Center for Scalable and Integrated Nano Manufacturing (SINAM)

-A NSF Nano-scale Science and Engineering Center (NSEC)

(5+5 Year Program, $40M)

UC Berkeley – UCLA – Stanford - UNCC

(20 faculty and 100+ students/postdoc/staff)

Director: X. Zhang, Co-Director: E. Yablonovitch

Overview given by Bob Hocken
Motivation of Starting the SINAM Center

Future Integrated Nano-Systems

- Nano-Photonic Layer
- Nano-Fluidic Layer
- Sensor Layer
- Electronic Layer

Ultra Compact light source & integrated photonics

Nano Fluidic Circuits

Ultra Sensitive Bio-sensor

Terabit Memory
Motivation: Grand Challenges in Nanomanufacturing

State of the Art

- Current optical litho tool ($20M/tool)
- EUV lithography
- Projection E-Beam lithography
- Nano-imprint lithography
- Self assembly

Technological Barriers

- Critical dimensions below 50 nm
- Heterogeneous integration
- Cost effective nano-manufacturing processes
Vision and Mission

A New Nano Manufacturing Paradigm that Enables the Quantum Leap from Lab Science to Industry Revolution

Mission:
• Develop nano-manufacturing: Design, Process, and Tools
• Enable the industrial quantum-leap
• Address work force crisis through innovative education program
Integrated Approaches

- Product Development
- Workforce Training
- Societal Impact

SINAM
Effective Team Communications

Physical Meeting
- Regular visits among team members
- Annual SINAM Workshop

Video-conference
- Video, audio, powerpoint
- Accessible for all institutes and NSF
- Audio access for traveler

UCB
HP
UCLA
UCSD
Stanford
NSF
UNCC
Traveler
SINAM Strategic Framework

- Requirements
  - Product Dev. Testbed
  - Scale-up Mfg Testbed
  - Design for Mfg Testbed

- Products
  - PNL Tool
  - NIL Tool
  - CNA Tool
  - NanoCAD

- System Integration
  - Plasmonic Lens
  - Flying Head
  - New Materials
  - Microelectrode array
  - Surface Binding
  - MultiScale Modeling
  - MAPS

- Technology Base
  - Physics
  - Chemistry
  - Biology
  - Materials Sci.
  - Fluid Dynamics
  - Control
  - Precision Eng.
  - Precision Eng.

- Knowledge Base
  - Wafe

- SINAM
System Level Focus and Testbed

- **Product**
  - *Device and Industrial product*

- **Manufacturing**
  - *Manufacturability, Scalability, Reliability, environmental*

- **Design**
  - *Nano-Mfg Knowledge Base*
    - Physics, Chemistry, Biology
    - Materials, Mechanics

- **Applications**

- **Tool**

- **Nano-CAD**
Integrated Research Project: Plasmonic Nanolithography

Scientific Breakthrough Enabling A New Manufacturing Field!

Plasmonic Lens Enables 60 nm nanolithography ($\lambda/6$)

Impact:

- Two papers published in *Science* in 2005 and 2007
- >120 Citations
- “R&D Magazine Micro/Nano 25” Award
- “Top 10 Nanotechnology Breakthrough” in 2005

SINAM leads the development of a new scientific field.

Zhang & Yablonovitch (lead), Bogy, Dornfeld, Fréchet, Grigoropoulos, Sun
Energy and Throughput Analysis of PNL

- PNL is 100x faster than E-Beam Lithography
- Superior to Projection Lithography:
  - Low cost, Diffraction-free
  - Flexible manufacturing suitable for frequent design changes

(Dornfeld, Zhang)
Integrated Research Project: Nano-Imprinting Tool Development

SINAM Multiscale Alignment & Positioning System (MAPS)

Nanoinprinting Head

Tsao and Prinz (lead), Chen, Dornfeld, Hocken, Hahn, Lavine
Nano-Imprint Lithography (NIL)
-The first with alignment capability

Low Cost NIL module being Commercialized by NanoLithoSolution
- Low cost Nano-Imprint Modules
- Fits popular Karl Suss MA6 aligner
- 30 nm Imprinting resolution
- 500 nm alignment precision

30 nm Imprinting

SUSS MicroTec MA-6 aligner
Wafer Holder and Chuck

SINAM Spin-off: Nanolithosolution Inc

Low Cost NIL module being Commercialized by NanoLithoSolution

Auto Release™
Mold Design*

Accurate Align Nanomprint System*

* Multiple patents and pending patents
MAPS: From Design to Realization

Through 4 years close collaboration among SINAM researchers
Integrated Research Project: Controlled Nano-assembly

Addressable surface patterning

Parallel Nano-assembler:
400 site CMOS electronic array

Lithographic surface patterning

Direct-assembled “NSF”

Features scales from 80 nm to 40 μm

Ho (lead), Chen, Heller, Hahn, Maynard, Majumdar
SINAM Accomplishments

New Top-down Nanomanufacturing
- High-throughput Plasmonic Nano-Lithography (PNL) process development
  80 nm PNL at a writing speed of 10 m/s!
- New Plasmonic Focusing lens design promising sub 50 nm focusing

Controlled Nano-assembly
- Demonstrated Parallel Nano-assembler using electrode arrays
- Sub-100 nm assembly on patterns defined combining top-down methods

