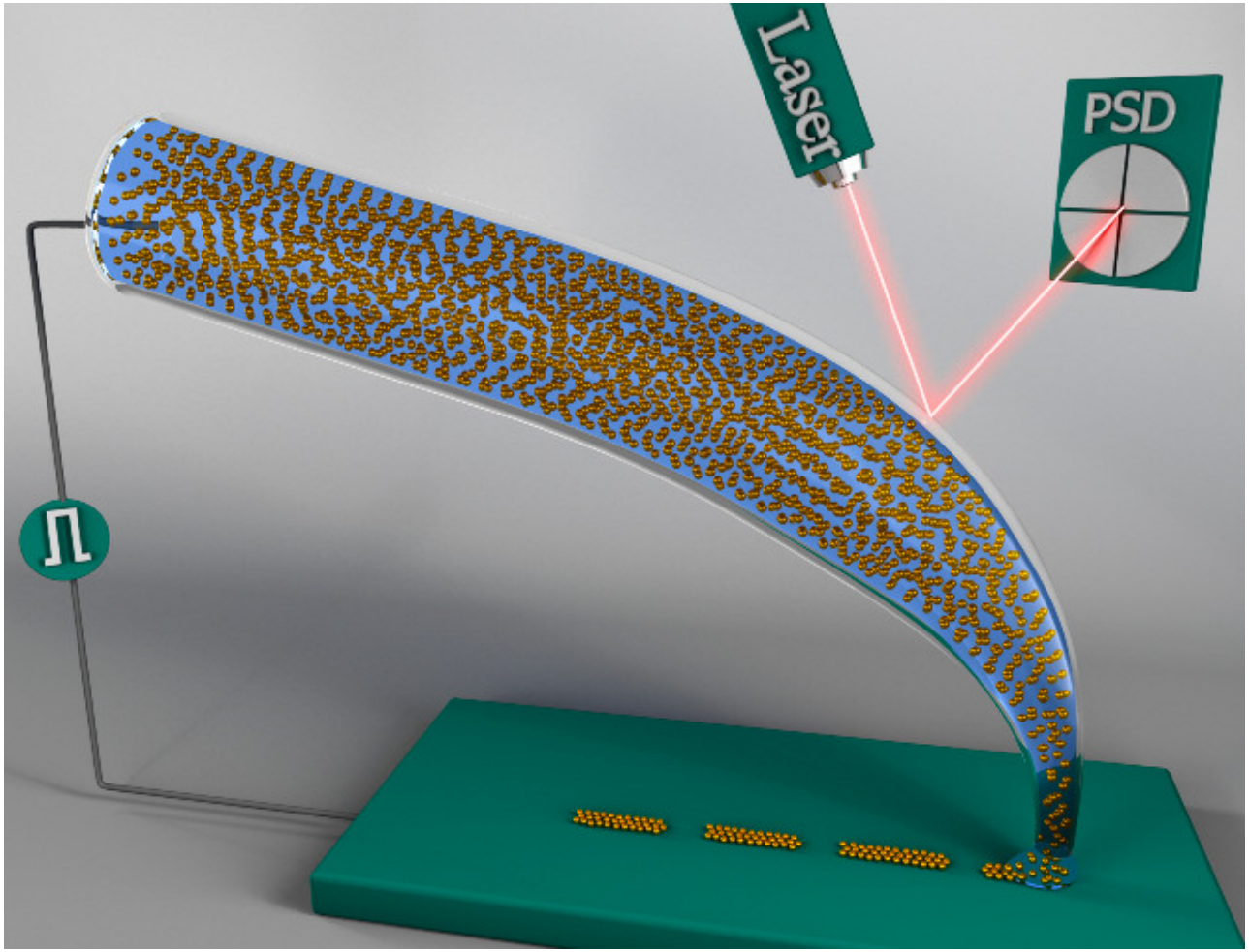
Now Nanonics Introduces Voltage Control of NanoChemical Deposition The Ultimate in NanoChemical Lithography

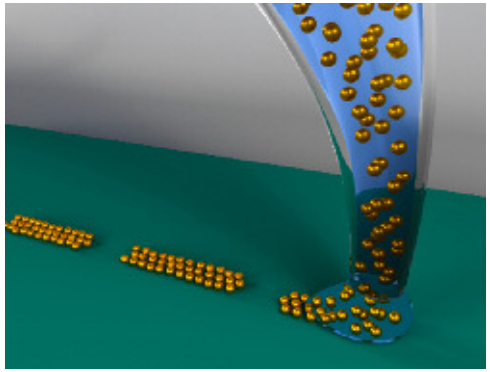
Protein Writing With Electrophoretic Voltage Control





The Ultimate in Writing Control
Voltage Controlled Deposition





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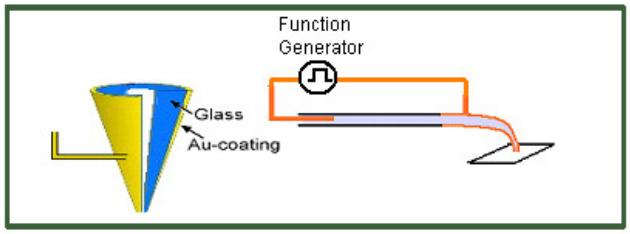
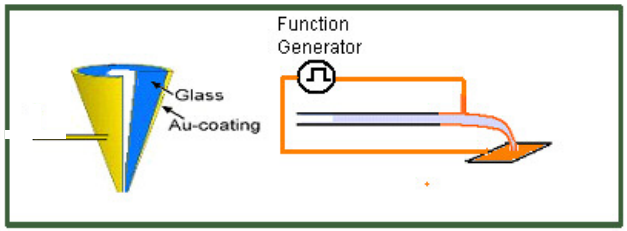
A Variety of Voltage Control Protocols

For a Variety of Setups

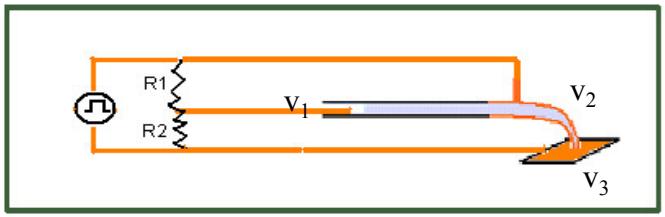
Voltage between
back side & front side of pipette



Voltage between
back side & sample



Voltage as above but also between the
back side of the pipette & the sample`



Positive pulse:

$V_3 > V_2 > V_1$

Negative pulse:

$V_1 > V_2 > V_3$

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Combining Voltage Controlled NanoChemical Writing With On-line Fluorescence & Raman

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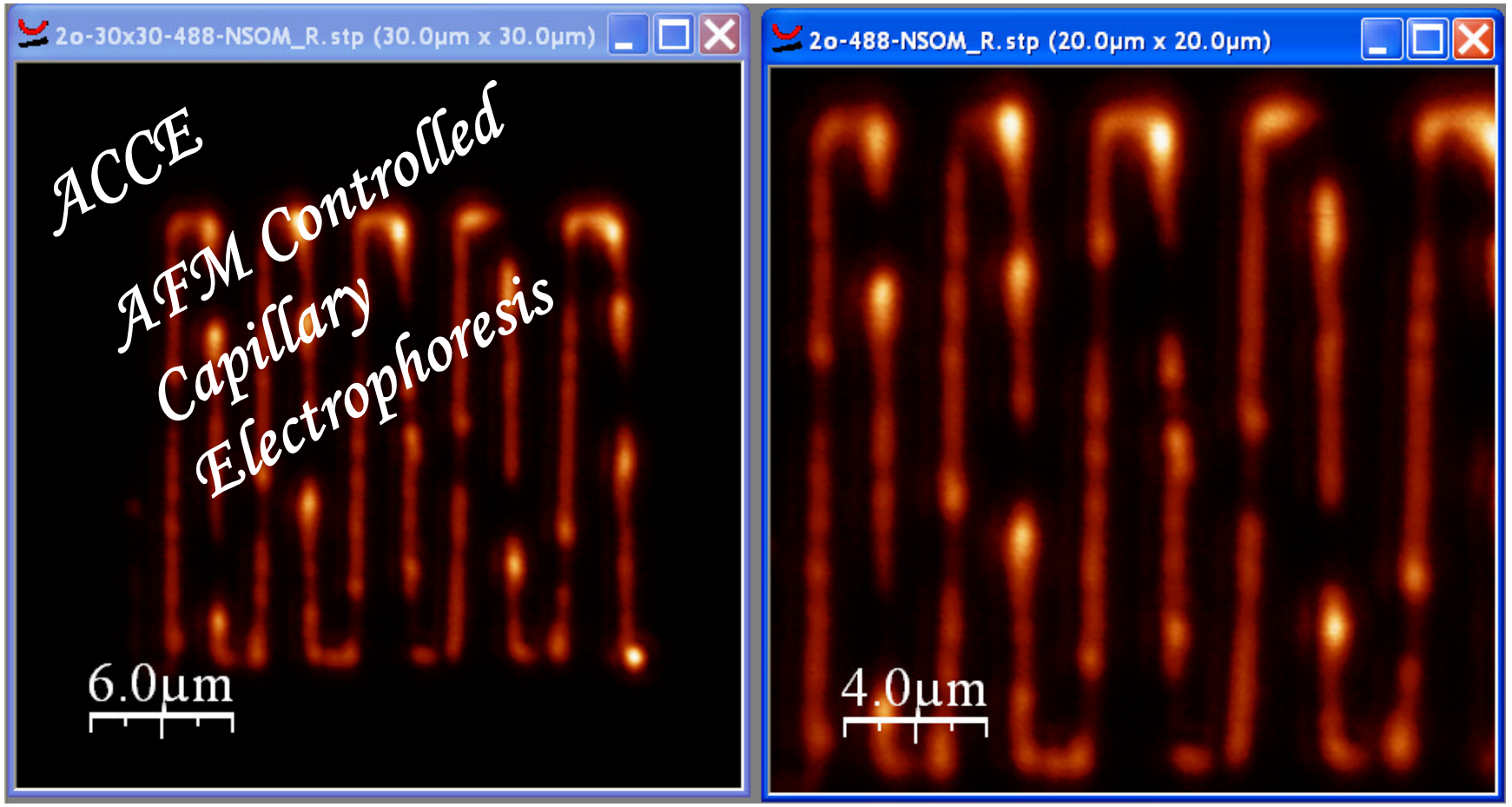
Transparent Integration of Nanonics FPN Systems With High End Spectroscopic Systems

