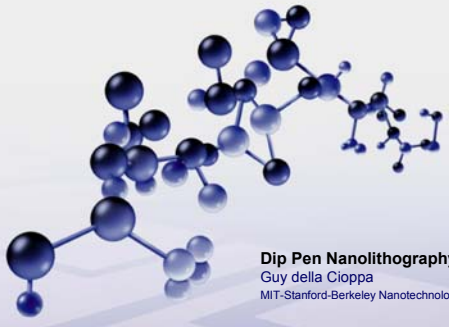

Dip Pen Nanolithography™
Guy della Cioppa
MIT-Stanford-Berkeley Nanotechnology Forum

nanoINK INC. | get small™

Nanotechnology

- ***Nanotechnology is a revolutionary technology that could obliterate current business models and restructure vast parts of the economy.***
- ***Nanotechnology is an early-stage, general-purpose technology that will generate a massive wave of creative destruction.***

From: "Big Money in Thinking Small"
Credit Suisse First Boston, May 2003

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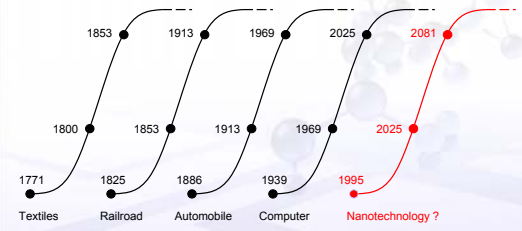
Growth Innovations



From: "The Next Small Thing", Merrill Lynch, 2001

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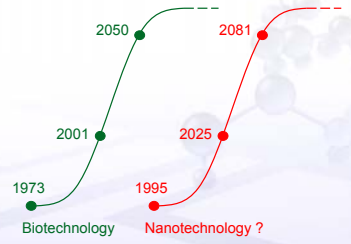
"Bio-Nano Convergence"



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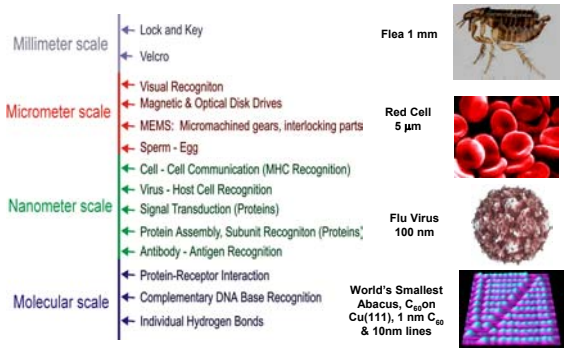
Why Nanotechnology in Bio-Science ?



Nanotechnology Definition

"The creation of functional materials, devices, and systems through the control of matter on the nm length scale and the exploitation of novel properties at this length scale."

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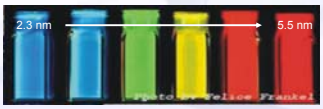
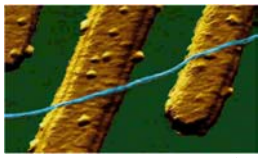
At the Nanoscale: Size Really Does Matter

- Hypothesis: Physical properties of all materials change when size (and shape) shrink to the nanometer scale.
- Problem: Studies on the nanoscale are limited by the availability of tools for evaluation and direct comparison.
- Example: Cadmium selenide nanoparticles fluorescing at different colors.



Carbon Nanotubes



The Future of Electronics

The Future of High Strength Materials

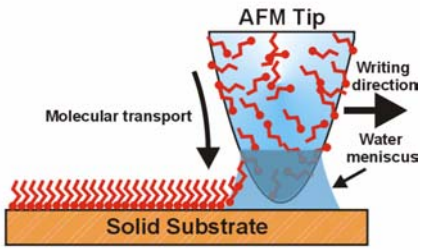
Why Nanotechnology Now?

- **Devices behave differently at the nanoscale.**
- **Nanotechnology can make old things in new ways, and makes new things we couldn't make before.**
- **90nm is about the smallest feature made currently with photolithography.**
- **Are there fundamental nanoscale building blocks to be discovered and patented?**
  - Broad composition-of-matter and utility patents?
  - Similarity to the genomics land rush?

