ME 498
Introduction to Nano Science and Technology

- Lecture 1: Overview

Nicholas X. Fang (University of Illinois)

Email: ***nicfang@uiuc.edu***

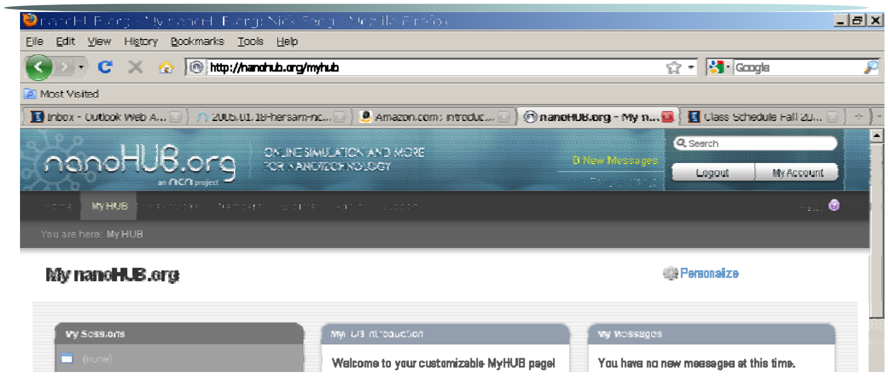
MechSE

About ME 498

- **Instructor:** Nick Fang, 4414 MEL
- *Tel*: 265-8262, *Email*: nicfang@illinois.edu
  - **Office Hours**: W 3:00-5:00 pm or by appointment
- **Class Time:** MWF 1-2pm, 218 MEB
- Website: on "nanoHUB.org"
  + "Illinois Compass"

MechSE

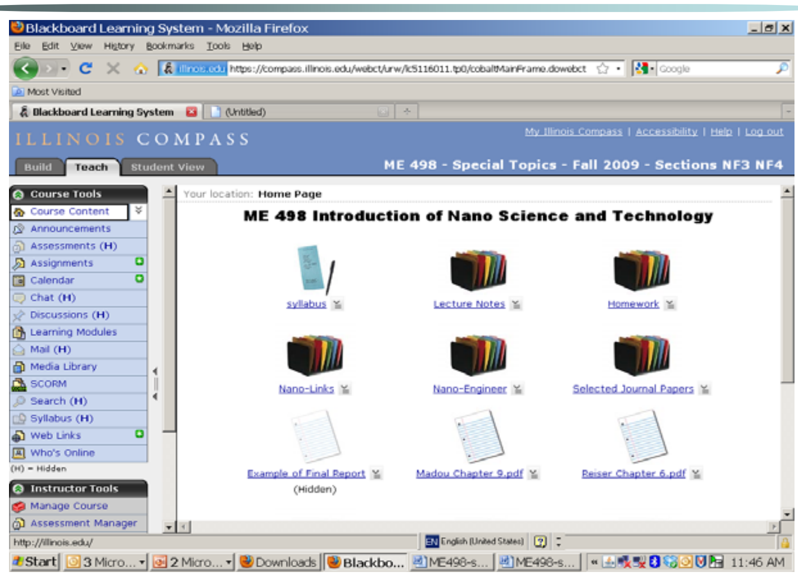
The Course Website (nanoHUB.org)



If you have a laptop, please bring it to the class this Wednesday

Prof Sobh from NanoHUB will tour you through the applications

The Course Website http://compass.illinois.edu



Illinois Compass Quick Help For Students: http://www.cites.uiuc.edu/edtech/resources/compass/student/quickhelp/index.html

Grading and Homework Policy

- **Grading:**

Midterms (2)	40%
Homework	20%
Class participation (including scribes)	15%
Final Exam	25%
Project (for GRAD)	25%

- **Homework Policy:**
  - HW must be turned in on Friday in class on the date due.
  - HW will not be graded if absence without excuse.
  - Work out all problems, arranging your work in a logical and neat manner. (neatness counts!)