MV 4000 MultiProbe Platform

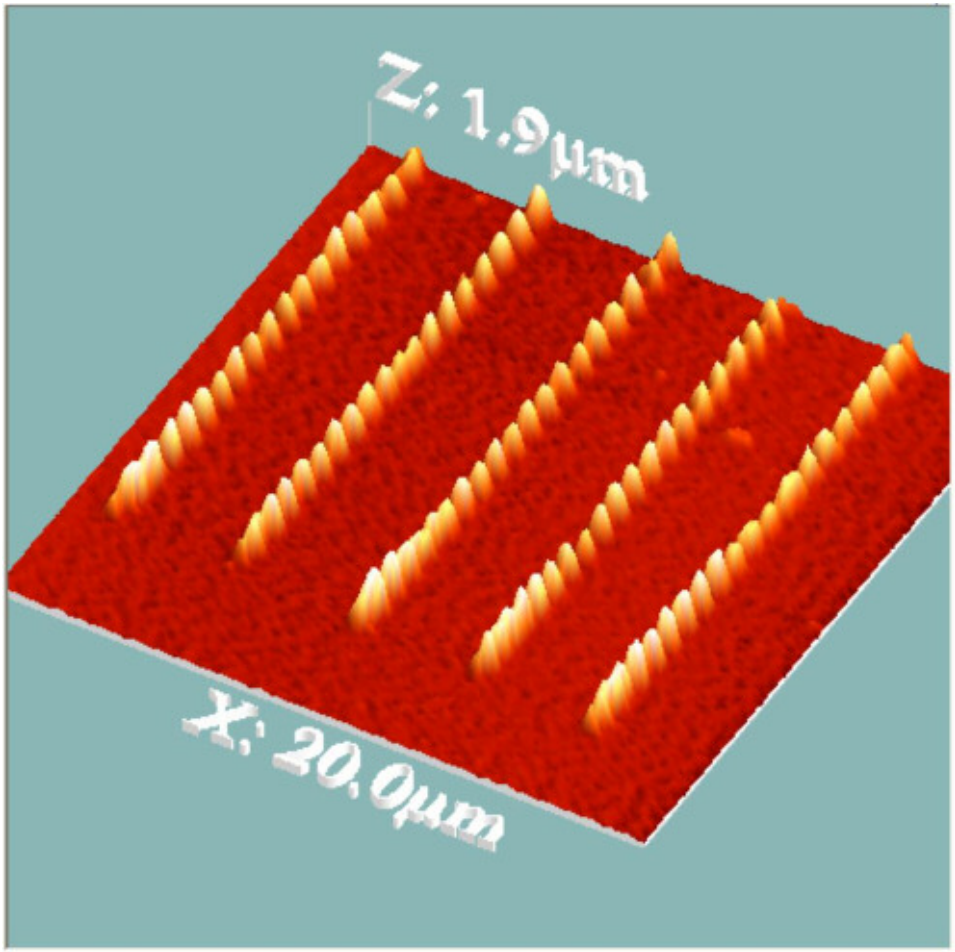
All MultiView FPN Systems Combine Transparently with On-line Spectral Analysis

MV 2000 Platform

Protein Writing With Electrophoretic Voltage Control & Fluorescence Detection



Protein Deposition With Voltage Controlled Electrophoretic Deposition



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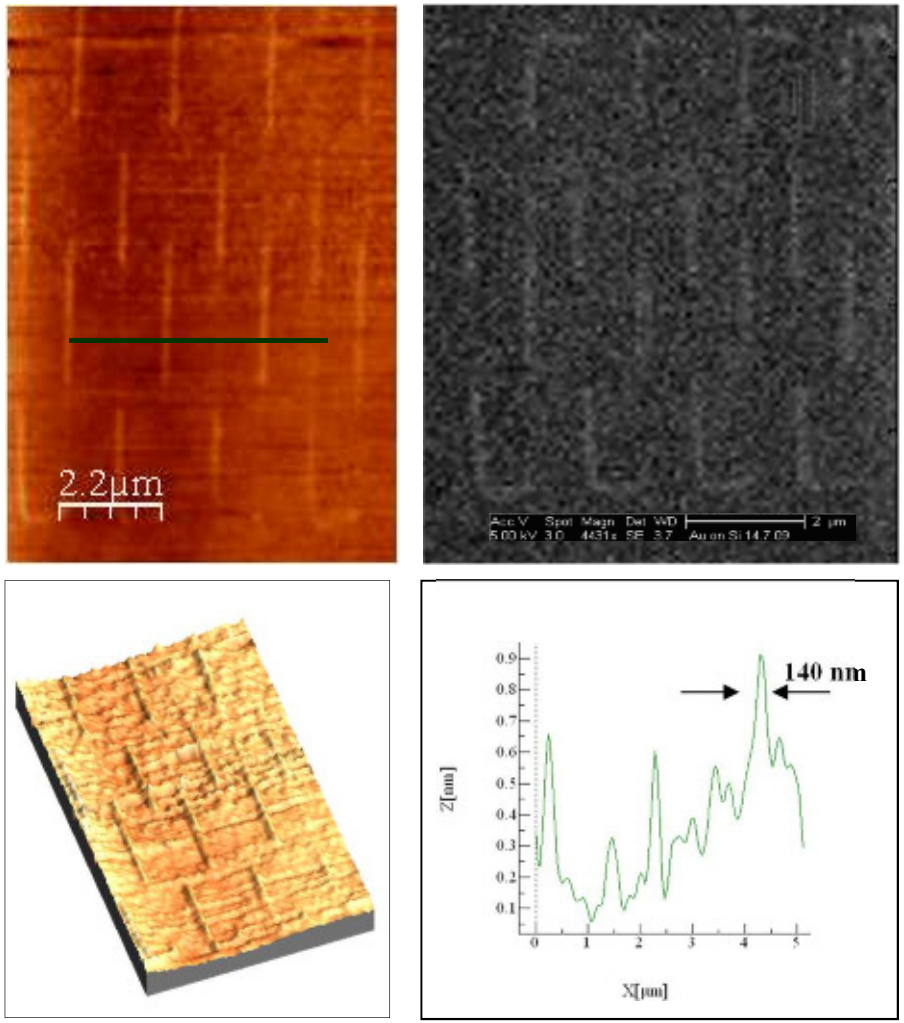
AFM & SEM of Nanowriting of Gold Nanoparticles in Methanol



