The Next Evolution in SPM

NANONICS IMAGING

FOUNTAIN PEN

NanoLithography Systems
Methods of Nanochemical Lithography

Fountain Pen NanoLithography


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


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
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

- Any view
  - Above
  - Below
  - Both
  - True independent MultiProbe operation

- Ultimate control-
  Voltage Controlled
  Electrophoretic &
  Dielectrophoretic
  Deposition

- 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 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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Ultimate control-
Voltage Controlled Electrophoretic & Dielectrophoretic Deposition
Gas Phase Delivery & Nanochemistry Only With FPN
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The Nanonics Multiprobe MultiView FPN System

Only Nanonics has Independently Controlled MultiProbes
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™.
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:

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

MultiProbe Friendly
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 Superaldehyde protein macrospotting substrates.

- No need for protein modification as in DPN
- Full protein activity for binding studies
Standard Macro Spotting of Proteins On Conventional Protein Spotting Glass Substrates from Telechem International

- 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
'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

FPN Probe With Its Reservoir & Inherent Writing Capabilities, 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

**Diagram:**
- Glass
- Au-coating
- Counter electrode
- Gold coating on the pipette exterior
The Ultimate in Writing Control
Voltage Controlled Deposition
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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Ultimate control-
Voltage Controlled
Electrophoretic &
Dielectrophoretic Deposition
Combining Voltage Controlled NanoChemical Writing With On-line Fluorescence & Raman
Transparent Integration of Nanonics FPN Systems With High End Spectroscopic Systems

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

MV 4000 MultiProbe Platform

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
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
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Ultimate control-
Voltage Controlled Electrophoretic & Dielectrophoretic Deposition
NanoWriting Polymer Nanoparticles
Nanonics Unique FPN Systems

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  - Organic
  - Aqueous with surfactant

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The Next Evolution in AFM
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
Raman Spectroscopy Insures The Chemical Character of the Lines

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- 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
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The Next Evolution in AFM
Problems With Complicated Surface Structure Such As Circuit Edit Can Be Attacked Only by FPN

Before

Z = - 2.2 μm

After

Z = - 1.4 μm

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

**Before**

Image showing an AFM scan of a sample before treatment. The graph on the left shows the profile along the X-axis with a Z-axis scale of 2.68 μm. The graph on the right shows a similar profile with a Z-axis scale of 0.00 μm.

**After**

Image showing an AFM scan of the same sample after treatment. The graph on the left shows the profile along the X-axis with a Z-axis scale of 1.73 μm. The graph on the right shows a similar profile with a Z-axis scale of 0.00 μm.
Immediately After

One Week After

400nm

Z[µm]

X[µm]
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Ultimate control-
Voltage Controlled
Electrophoretic &
Dielectrophoretic
Deposition &
Registration
Ultimate In Registration & Deposition
With Voltage Controlled NanoPrinting
for Controlled Short Circuiting

(a)  
(b)  
(c)  

(d)  
(e)  

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  - Deposition &
  - Registration

The Next Evolution in AFM
Selective Protein Deposition in a Single Hole of a 1.5 micron Photonic Band Gap
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