Midterms (2 times):

- 1 hour, close book and notes
- Typical problems: design questions and quantitative analysis (formula sheet provided)
- Makeup exams: with medical excuse only

How To Do Well in This Class

- Recognize early that it is different than other courses, survey of materials and properties so change topics frequently – nature of the course
- Attend and participate discussions in class
- Finish the reading assignments before the class
- You should expect to spend 8 to 10 hours outside of class per week on homework and projects.
- Do homeworks and understand them, and exercise similar problems.

Week	Lectures
1 (Aug 24-Aug 28)	Introduction, Basic Quantum Mechanics
2 (Aug 31- Sep 4)	Molecular transport and thermodynamics
3 (Sep 7-Sep 11)	Continuum Solid Mechanics
4 (Sep 14-Sep 18)	Momentum/energy transfer at Nanoscale
5 (Sep 21-Sep 25)	Surface and Interface I/**1st Midterm**
6 (Sep 28-Oct 2)	Adhesion, surface tension, lubrication
7 (Oct 5-Oct 9)	Collective phenomena, self assembly
8 (Oct 12-Oct 16)	**Project proposal**
9 (Oct 19-Oct 23)	Nanophase materials
10 (Oct 26-Oct 30)	Thermal and Fluidic Aspects in Nanodevices
11 (Nov 2-Nov 6)	Sensing and Actuation in Nanoscale
12 (Nov 9-Nov 13)	Nanoscale Energy conversion / **2nd Midterm**
13 (Nov 16-Nov 20)	Nanomanufacturing
14 (Nov 23- Nov 27)	**Thanksgiving Break**
15 (Nov 30-Dec 4)	**Summary, Final presentation**

Course Objectives

1. Serving as a gateway course to a set of nanocourses for engineers
2. Introducing concepts of nanoscience: scaling laws, departure from continuum, surface and interface issues, characterization technologies
3. Understanding basic tools (synthesis, fabrication, sensing and actuation) of nanotechnology and relate them to design problems.
4. Practice on design and analysis used to determine nanodevice performance and cost aspects. Also exercising engineering report writing.

General Course Outline

- Nanoscale Science

  - E.g. photon, phonon, electron;
  - Wavelength, density of states, mean free path
  - VdW force, double layer, osmotic pressure

- Nanotechnology

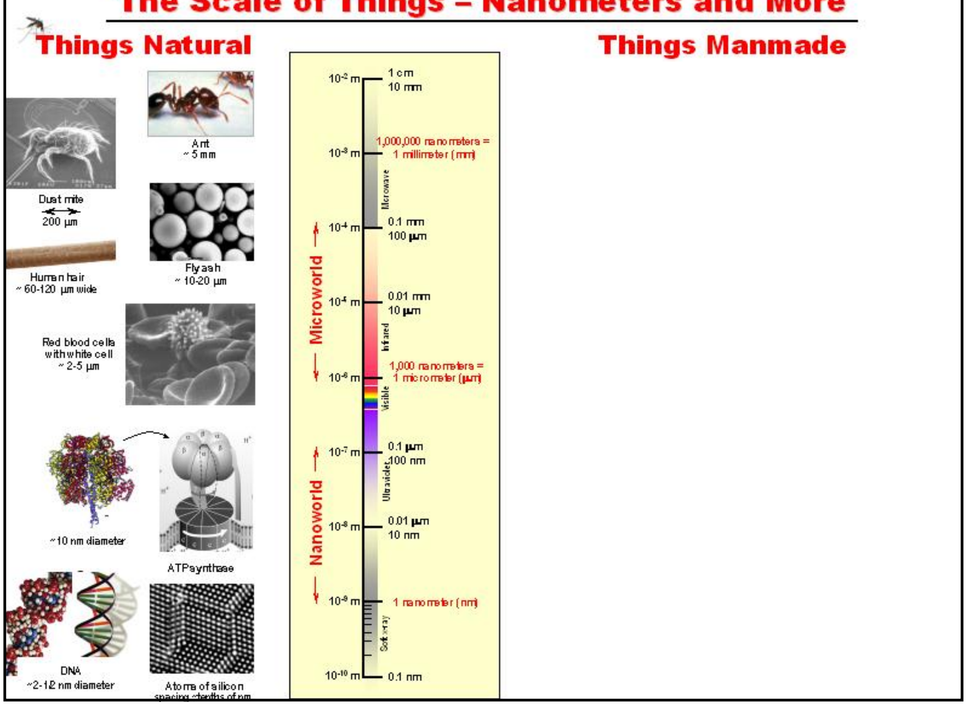
  - Fabrication: e.g. lithography, nanoimprint, self assembly;
  - Modeling: e.g. molecular dynamics, Quantum Monte-Carlo;
  - Sensing, Actuation and conversion: e.g. solar cells