Mission

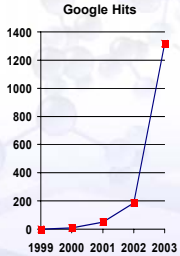
Objective:	**To be the worldwide leader in nanometer-scale manufacturing and application development**
Method:	**Leveraging the power and flexibility of Dip Pen Nanolithography™**
Advantage:	**Developing products in a broad cross section of different industries**

Dip Pen Nanolithography (DPN™)



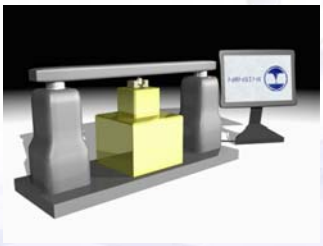
Peer-Reviewed Publications >70


"Dip-Pen" Nanolithography



DPN Users Worldwide

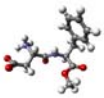
The DPN Process

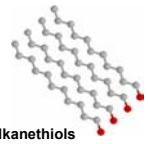


Attributes of DPN

- **Flexible**
  - Direct Write of Materials
  - Molecule and Substrate General
- **High Resolution**
  - 15 nm Linewidth Resolution
- **Accurate**
  - Nanoscale Alignment Accuracy
- **Scalable**
  - Automated via Software/Instrumentation
  - Parallel/Scalable via Pen Systems/Ink Systems

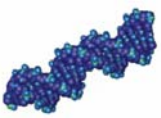
Materials Patterned with DPN

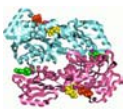

Small Functional Molecules


Alkanethiols


Conducting Polymers

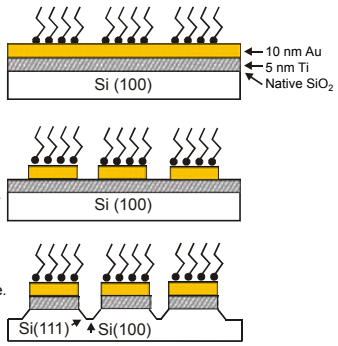

Inorganic Nanoparticles


DNA


Proteins

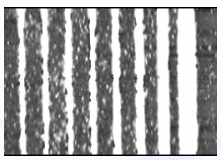
Solid-State Nanoresists

1. "Write" regions of octadecanethiol (ODT) on Au thin film.
2. Selectively etch Au using wet chemical etchant (ferri/ferrocyanide 2-5 min).
3. Remove Ti and SiO_2, etch Si, and passivate Si surface.



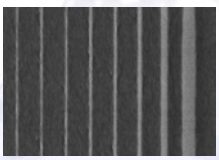
Combinatorial DPN/Si Etching

AFM Topography Image



height = 75 nm

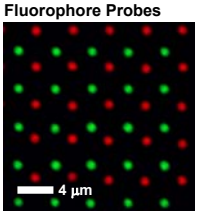
Field Emission SEM Image



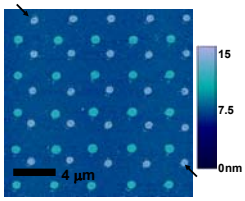
45 nm 120 nm 510 nm

Direct-Write DNA Patterns on SiOx

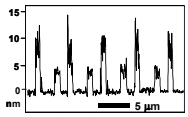
Optical Microscopy w/ Fluorophore Probes