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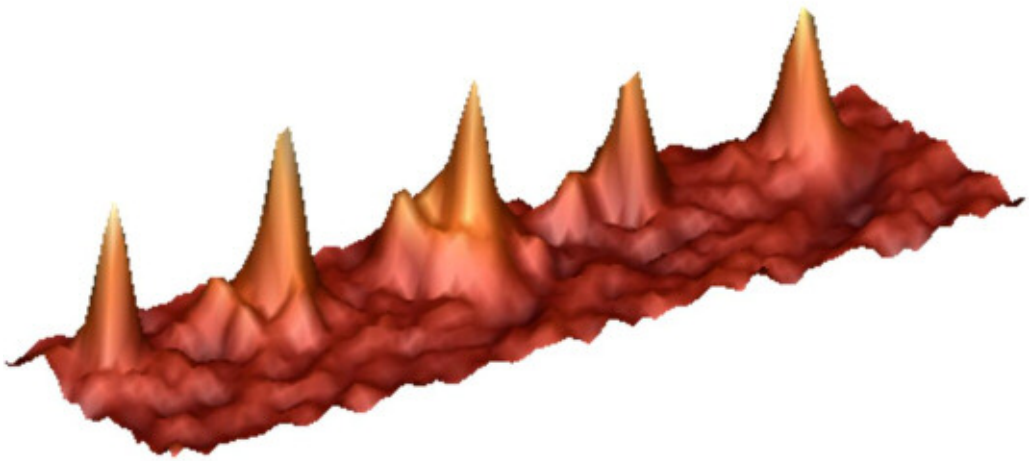
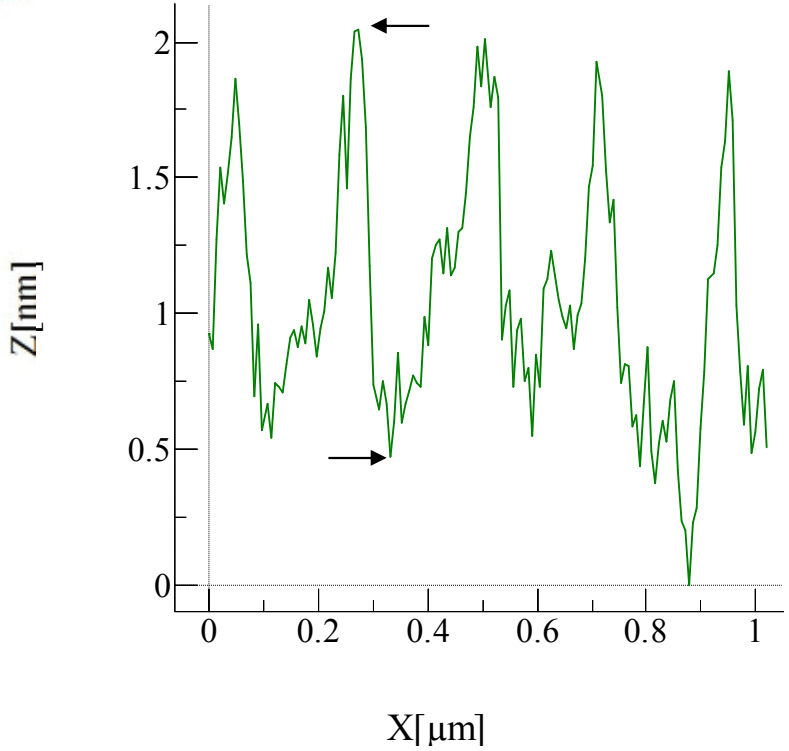
Electrophoretic Deposition of Single 1.4 nm Gold Nanoparticles



Height in AFM defines colloid or quantum dot dimensions
Fountain Pen Aperture I.D. 20nm
O.D 40nm

Height 1.4 nm
Reproducibility of ± 0.2 nm. The Reproducibility of the Supplied Gold Colloids



Nanonics Unique FPN Systems

- Any solvent
  - Organic
  - Aqueous
- Any surface
  - Smooth surface
  - Rough surface
  - Any material surface: Silicon; Glass; Metal
- Any ink
  - Gold nanoparticles
  - Gases
  - Proteins
  - Nanotubes
  - Rods
- Any Problem
  - Etching
  - Printing conducting patterns
  - Gas deposition
  - Protein chips
  - Hydrophobic polymer nanoparticles
  - Circuit edit
  - Photonic circuits
- Ultimate control- Voltage Controlled Electrophoretic & Dielectrophoretic Deposition
- Any view
  - Above
  - Below
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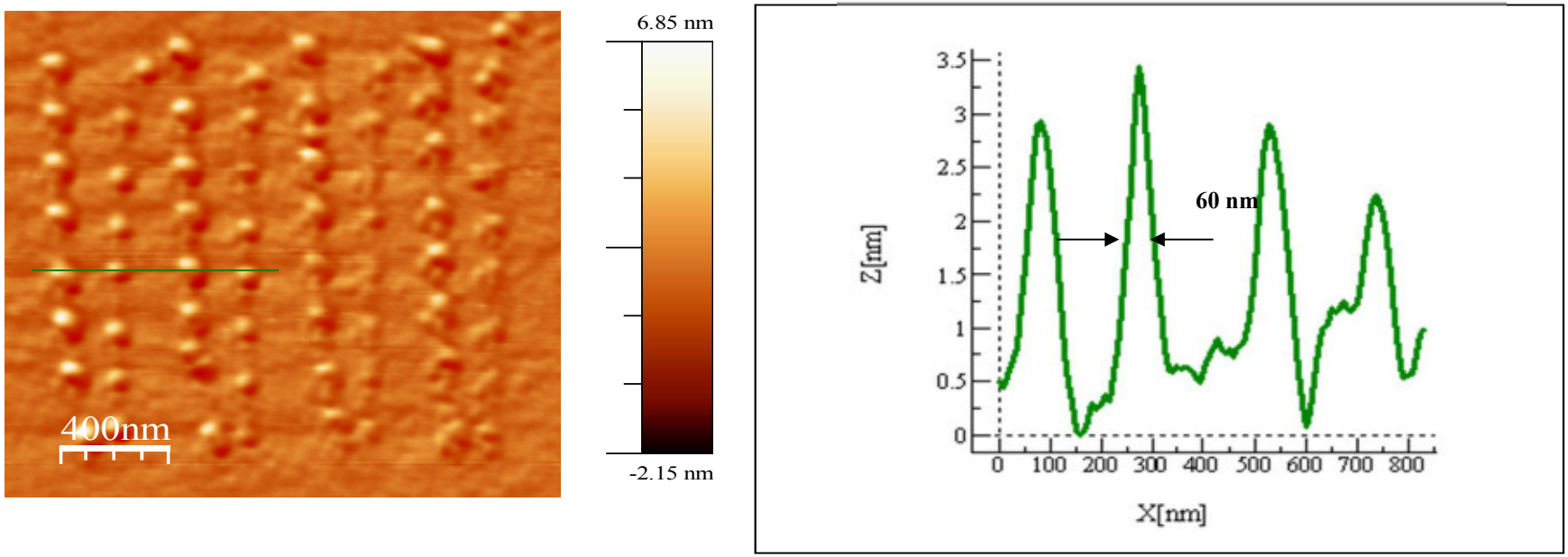
- On-line spectroscopic characterization
  - Fluorescence
  - Raman
  - Near-Field optical

Voltage Controlled Dielectrophoretic Deposition of Polymer Nanoparticles in Hexane



NanoWriting Polymer Nanoparticles

NANONICS IMAGING

Nanonics Unique FPN Systems

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  - Organic
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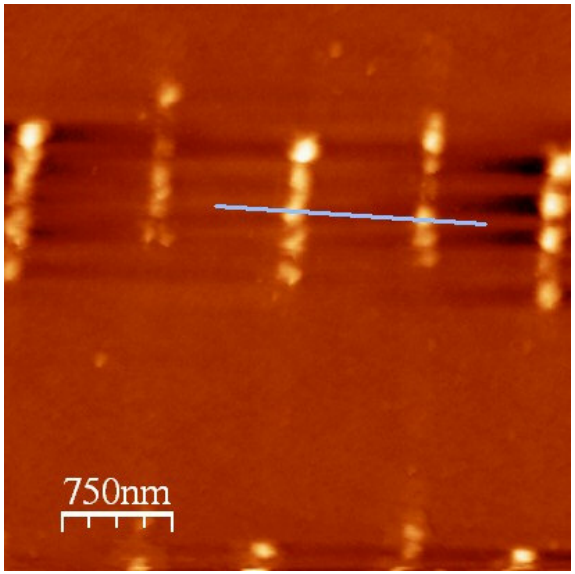
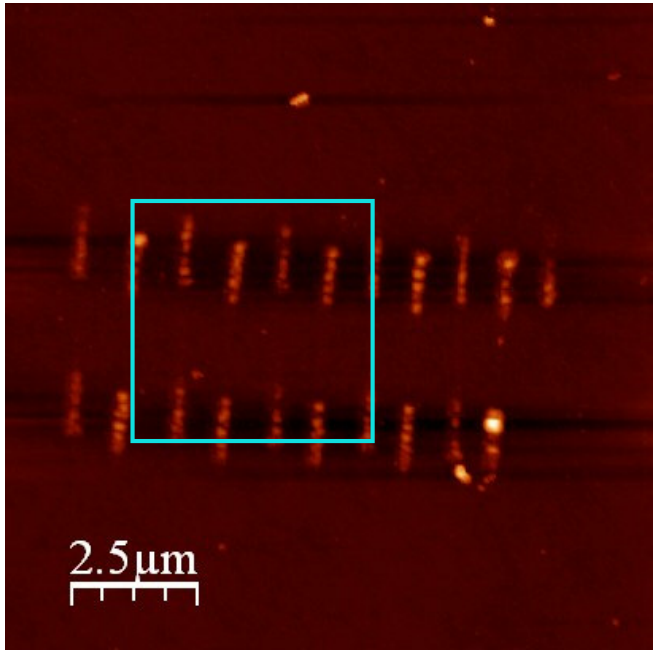
Carbon NanoTube NanoDielectrophoretic NanoWriting with Surfactant