- Special Topics

Incomplete list of Nanocourses At UIUC

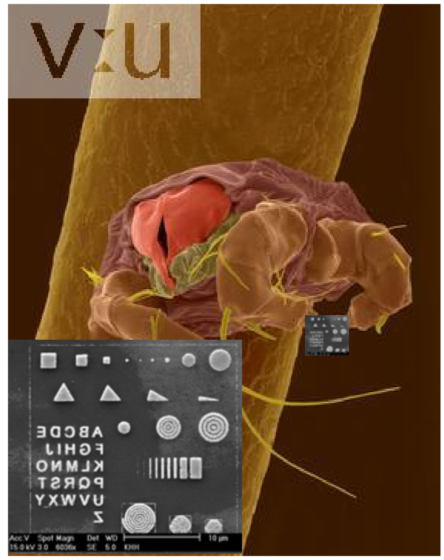
ME/ECE 485 Introduction to Microelectromechanical Devices and Systems
ME 498 Theory, Fabrication and Characterization of MEMS
ME 498 Modeling and Simulation of MEMS
ME 498: Introduction of Biology for Engineers
ECE 498 Introduction to Nanotechnology
TAM 524 Micromechanics of Materials
CHBE 553 Surface Chemistry
MSE 582 Surface Physics
ECE 583 Semiconductor Nanotech Lab
ECE 598 Quantum Mechanics for Nanotechnology
ME 598HJ: Nanomechanics of Electronic Materials
ME 598 Manufacturing at the Nanoscale
ME 598 SGK Microfactories for Microsystems Manufacturing
ME 598 Microtribodynamics
ME 598 Introduction to Nanomechanics

The Scale of Things – Nanometers and More



What is and Why Nanoscale?

- 100nm ~ 10^3 atoms
- ~10^3 structures across one hair
- Significant surface area
- Departure from continuum
- Unusual mechanical/physical properties



MechSE

There is Plenty Room at the Bottom (?)

Richard Feynman, Caltech, 1959

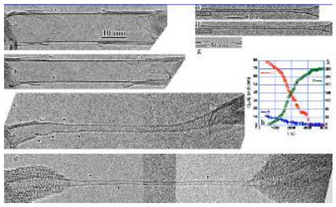
I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle. … it is more like solid-state physics in the sense that it might tell us much of great interest ***about the strange phenomena that occur in complex situations.*** *Furthermore, a point that is most important is that it would have an enormous number of technical applications.*

What I want to talk about is ***the problem of manipulating and controlling things on a small scale.***

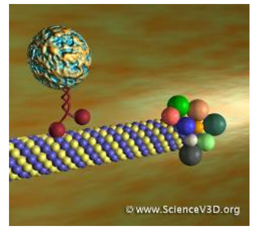
http://www.zyvex.com/nanotech/feynman.html

MechSE

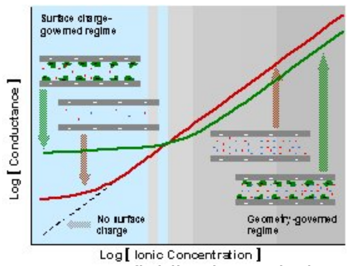
Nanoscience examples



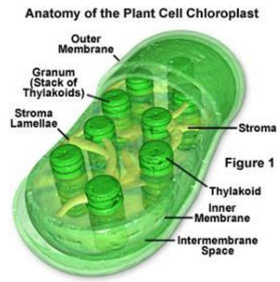
Super-plastic carbon nanotubes (MIT)



