# Lecture 1-1 Introduction to Micro System Design

## ⇨ Scope of Micro System Design

Introduction to MEMS => Micro System design => Micro System implementation
BioMEMS, RFMEMS, Optical MEMS, Micro System Material, Micro scale Fluid Mechanics and Heat transfer, Micro Fabrication lab, Advance Micro Fabrication Lab, Micro transducers (sensors and actuators), Advanced Micro System Technology.

## ⇨ Richard P. Feynman two inspiring lectures:

**1. "There is plenty of room at the bottom"**, invited talk in Annual meeting of American Applied Physical Society, December 26, 1959. (1965 Nobel prize in Physics: R. Feynman, 1947 first Semiconductor transistor invented, 1956 Nobel Prize in Physics: John Bardeen, Walter Houser Brattain, and William Bradford Shockley)

- New field-manufacturing and controlling things on a small scale
- Write 24 Volumes of Encyclopedia Britannica on the head of pin=>32 atoms of a dot
- How to write? Reverse micro scope, small photoelectric screen, 24 million books in 3 square yards=>there is "plenty room" at the bottom
- Digitized-100 atoms/bit, but 3D writing=> 1/100-1/200 inch cube for all books, DNA use 50 atoms/bit
- Best SEM: 10 Angstroms, wavelength: 1/20 Angstroms, 100 times better microscope=>help chemist and biologist.
- Comparison between Computer and human brain: lot of materials, heat generation, power, speed, etc
- How to fabricate? Evaporation, small lathe, hundred of tiny hands, rearranging atoms, etc…
- Problems in small scale: inertial force, strength of materials, grain structure, magnetic force, lubrication, heat transfer
- Utilities: small surgeon, help chemical synthesis, find DNA sequence by physics.

- Two competitions: (1). 1/25,000 book-Tom Newman, 1976?, A tale of two cities in 5.9*5.9 $\mu$m, (2) 1/64 motor~100 μm-- 1960, William McLellan

**2. "Infinitesimal Machinery"**, invited talk in Jet Propulsion Laboratory, Pasadena CA, USA, February 23, 1983. (64 y, died 1988)

- Revisiting "There is plenty of Room at the Bottom—some progress in information storage, but no progress in small machinery.
- How to make them—predict the sacrificial methods, drive by electrostatic force.
- How to use them—light valves, rollers or drills on a surface, micro robot for computer testing, Active masks, micro fluidic systems, three dimensional circuits.
- Electrostatic actuations—sliding devices.
- Mobile Microrobots—entertainment, using electrical induction or chemical in the environmetn as energy source, light for signal sending, small surgeon.
- Making precise things from imprecise tools– grind stones with one another, casting finite number of atoms.
- Friction and Stiction—molecule attraction, using oxide as lubricant
- Computing with atoms– using any two state system.

⇨ **The name of Micro Systems**:

- US: MEMS (MicroElectroMechanical Systems)
- Japan: Micromachines
- Europe: MST (Micro System Technology)
- Scale of device: roughly from 0.1 $\mu$m-1mm.

⇨ **Historical review of the development of Micro System Technology**:

- The initiation (from micromachines-a new era in mechanical engineering, by Iwo Fujimasa )
  **USA:**

- 11/9, 1987, "Micro Robots and Teleoperators workshop: an investigation of micromechanical structures, actuators and sensors, Hyannis, Massachusetts.
  Silicon Technologist: tiny gears, turbines, electrostatic motors, and vibrators.
  K.J. Gabriel, W. Trimmer, AT&T Bell Lab, Opening address
  R. Howe, UC Berkeley, Micro Structural fabrication technology
  K. E. Peterson, Nova Sensor, Silicon micromachanics foundry
  R.S. Muller UC Berkeley, Micro structures
  Senturia, MIT, Microrobotic devices

  Mechanical Engineers:
  Jacobsen, U of Utah, R. Howe, UC Berkeley, Fujita, U of Tokyo, Fukuda, Science U of Tokyo, Brooks, MIT
  LIGA (before 1987), Ehrfeld
  Autoassembling machine, Drexler, Stanford U.