- The ink: CNT with surfactants in water solution.
- CNT dimension : diameter of 0.7-1.4 nm
  Length of 1-1.5 µm.



AFM image of deposited Carbon Nanotubes



But is the written pattern really carbon nanotubes?

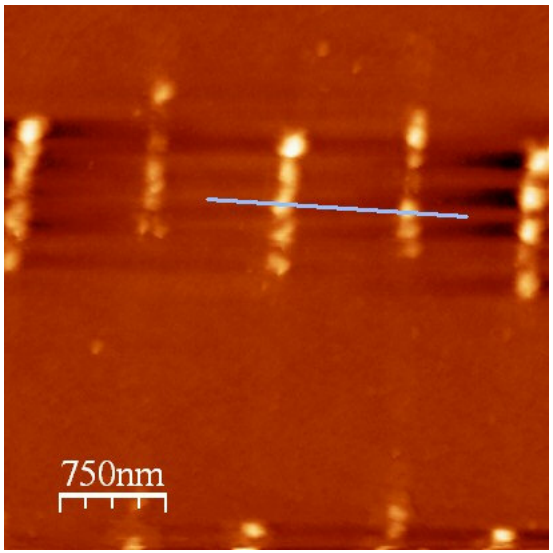
Raman can tell us!

Combining Voltage Controlled NanoChemical Writing With On-line Raman

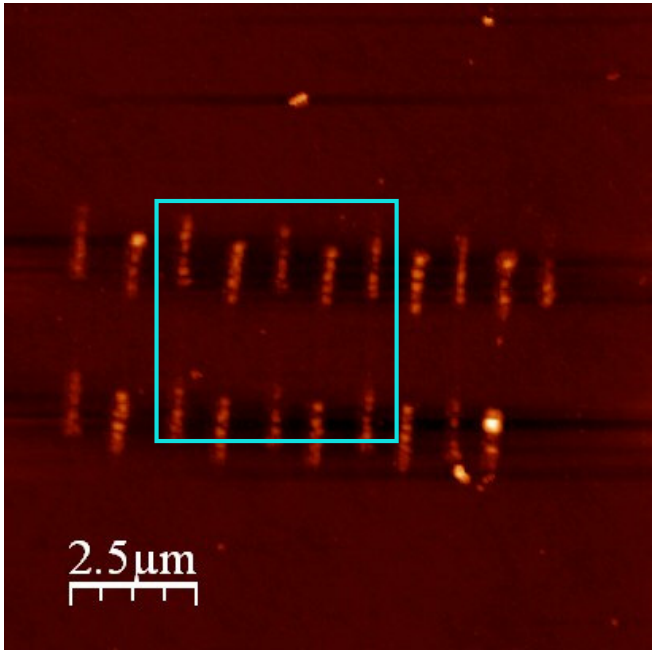
NANONICS IMAGING

Raman Spectroscopy Insures The Chemical Character of the Lines

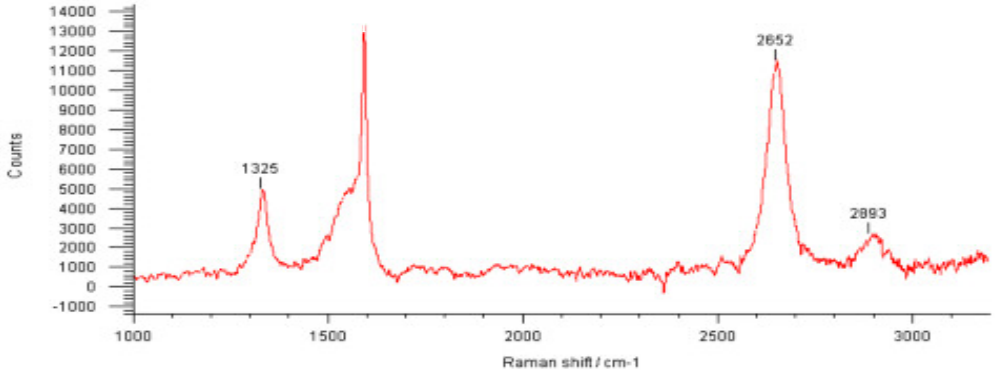
- The ink: CNT with surfactants in water solution.
- CNT dimension : diameter of 0.7-1.4 nm
  Length of 1-1.5 µm.