Myosin molecular motors (UIUC)

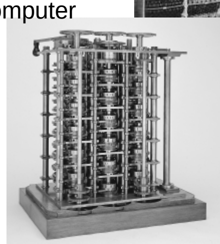


Nanofluidic channels (Berkeley)

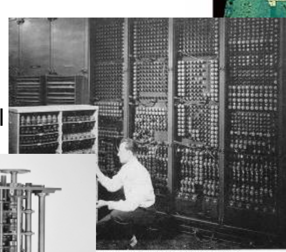


Evolution of Computer Technology

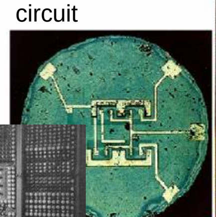
1st mechanical computer

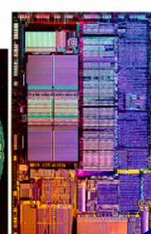


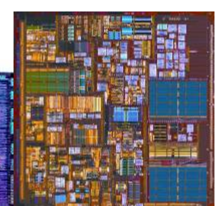
1st electrical computer



1st integrated circuit

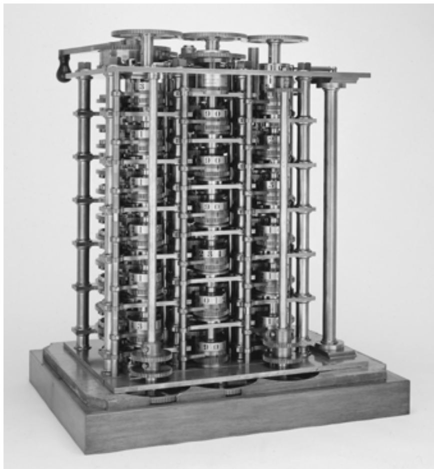






Can we extend the exponential growth to other domains?

The First Computer



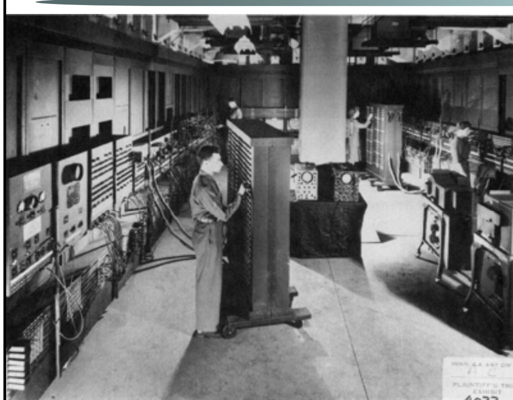
The Babbage Difference Engine (1832)

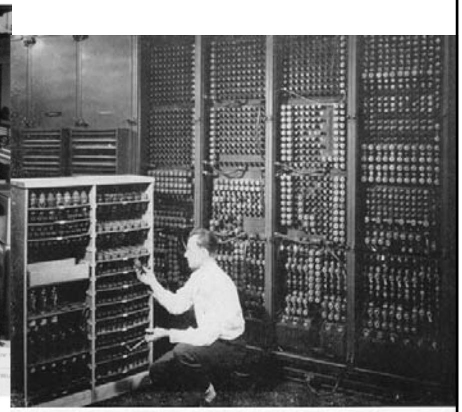
2,500 parts

6 years to build

Cost: £17,470

ENIAC – First electronic computer (1946)