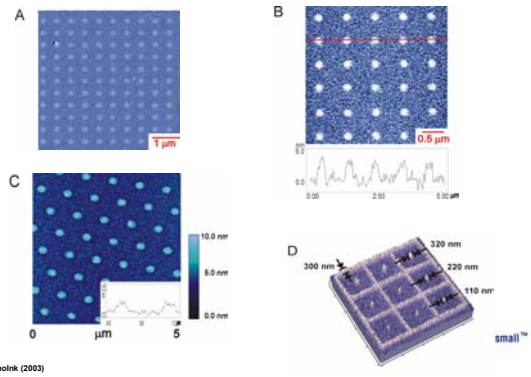
AFM w/ Nanoparticle Probes



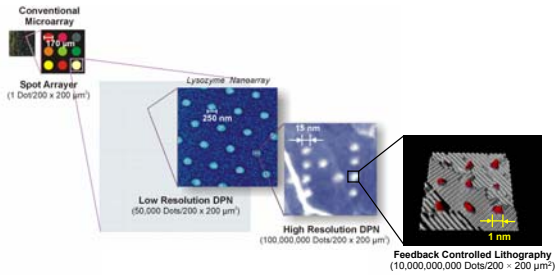
AFM topography line scan →



Protein Nanoarrays



The Ultimate in High Density Arrays



Biological Nanoarrays:

- More than just miniaturization with higher density
- New opportunities for biodetection and studying biorecognition

Consider a "Universal Gene Chip"

Tennis Court

4^{17} 50 µm diameter dots with 50 µm spacing (13m x 13 m).
Too big to be practical

Penny

4^{17} 50 nm diameter dots with 50 nm spacing (13 mm x 13 mm).
Reasonable

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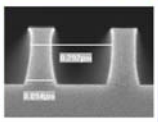
Atomic Force Microscope (AFM)

Inexpensive and non-destructive characterization of surfaces →



The AFM Tool Universe ↵

Images courtesy Veeco and IBM

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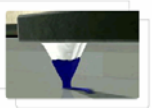
AFM: More Than Just Metrology

- **AFM is the most successful metrology tool ever and has proven its utility as the pick-and-shovel of nanotech.**
- **Invented in the 1980s**
  - Scanning Tunneling Microscope (Nobel Prize)
- **AFM technology for read/write instrumentation 1990s**
  1. Millipede Device (IBM)
  2. DPN Writer™ (NanoInk)



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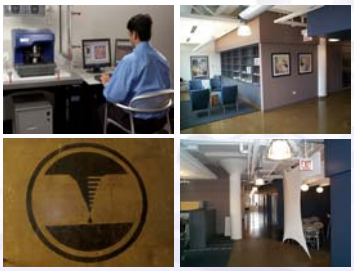
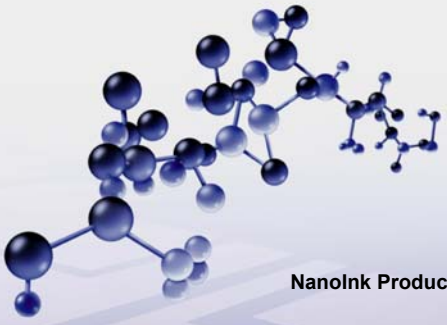
About NanoInk

- Started Operations November 2001
- $13mm of Equity Capital Raised to Date
- Booked First Revenue in July 2002
- California MEMS Manufacturing Facility, July 2002
  - 5,800 square-foot facility, Campbell, CA.
  - Over $2 million worth of the latest process equipment
- Chicago Headquarters Opened December 2002
  - 44,000 Square Feet
  - City of Chicago provided $1 million
- SBIR Funding (NIH) for "DNA Nanoarrays," September 2003
- 31 Employees as of October 2003

NanoInk Facility in Downtown Chicago





NanoInk Products

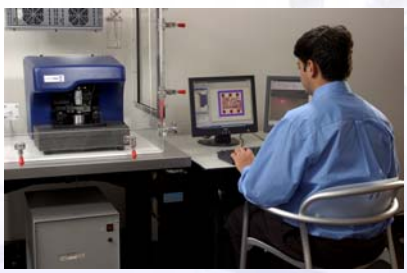
Product Portfolio

1. DPN Software
   - First Version Released June 2002
   - Enables Basic Research Use

Product Portfolio

1. DPN Software
   - First Version Released June 2002
   - Enables Basic Research Use
2. DPN Instruments
   - First Version Released June 2003
   - Enables Dedicated Nanofabrication

Dedicated DPN Tool Makers



NSCRIPTOR™: Dedicated DPN Instrument

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"See the Power" Advertising

Genetic Engineering News
6"x7"