System Engineering
- Nano-Imprint Lithography (NIL) machine completed
- Spin-off company - NanoLithoSolution
- Systematic Analysis on Manufacturability and the environmental impact
- Completed MAPS system design, fabrication and assembly
- Established the building block of Nano-CAD
Product Development

Application test-bed

- High-throughput nano-sensor array for biomedical diagnostics
- Smart drugs for drug delivery

Molecule Sensor System

Intelligent Therapeutic System (ITS)
Integrated Nano-sensor Platform

Micro/nano Fluidics

Bio-Fluidic

Micro pump

Filter

Outlet

Bio-Chip

Addressing & Data acquisition

Assembly Motherboard
Future Work: Control System for MAPS

Automatic control system and software

Nano precision control for MAP system

Delta Tau UMAC
Future Work: Nano-imprinting Tool System

NIL Application Testbed

- Integrate Imprint Process with MAPS.
- Investigate alignment-pressurization interactions & develop process control
  - Mechanistic process model
  - Measurement and model identification/calibration
  - Predictive & feedback process control
# MAPS PERFORMANCE SPECIFICATIONS

- **CD (approximate)**: 15 nm
- **Overlay**: 5 nm
- **Field Size (Imprint)**: 25 x 25 mm
- **X & Y Travel**: 10 x 10 mm
- **X & Y Positioning Resolution**: 0.15 nm
- **X & Y Scanning Speed**: 10 mm/s
- **Z Gap Error**: 10 nm
- **θ_x & θ_y Leveling Error**: 1 μ-rad
- **Alignment Time**: 10 sec max
- **Imprint Pressure**: 347kPa (50psi)
DESIGN FEATURES

- Halbach Magnet Array Linear Motors (x, y, & yaw)
- Eddy Current Damping
- PZT Actuators (z, pitch, & roll)
- Vacuum Preloaded Air Bearings
- Capacitance Sensors (z, pitch, & roll measurement)
- Laser Interferometer (x, y, & \( \theta_z \) measurement)
- Moiré Fringe Mask Alignments Techniques
- Fused Silica Vacuum Pin Chucks
- Kinematic Couplings
- Nano-scale Imprint Lithography (NIL)
- Nano – Surface Topography Instrumentation
Next big metrology challenge
Plasmonic nanometrology tool

• Specifications similar to MAPS except that there are two possible designs and no force is required

• Rotary design (like a disk drive)
  – High surface speed 2000 mm/sec
  – Parallel writing
  – Nanometric resolution

• Raster design (new head for MAPS)
  – Still high speed and parallel writing
SINAM’s Educational/Outreach Program

Mission: Address a serious nanotechnology workforce crisis:
- Quarter of current science/engineering workforce will retire by 2010.
- Need for higher levels of academic and vocational training.

Middle and High School Outreach (7-12)
- Photolithography Experiment involving 82 students

Community College Outreach
- Technical Explosion
- College of the Canyons course development

Undergraduate Outreach
- Nano-manufacturing Summer Academy

Graduate Programs
- Graduate Young Investigator Program
- SINAM Student Leadership Council
SINAM in the News!

The New York Times

From ordinary objects, ‘metamaterials’ that manipulate light.

Researchers led by Xiang Zhang, a professor at the University of California, Berkeley, have demonstrated that a thin, flat piece of silver can indeed produce such images, able to resolve two thin lines separated by 70 billionths of a meter.

“You put your object on one side and your image will be projected on the other side,” Dr. Zhang said.

The superlens can also preserve detail lost in conventional optics. Light is usually thought of as having undulating waves. But much closer up, light is a much more jumbled mess, with the waves mixed in with more complicated “evanescent waves.”

The evanescent waves quickly dissipate as they travel, and thus are usually not seen. A negative refraction lens actually amplified the evanescent waves, Dr. Pendry calculated, and that effect was demonstrated by Dr. Zhang’s experiment. A negative refraction could someday lead to an optical microscope that could make cut tiny biological structures like individual viruses.

June 12th 2007

Soft Matter

Cover: May 7th 2007

MRS BULLETIN

November 2006

“Plasmonic focusing”

Biology Times

“The quest for the Superlens”

July 2006

BUSINESS TIMES

“UC-Berkeley’s ‘hyperlens’ improves imaging”

May 7th 2007

“Nano-objects under the light microscope”

March 2007

chemistry world

“Beyond diffraction”

Nature 447 May 2007

NEWS & VIEWS

OPTICS

November 2006
ALIGNMENT CONCEPT AND SIMULATION

Sub-10 nm alignment

Interference Pattern

CCD

Partially Reflecting Mirror

Light Source

Imaging Lens

To Frame Grabber And Computer

Mask

Substrate Stamp

Aligned

Out of Align

Substrate

Stamp

Simulations performed by Ayman Samara

SINAM
MOIRE FRINGE RESULTS

\[ p_1 = 4.0 \mu m \quad \text{&} \quad p_2 = 4.3 \mu m \]

Resolution \( \sim 1.3 \text{ nm} \)

\[ p_1 = 2.0 \mu m \quad \text{&} \quad p_2 = 2.1 \mu m \]

Resolution \( \sim 0.8 \text{ nm} \)
4 PASS INTERFEROMETER

- $\lambda/20$ flatness.
- Zerodur Target mirror
- Mirrors will be error mapped to $\lambda/50$

All the optics and handling equipment is purchased. Working on how to assemble them!!
CAPACITANCE GAGE
IMPRINTING MODULE