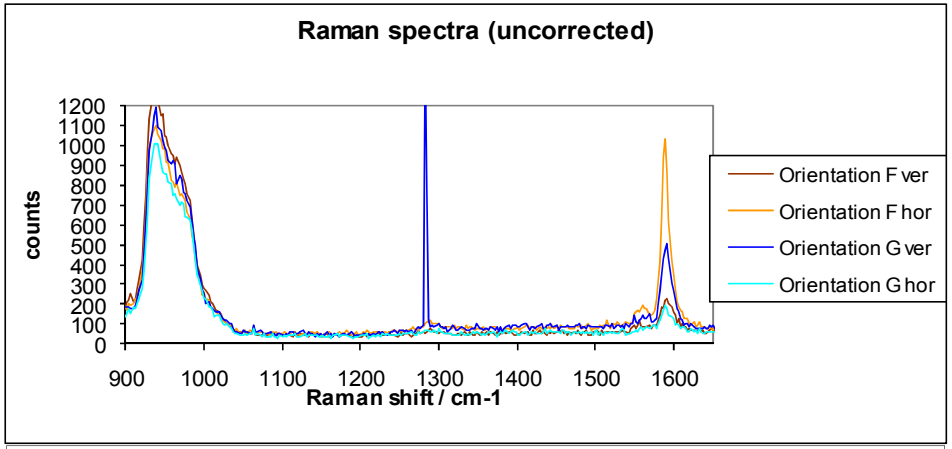
AFM image of deposited Carbon Nanotubes

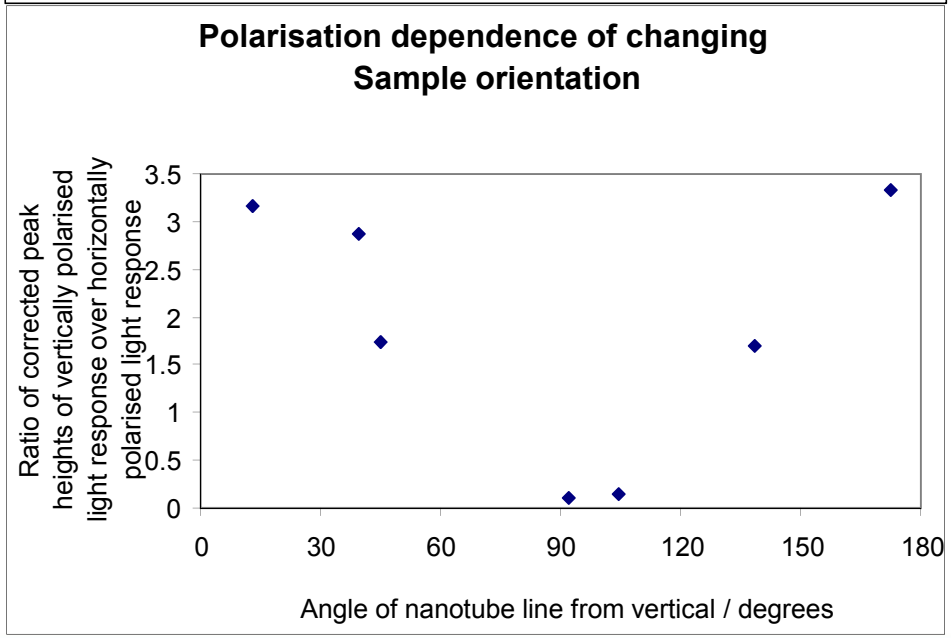


Raman spectrum from the Carbon Nanotubes lines



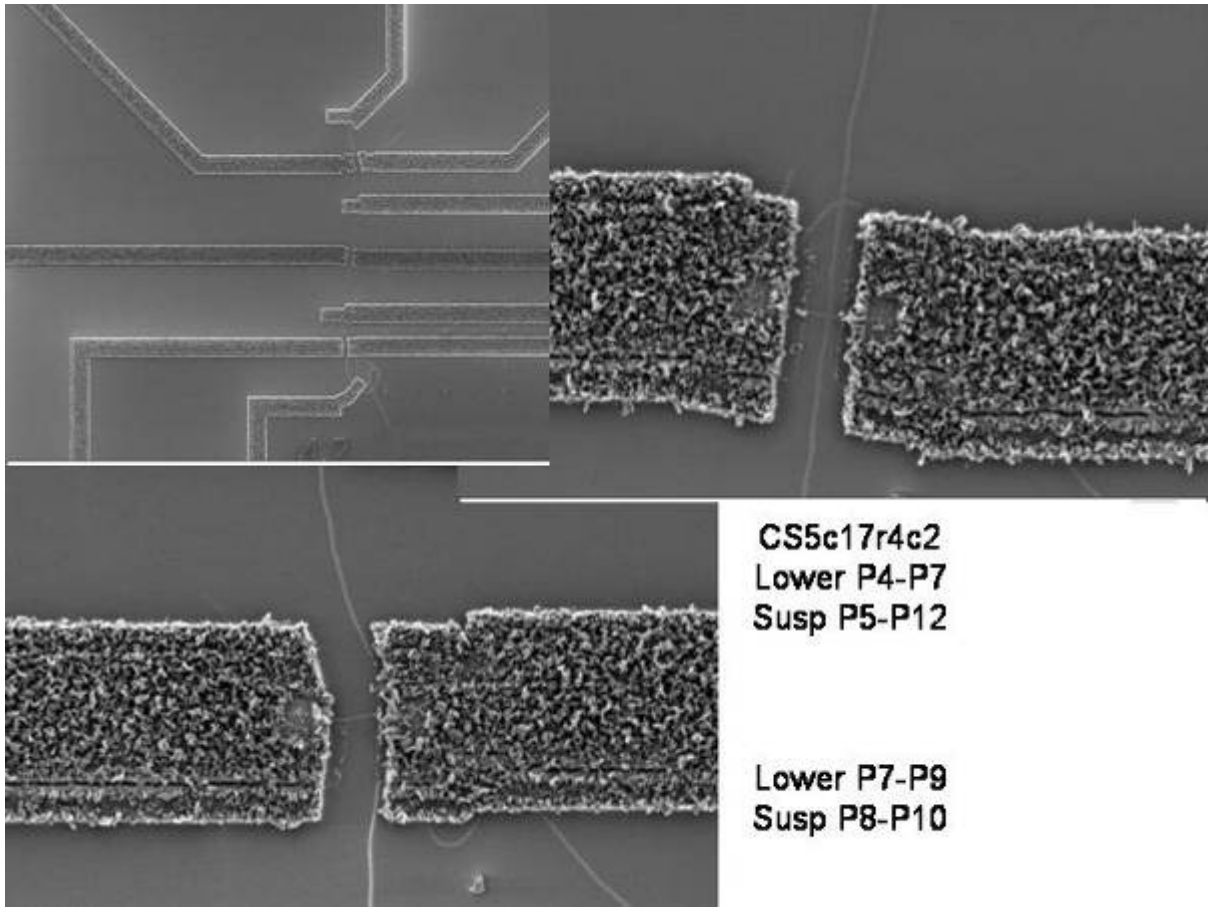
Raman Polarization Analysis Further Shows Aligned Carbon Nanotubes





On-line Raman polarization analysis show orientation due to the dielectrophoretic controlled voltage writing process that also has the potential for conducting and semiconducting tube separation

SEM of Deposited & Registered Carbon NanoTube



NANONICS IMAGING

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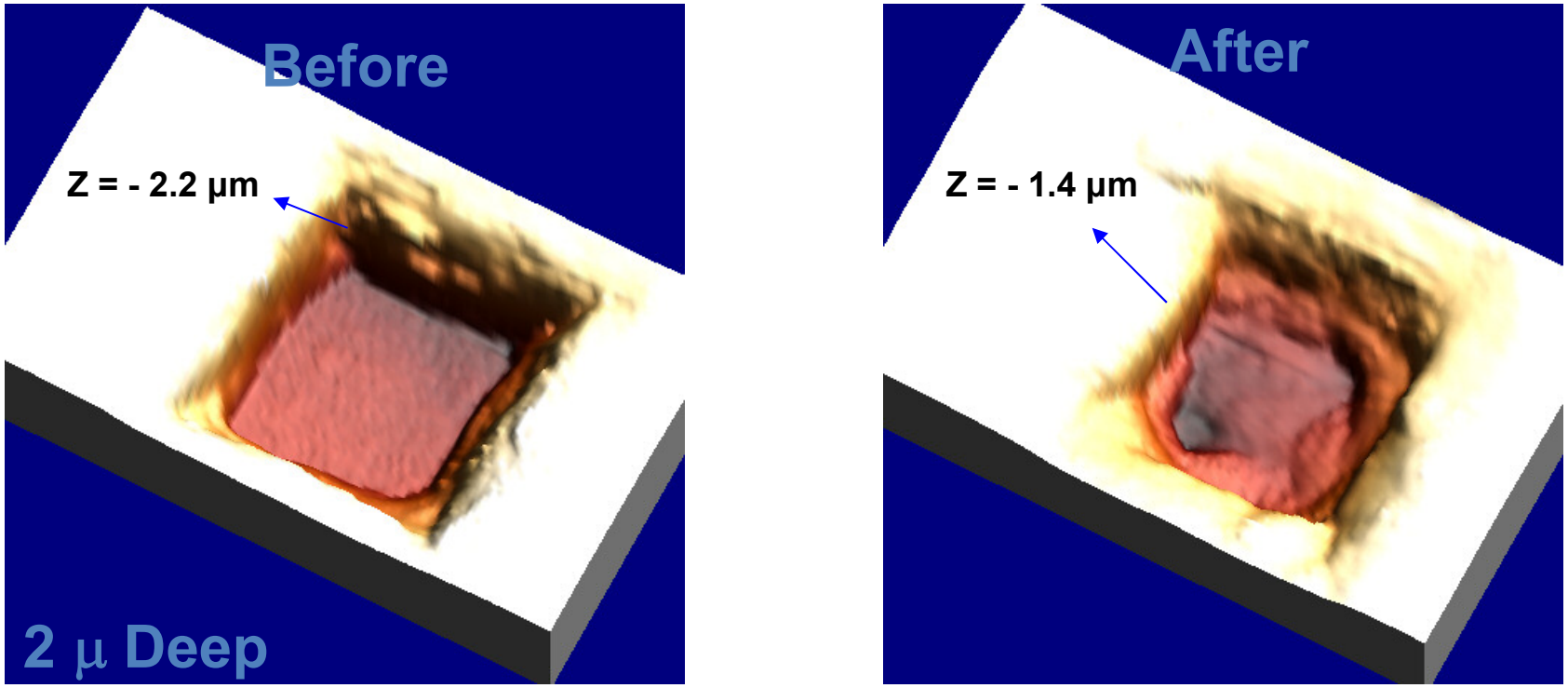
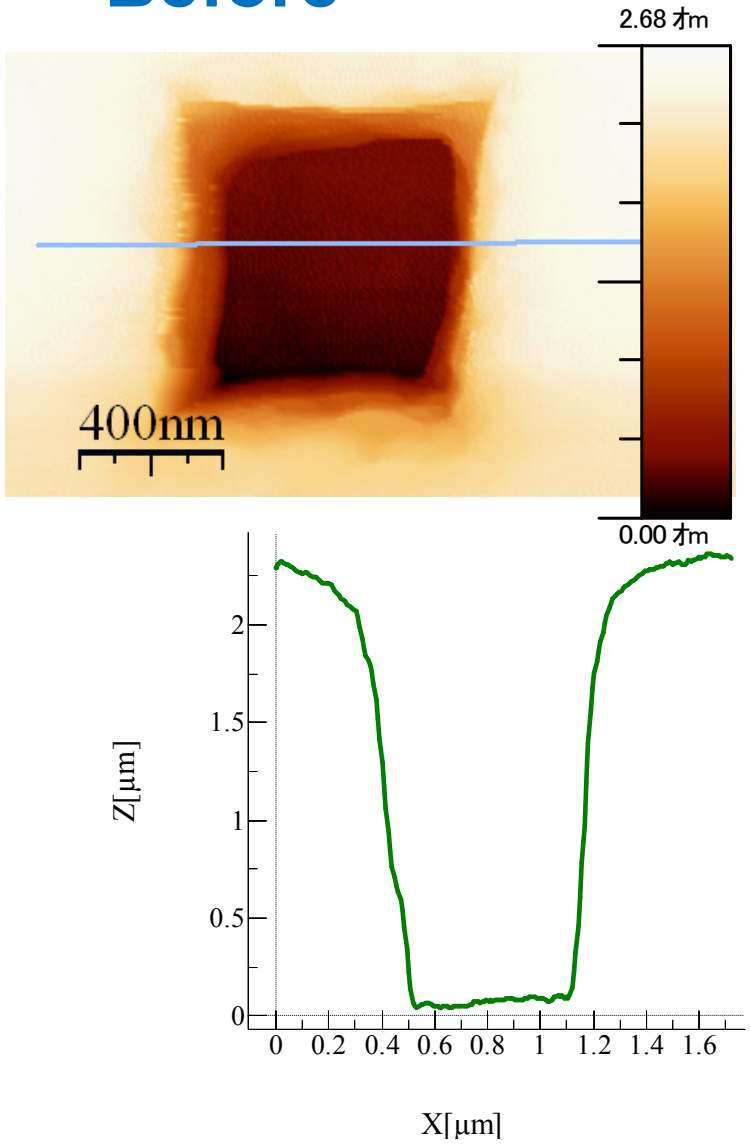
NANONICS IMAGING