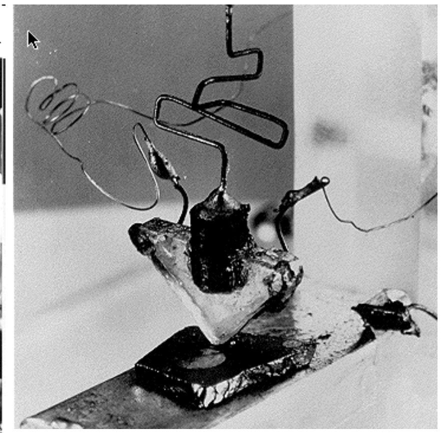




Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

Built by John W. Mauchly (computer architecture) and J. Presper Eckert (circuit engineering) , Moore School of Electrical Engineering, University of Pennsylvania. Formed Eckert & Marchly Computer Co. and built the 2nd computer, "Univac". Went bankrupt in 1950 and sold to Remington Rand (now defunct). IBM built "401" in 1952 (1st commercial computer) and John von Neumann invented controversial concept of interchangeable data and programs.

The First Transistor



John Bardeen and **Walter Brattain** at Bell Laboratories constructed the first solid-state transistor (operated with a power gain of 18 on Dec. 23, 1947). With their manager, **William Shockley**, they won the **Nobel Prize in 1956**.

The First Transistor Product

Sony

The first transistor radio was a joint project of the Regency Co. and Texas Instruments. TI built the transistors; Regency built the radio. On October 18, 1954, the Regency TR1 was put on the market. It was a scant five inches high and used four germanium transistors. It was discontinued in 1955.

In Japan, a tiny company had other ideas. **Tsushin Kogyo** was close to manufacturing its first radios when it heard that an American company had beaten them to market. But they persevered and made a radio, the TR-52, which later entered US market as Regency quit.

The founders, Ibuka and Morita, thought of using a Latin word **sonus** meaning "*sound*." Akio Morita knew some English, and made a simple variation that became their name from then on:

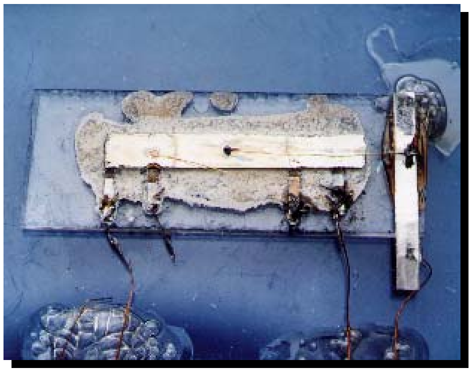
SONY

First Integrated Circuit
(An oscillator circuit on germanium substrate)

Jack Kilby,1958, US Patent Application (Texas Instruments)

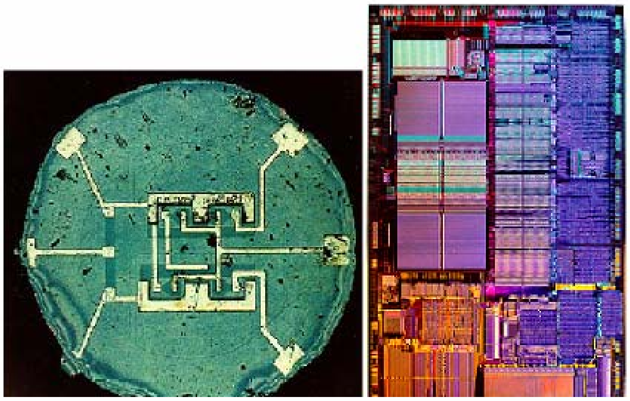
Nobel prize, 2000

Edward Noyce, 1959, US Patent Application (Fairchild Semiconductor, which later becomes Intel)



By Jack Kilby, Photo courtesy of Texas Instruments, Inc.

Integrated Circuits in Evolution



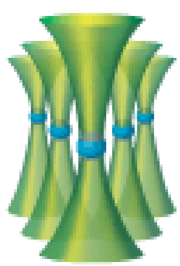
- 1960s and early 1990s integrated circuits.
- Progress due to:
  - Feature size reduction - 0.7X/3 years (Moore's Law).
  - Increasing chip size - ≈ 16% per year.
  - "Creativity" in implementing functions.