- NSF pour funding: 1988 US$105 millions, 1989 US$200 millions C

**Japan:**

- Early 1980s, Hayashi, Tokyo Institute of Technology, planning to found a miniature machine society-electric, chemical, pneumatic power mechanical actuators.
- First meeting, 8/28/1988, U of Tokyo, Komaba
- Dec./1988, first symposium on micromachines, found Micromachine society: Rujmasa, Nakajima, Fujita, U of Tokyo
  Esashi, Tohoku U.
- Industry: 1973, Igarashi, Toyota Central Research and Development Lab.: micropressure sensors and accelerometers.
- 1991, MITI (Ministry of International Trade and Industry) funded 4 directions:

1. Microelectromechaincal Systems
2. Micro robots
3. micromachine applications in clinical medicine
4. & Biotechnology

**Europe:**

- 1988 10-yaer microfabrication machinery project, Germany. Key researchers:
  Heuberger and Benecke, (IMT, Institute for Microstructure Technology), Reichel (TU, Technology University)
  Ehrfeld, Institut fur Kernverfahrenstechnik.
- 1990-1993, BMFT (Ministry for Research and Technology)
  DM 400 millions on Micro System Technology
- First conference: 1988, international conference on Micro, Electro and Optomechanical Systems and Components, Berlin
  Lithographical techniques, wet etching, ion etching, laser assisted etching, X-ray lithography, micromechanical sensors, microstructures, optoelectronic elements, fluidic elements.
- Other activities in Europe:
  1. Since 1986, Middelhoek, Delf U. of Technology, The Netherlands, MEM sensors (radiant, mechanical, thermal, magnetic and chemical) by silicon technology
  2. University of Twente in the Netherlands
  3. Swiss Federal Institute of Technology, Zurich
  4. De Rooji, Institute de Microtechnique, University de Neuchatel, Switzerland: microtip catheter, needle sensors

⇨ **Status**: Similar to IC industry in 1950s (first transistor invented in 1947 in Bell lab)

⇨ **Research activity in USA:**

UC Berkeley: R. Howe, R. Muller,
Cal Tech

UCLA
U of M
Stanford U.
Case Western Reserve U.
Georgia Tech
Cornell U.
MIT
University of Hawaii at Manoa
Carnegie Mellon U.
U. of Colorado
UC, Davis
UC, Irvine
USC
NJIT
Louisiana Tech U.
UW at Madison
UI at Urbana-Champaign
Sandia National Lab
Jet Propulsion Lab
Laurence Livermore National Lab
IBM research
Bell lab
Industries…
And more…

⇨ **MEMS literatures**:

**Journals:**

**JMEMS**: Journal of Microelectromechanical Systems, IEEE/ASME joint publication (ISSN 1057-7157), quarterly from March 1992.

**Lab on a Chip**, Royal Scociety of Chemistry, UK.

**JMM**: Journal of Micromechanics and Microengineering, American Institute of Physics (ISSN 0960-1317), quarterly from March 1991.

**S&A:** Sensors and Actuators A or B, Elsevier Sequoia (ISSN 0924-4274), 5 Vol. Per year, 3 issues per volume.

**S&M**: Sensors and Materials, Scientific Publishing Division of MY, Japan (ISSN 0914-4935). 6 issues per volume.

**B&B**: Biosensors and Bioelectronics, Elsevier Science (ISSN 0956-5663), 12 issues per year from 1986

**BM**: Biomedical Microdevices-BioMEMS and Biomedical Nanotechnology,

Kluwer Academic Publishers (ISSN: 1387-2176), 2 issues per year from 1999.

**Sensors**: IEEE Sensors Journal, IEEE press, (ISSN: 1530-437X), published bimonthly, started June 2001.

**Conferences:**

**MEMS##:** IEEE Micro Electro Mechanical Systems
1987 and annual form 1989, held in February (Abstract due in Sep.)

**ASME IMECE:** ASME winter annual meeting
Annual (MEMS symposium from 1990), in Nov/Dec (Abstract due in Feb.)

**Trans##**: International Conference on Solid-State Sensors and actuators (Transducers "xx) biennial from 1981, in June (Abstract due in Dec.)

**HARMST##**: International conference on High Aspect Ratio Micro System Technology, biennial started from 1995, usually in June close to transducer.

**μTAS##:** Micro Total Analysis System, start 1994, biennial from 94-00, annual start from 2001.

**HH##**: IEEE Solid-State Sensor and Actuator Workshop, biennial from 1984, in June (Abstract due in Jan.)

**SPIE##**: International Society for Optical Engineering, conference for MEMS or Optical MEMS, annual

⇨ **Conclusion**:

**Micro System Technology has lots of opportunities for you to explore in the future!**

Handout:

1. "There is plenty of room at the bottom", Richard P. Feynman, invited talk in Annual meeting of American Applied Physical Society, December 26, 1959.
2. "Infinitesimal Machinery", Richard P. Feynman, invited talk in Jet Propulsion Laboratory, Pasadena CA, USA, February 23, 1983.

References:

1. Fukimasa, "Micromachines-A New Era in Mechanical Engineering", Oxford University Press, 1996
2. W. S. Trimmer, "Micromechanics and MEMS-Classic and Seminal Papers to 1990", IEEE Press, 1997
3. Technical Digest of IEEE Internal MEMS'99 Conference, Orlando, Florida, USA, 1999.