Problems With Complicated Surface Structure Such As Circuit Edit Can Be Attacked Only by FPN

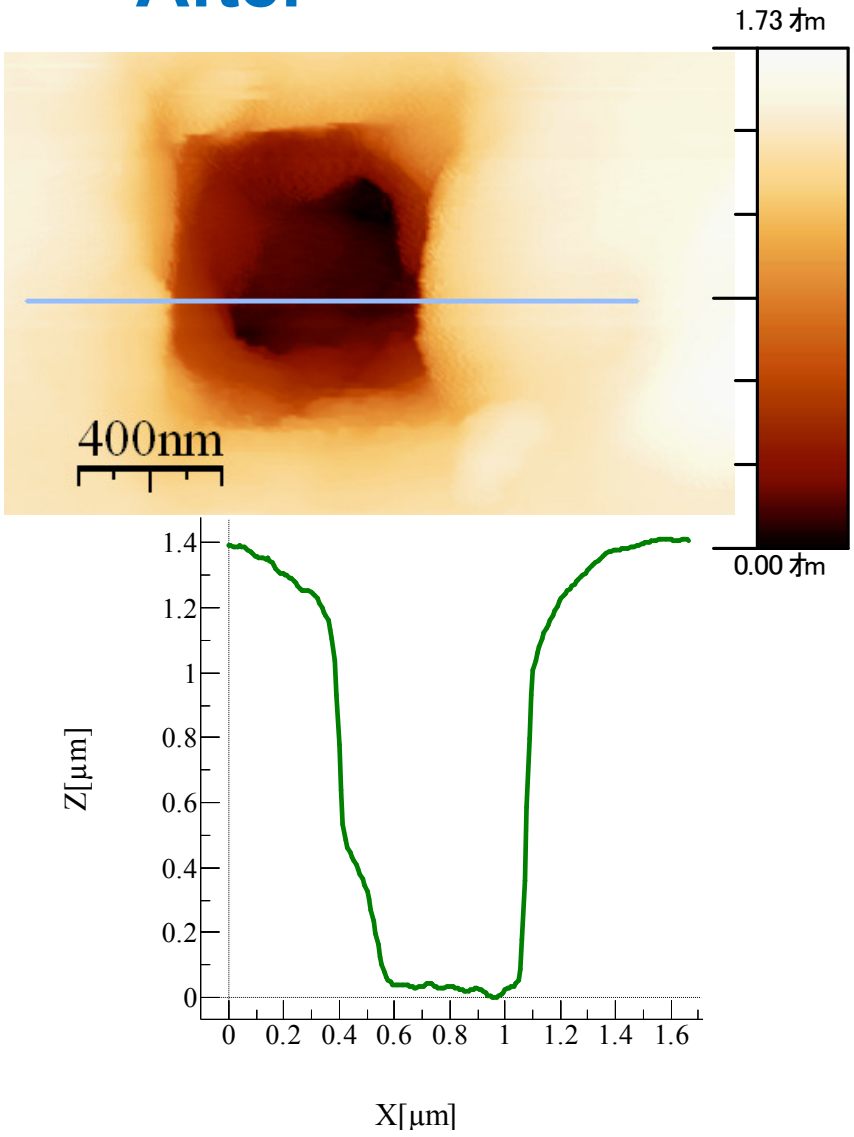


Controlled filling of 0.5 m X 0.5 m trenches in silicon with pure gold nanoparticles in a circuit edit application