Investing Micro/Nanotechnology: Examples

- Arryx
- Rolltronics
- Zyvex
- Memgen
- Alientechnology
- NanoOpto
- Surface Logix
- Opticomasa

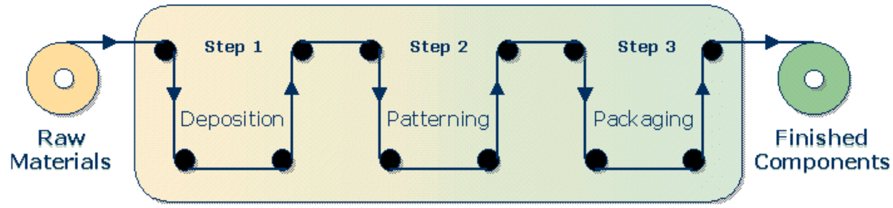
And many more!

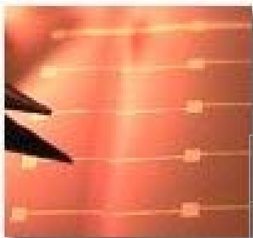
http://www.arryx.com/



Founders	Lewis Gruber, Dr. Kenneth Bradley, ARCH Nanophase
Funding	ARCH,DFJ, $3M
What's Interesting	Parallel Manufacturing Technology

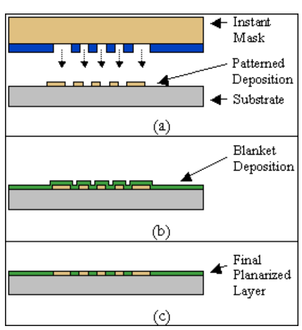
http://www.rolltronics.com/

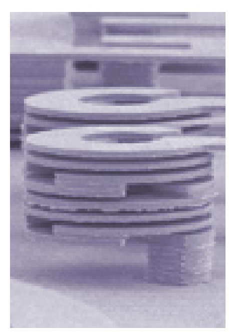




Founders	Michael Sauvante
Funding	Angel?
What's Interesting	Acquiring Pieces from Other Industries

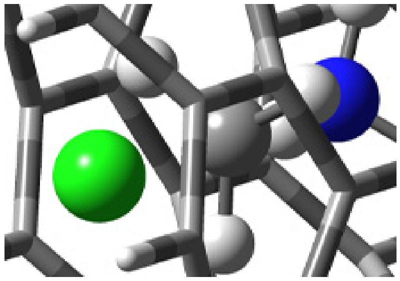
http://www.memgen.com/

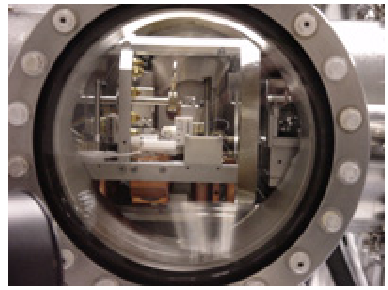




Founders	Adam Cohen, Veteran of 3D Printing Industry, F Cube, 3D Systems
Funding	Dynafund
What's Interesting	Micro rapid prototyping technology

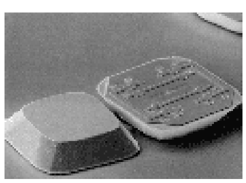
http://www.zyvex.com





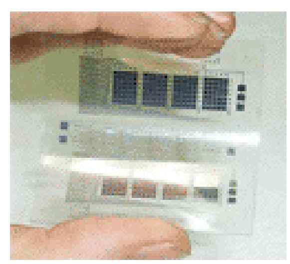
Founders	Jim Von Ehr II, Freitas, Merkle, Futurists, Xerox
Funding	NIST ATP $25 M
What's Interesting	Nanomanipulation by robotic Assemblers

