Recent trend of MEMS and Nano manufacturing in AIST

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MEMS R&D for Future Business Success

- MEMS (Micro-Electro Mechanical Systems)
  - What is MEMS, and why MEMS
  - MEMS history
  - Future trends and Difficulties in Business Success
    - Micro to Nano machining (Optics, Photonics, Bio, RF) - Large investment for facilities
    - Small batch production rather than Mass production
    - Long R&D time
- M/NEMS for commercialization-Consistency of Cost and Fine machining
  - Foundry, Service and Killer Application R&D
  - Design tools and Data Base
  - Nano level cost effective manufacturing (Nanoprint)
  - From Mass Production to Custom Production (Desk-top MEMS factory)
  - M/NEMS Packaging
Why M/NEMS in Japan
Motivation for R&D

Wide variety of Applications
(Communication, Peripherals, Bio and Energy)

1980's Japan as Number one
Electronic Component Industry

2000's Sudden
Manufacturing Industry
(Need to Change
Mass Production to R&D oriented)

New Process and Materials Technologies
Speedy Realization of Ideas
Small Batch R&D Proto-typing

What is MEMS

- Miniature Energy Transducers
- Manufactured by photolithographic batch process

Micro Reactor
Optical scanner
RF switch

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Mega Hit History—What’s next?

Overview on successfully commercialized applications

Projected world sales of 2003

- Automotive Pressure Sensors:
  - 120M Units/yr -> 60M pcs wafers/yr
  (In case throughput per 6" wafer is 200 dies.)
- Medical Pressure Sensors:
  - 30M Units/yr -> 15M pcs wafers/yr
  (In case throughput per 6" wafer is 200 dies.)

Inkjet printer heads:

- 400M Units/yr -> 2,000K pcs wafers/yr
  (In case throughput per 6" wafer is 200 dies.)
- 150M Units/yr -> 75M pcs wafers/yr
  (In case throughput per 6" wafer is 200 dies.)
- DMD
  - 50M Units/yr -> 10M pcs wafers/yr
  (In case throughput per 6" wafer is 50 dies.)

Reference Forecast Data by SPC (Jan 1999)

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MEMS—Market in the near future

- Large coupling loss of electronics switch at higher frequency more than 5 GHz
- MEMS switch can reduce the consumption power more than 30%.
- Wireless LAN communication, multi-band communication
- RF—MEMS annual growth rate is more than 40%.

R&D items

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MEMS difficulties and solutions

Difficulties
- High cost and low reliability of facilities
- Application is not always Mass Production based devices
- A lot of Know-how for MEMS Process
- Design engineer should know process
- Difficulties of Packaging

Solutions
- MEMS Foundry
  - Standard MEMS (Taiwan, US) Low cost but restriction of design and materials
  - Custom MEMS (Japan) High cost but high degree of freedom for design
- Killer Application R&D
  - RF MEMS for Mobile Devices (OMRON)
  - MEMS Packaging for Mobile devices (Panasonic)
  - Optical MEMS (Projector and Semicon) (Olympus)
- MEMS Process Education (Number of MEMS engineers is less than 1500 in Japan)
- MEMS design tools and Database
- Low Cost Process
  - Nanoprinting
  - Desktop MEMS
  - Integration of New Materials to MEMS (Carbon, PZT, Glass)

Development of MEMS/NEMS

Bridge from Basic Study to Commercialization

- Open network environment for Industries and Academic Institutes
- Open Collaborative laboratories and Clean Rooms
- We provide
  - Number: Nano Level
  - Manufacturing facilities: EB writer, Stepper for MEMS, ICP, deep RIE, Nanoimprinting
  - Only nano Materials Technologies for MEMS (PZT, Glass, Carbon)
  - All-in-one Manufacturing facilities and know-hows
- Class 1000 x 300m2
Nanoimprint
Low cost process for sub micron machining

Photonics
Laser array
Diffraction lattice
Optical guide
Photonic devices

Bio-chemical technology
Reactor
Micro chip
Bio-chip

Electronics
Magnetic memory
Display

Storage Media
HDD

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Nanoimprint R&D in AIST

(a) Double-sided embossing (10um resolution), process speed (from 10min to 90sec)
High temperature (1400°C)
(b) Step and repeat embossing (1um resolution), process speed up (10sec)
(c) Conventional release, (d) Ultrasonic release
Nanoimprint of Glasses - high reliability materials

Glass is good materials for Optics, Photonics and Bio applications.

Welcome to Desk-top Nanofactory
Why Desktop Nanofactory

TOP-down Nanotech
or MEMS approach

Winner
American Capital
China Production

Need Change

Miniaturize and Customize for flexible R&D

From Mass Production to Custom Production — Desktop Nanofactory

- Low cost R&D
  - Facility Miniaturization
- On demand fabrication
  - Ultra small batch production
- For large scale production
  - Conventional method
  - Multiple array of nanofactories

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Desktop Nanoimprint (ESCO)

- 10x10 mm²
- 700 degree C
- Small tact time

Ceramic heater

Desktop EB lithography
- 0.1 um resolution
- 150 nm Line and space
- 10x10 mm²
- No movement of the table
- Under US$ 50,000
From Mass Production to Custom Desk-top MEMS FAB

- Development of Machine family
  - Tiny EB writer: March 2005
  - Desk top Nanoimprint: February 2005
  - Next stage (Etching, Plating, Packaging, FIB)

- Business strategy
  - Total design
  - Patent issues
  - Standardization of Machine family and samples
    Sample positioning
    Exhausted gas treatment
  - Collaboration with companies and institutes

NPO PEN's Strategy

What is NPO PEN?
Non Profitable Organization

Activities are limited
Too many Rules and Bosses
Not for Public Lack of funding resources

NPO is an Answer for:
Quick realization of Ideas
Network collaboration among institutes and Companies
for Commercialization of High Technology
MEMS/NEMS projects
Bridge from Basic Study to Commercialization

- Training of High Technology (MEMS simulation, fabrication and Measurement)
- Nano-imprinting Consortium
- MEMS foundry and prototyping Service
- Asian Initiative Program
  - The aim of the Shanghai Office
    - Establishment of New Research Institute
    - Training (Technology, Language)
    - Seminars
    - Recruiting service between Academia, Companies and students
    - Networking of foreign researchers in China

MEMS Commercialization at AIST

- Short range of R&D (National Project "Focus 21", Collaboration with companies)
  - RF MEMS for Mobile devices
  - MEMS Packaging for Mobile devices
  - Optical MEMS (Projector and Sensors)
- Long range of R&D (Governmental Funding)
  - Bio-technology applications (uTAS, Artificial Organs)
  - Security monitoring of Nature and Constructions
  - Integration of New Materials to MEMS (Carbon, PZT, Glass)
  - New process development for MEMS
    - High aspect ratio structuring and thick film deposition
    - Forming and Nano-imprinting
    - Miniature MEMS fabrication system
- Education for Industry
- Data base of MEMS Fabrication (NEDO project)