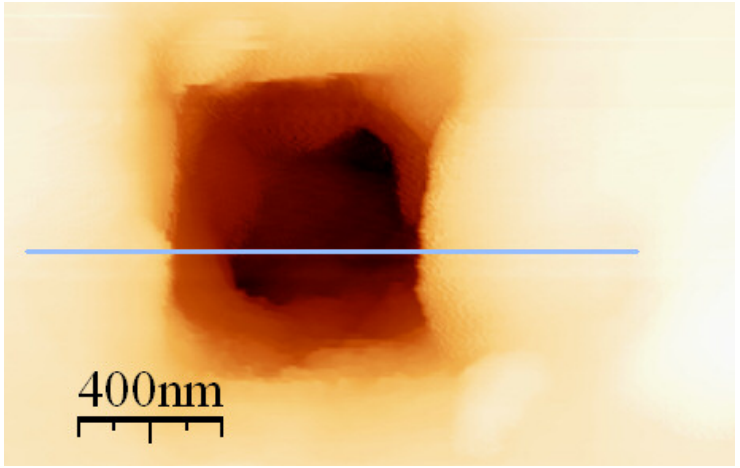
Before



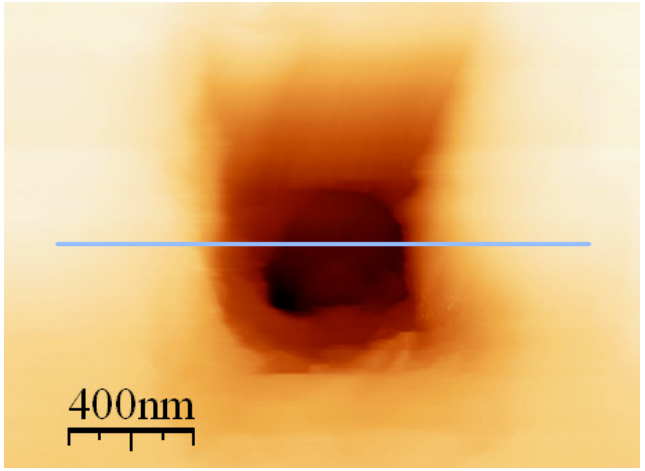
After

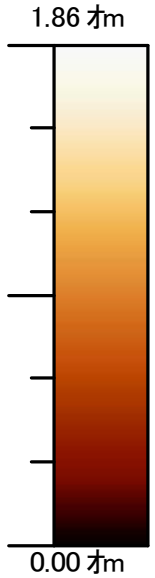


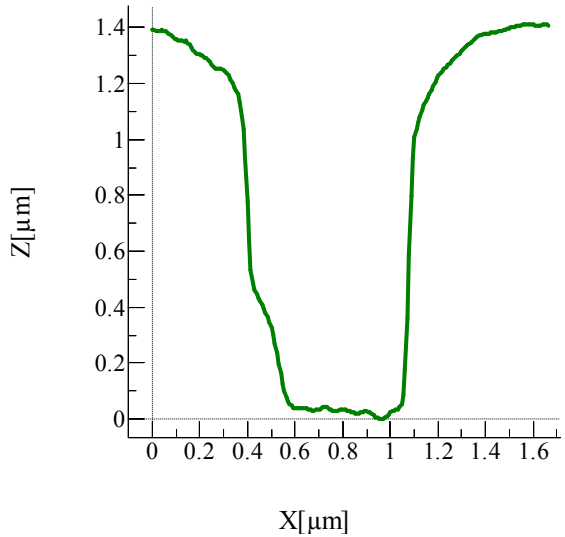
Immediately After

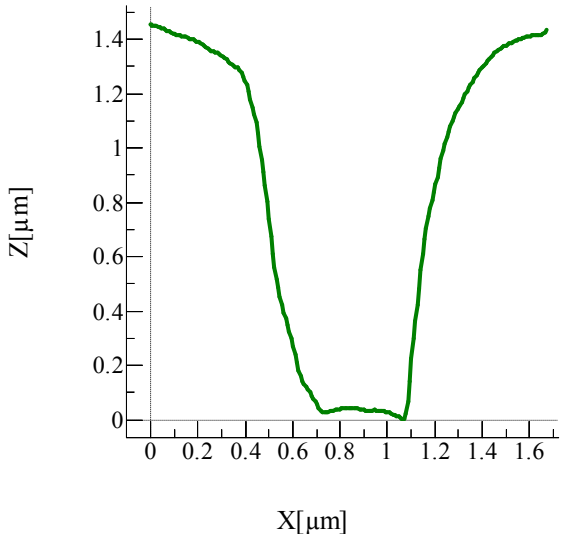


One Week After









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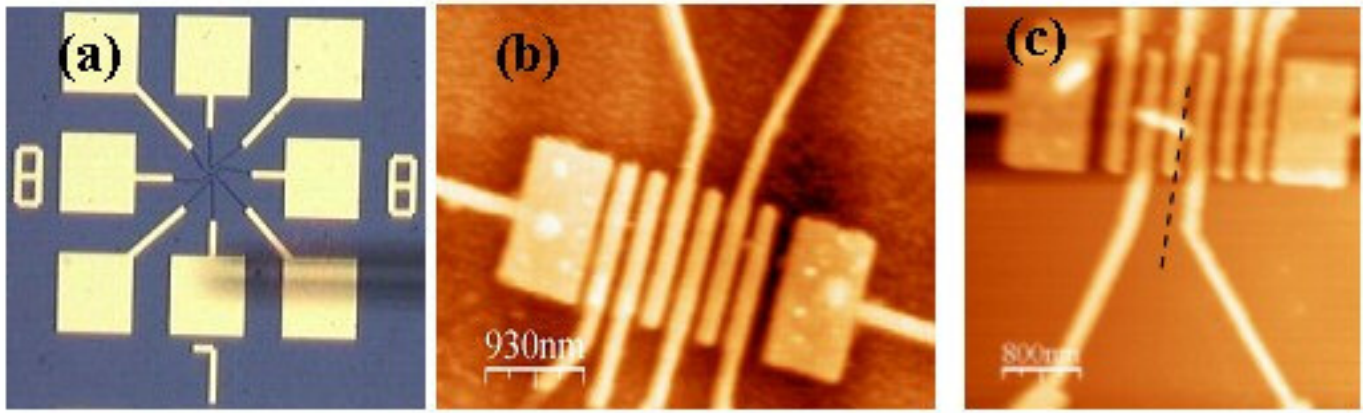
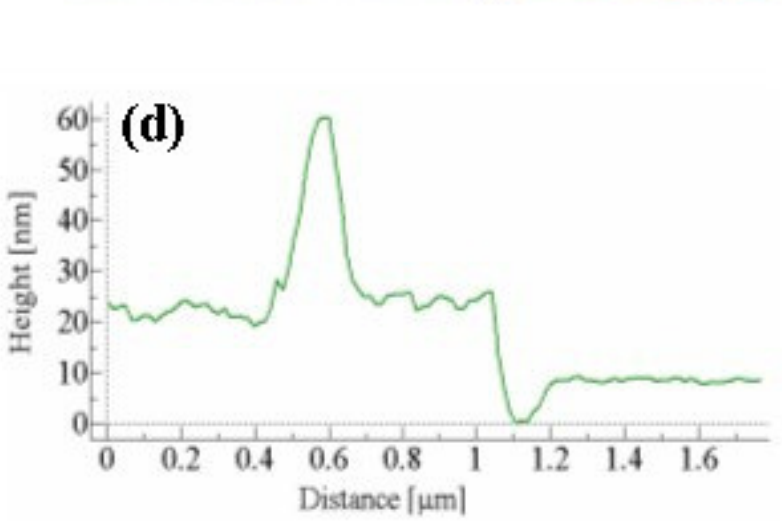
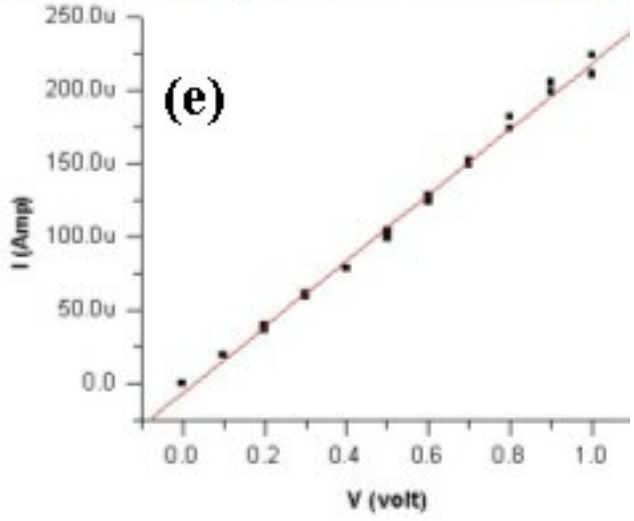
Ultimate In Registration & Deposition With Voltage Controlled NanoPrinting for Controlled Short Circuiting