http://www.alientechnology.com



SEM Photograph of 185 Micron NanoBlocks

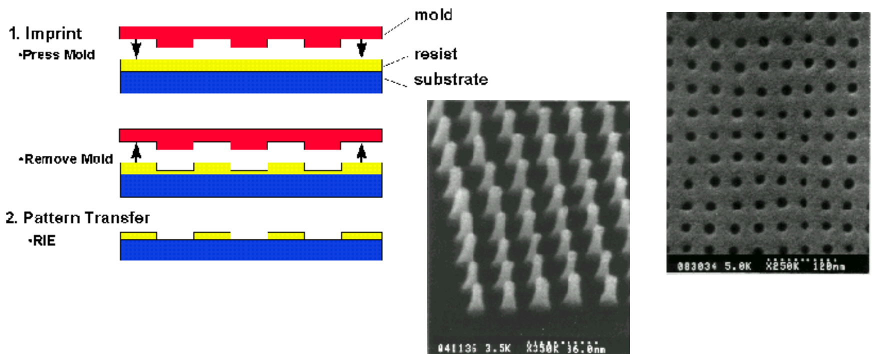
185 and 70 Micron NanoBlock circuits on top of a dime



Flexible PET substrate using single crystal silicon NanoBlocks and sputtered aluminum interconnects

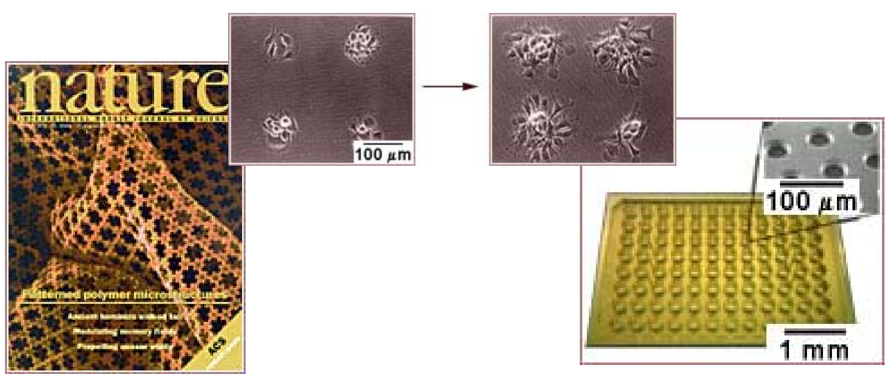
Founders	Jeff Jacobsen, KOPIN
Funding	Philips, DuPont,Seven Rosen $80 M
What's Interesting	Fluidic Assembly

http://www.nanoopto.com/



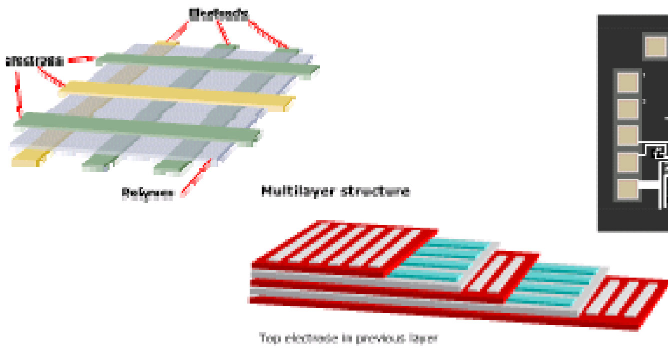
Founders	Stephen Chou, Princeton
Funding	Bessemer, Morganthaler $16 M
What's Interesting	NanoImprint Lithography – 10 nm structures applied to passive optical structures

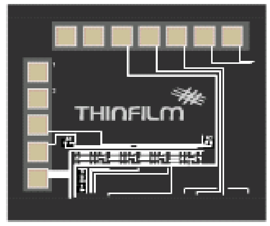
http://www.surfacelogix.com/



Founders	Carmichael Roberts,George Whitesides
Funding	Venrock
What's Interesting	Printed Chemistry

http://www.opticomasa.com/





Founders	**Gudersen**
Funding	**Intel**
What's Interesting	**Stacked Polymer Memory**

Next Lecture ...

Tour of NanoHUB

Thinking of Small Scale

- Proportion and Size …
- Relative Importance of Forces in small scale …