Nature Materials
3.375"x10"

Small Times
5"x7.5"

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Product Portfolio

1. **DPN Software**
   - First Version Released June 2002
   - Enables Basic Research Use
2. **DPN Instruments**
   - First Version Released June 2003
   - Enables Dedicated Nanofabrication
3. **DPN Consumables**
   - Pen Systems, Ink Systems for Advanced Patterning
   - First Versions Released October 2003

ALL Product Classes have Generated Revenues

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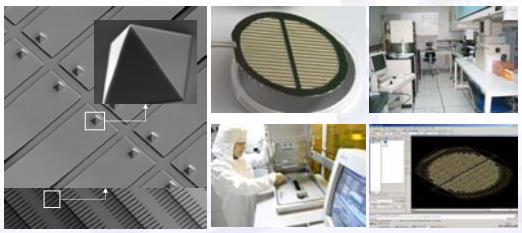
DPN "Pen Systems" Consumables



NanoInk's MEMs Fab for
DPN™ Pen and Ink Delivery Systems

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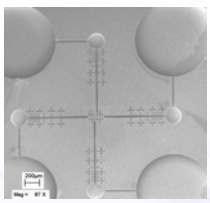
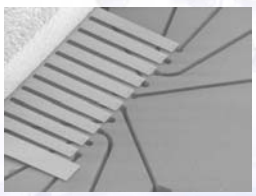
DPN "Ink Systems" Consumables



A) Microfluidic Ink wells



B) Ink wells in registry with parallel pens

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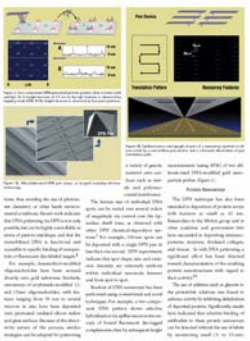
GENETIC ENGINEERING NEWS

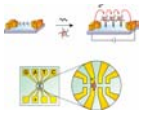
DRUG DISCOVERY

Nanotechnology to Advance Discovery R&D

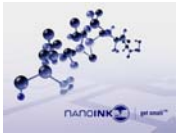
Tutorial:

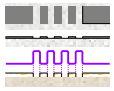


Nanoelectronic & Biological Applications of DPN™

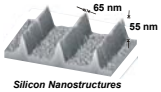


Nanoelectronic Sensors





Photomask Repair

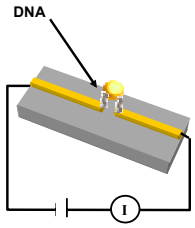


Silicon Nanostructures

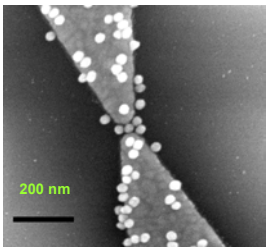
DPN Templates for Directed Self Assembly

Ultrahigh Density DNA Arrays

DNA Detection via Nanoelectronics



Pattern gold electrodes with DNA
Single Au particle bridges the gap



FE-SEM of 30 nm DNA-Au-NPs selectively hybridized between metallic electrodes

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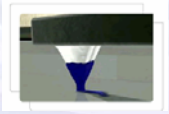
The Innovator's Dilemma

"It is simply *impossible* to predict with any useful degree of precision how disruptive products will be used or how large their markets will be.

Clayton Christensen, 1997



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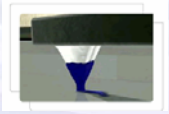
The Innovator's Dilemma

"Markets that do not exist cannot be analyzed….not only are the market applications for disruptive technologies *unknown* at the time of their development, they are *unknowable*."

Clayton Christensen, 1997



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Acknowledgements

- **NanoInk SAB members**
  - Chad Mirkin, Northwestern
- **NanoInk MEMS team (California)**
  - Joe Fragala
  - Terrisa Duenas
  - Deb Banerjee
  - Roger Shile
- **NanoInk Chemistry team (Chicago)**
  - Linette Demers
  - Bjoern Rosner
- **NanoInk PD and Software team (Chicago)**
  - Ray Eby
  - Mike Nelson

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