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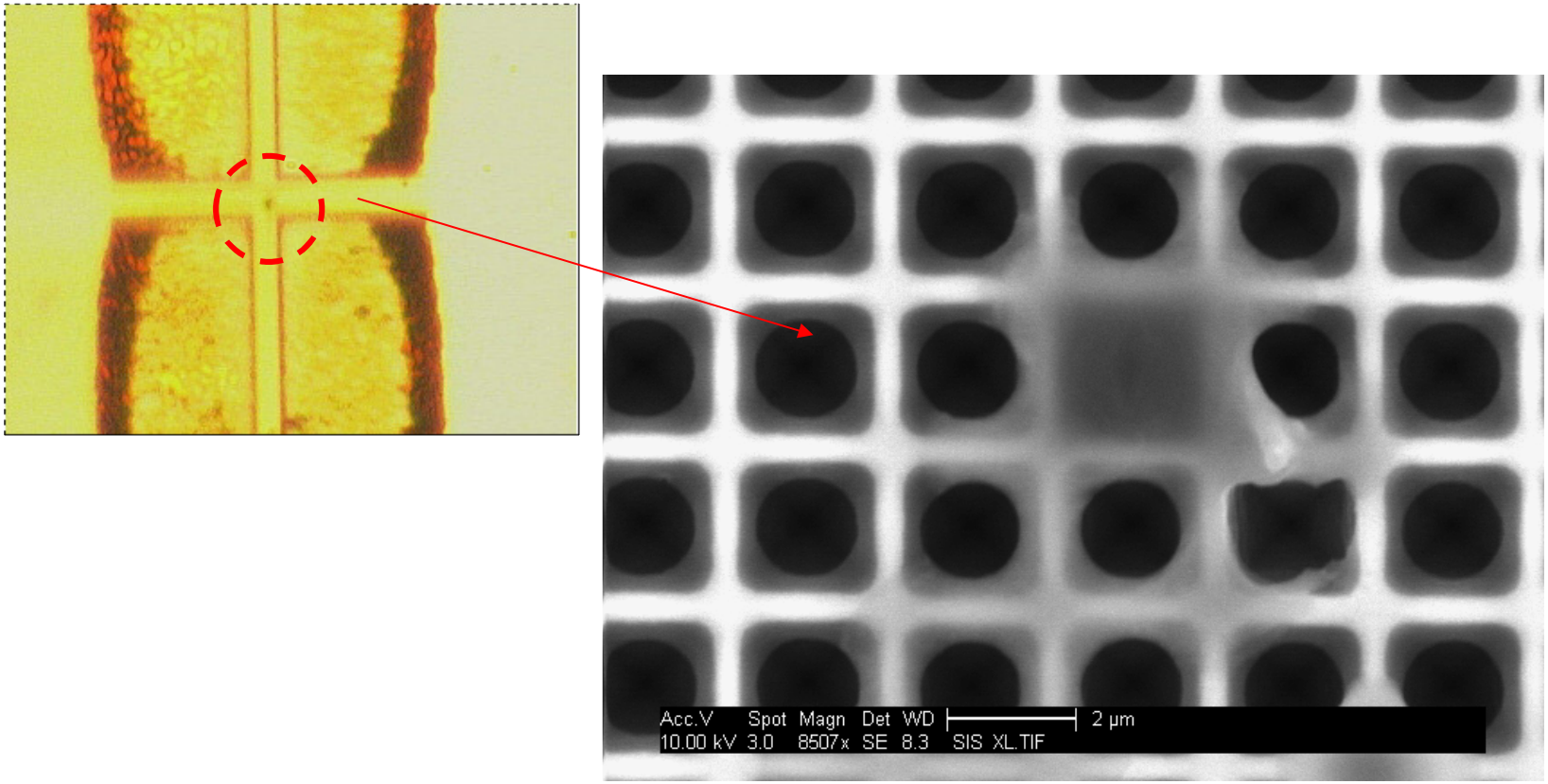
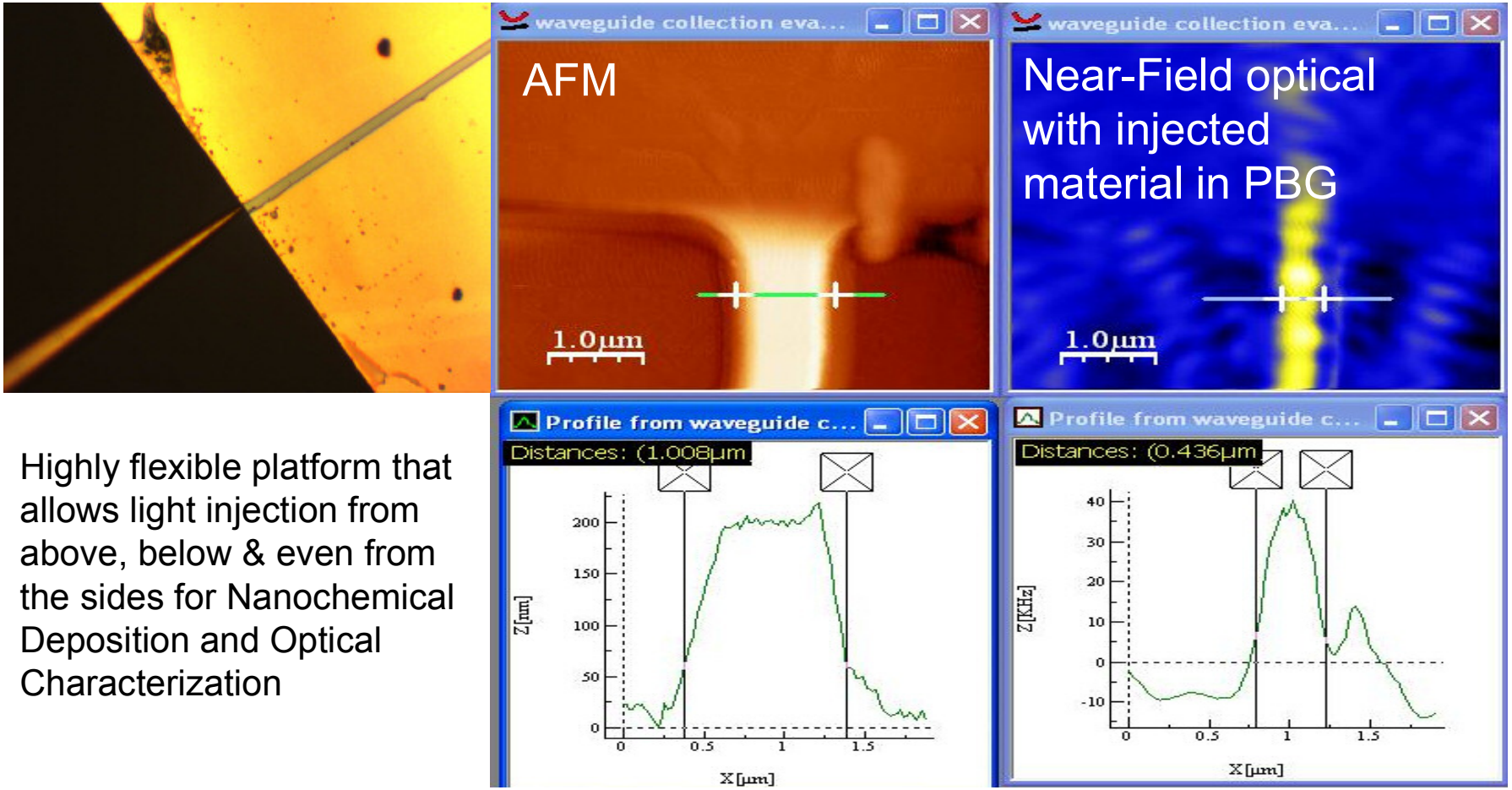
Selective Protein Deposition in a Single Hole of a 1.5 micron Photonic Band Gap



With Near-field Optical Characterization



Highly flexible platform that allows light injection from above, below & even from the sides for Nanochemical Deposition and Optical Characterization

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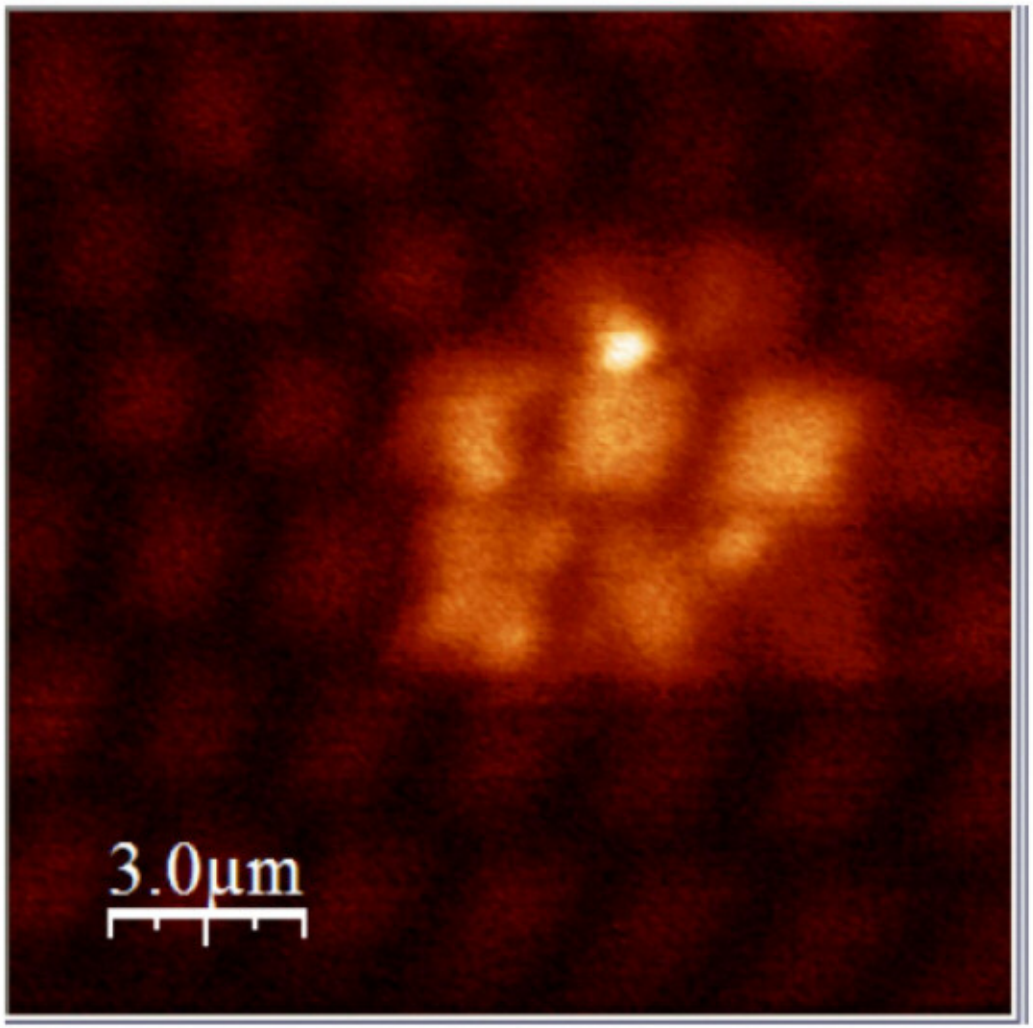
Selective Fluorescent Protein Deposition in a Photonic Band Gap

Fluorescence Image BSA in Photonic Band Gap With Center Surround Control



ENTER A NEW WORLD OF NANOCHEMICAL LITHOGRAPHY with Nanonics Exclusive FPN & ACCE Atomic Force Controlled Electrophoretic Depositon Technology