State of the art and future trends in microassembly technologies

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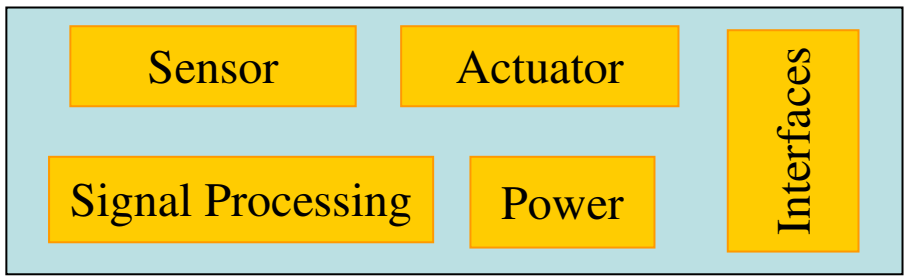
State of the art and future trends in microassembly technologies

Ajit Pardasani & Shafee Ahamed

AMT 2007, London, Ontario

What is a microsystem*

- Microsystem is a multifunctional device with micron-scale features.



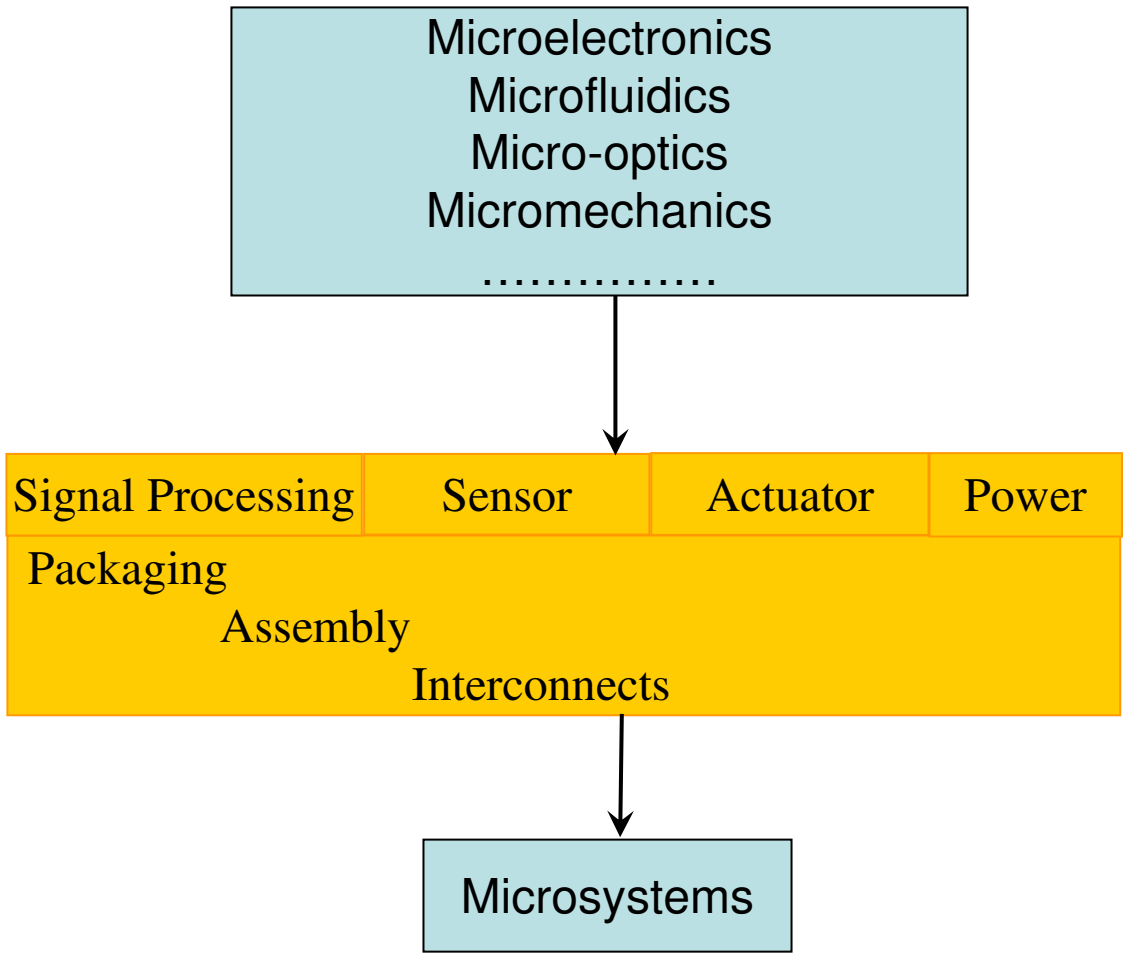
- Aka MEMS (Micro Electro Mechanical Systems) in the US micromachines in Japan

Micro Robot

BioMicroFuelCell™

Source: Sandia National Labs

Microsystem



Microsystems Examples

Encapsulated Endoscope

Olympus,
26mm x 11 mm
5,000 images

Middle Ear Implant

Implex AG

Implantable Infusion Pump

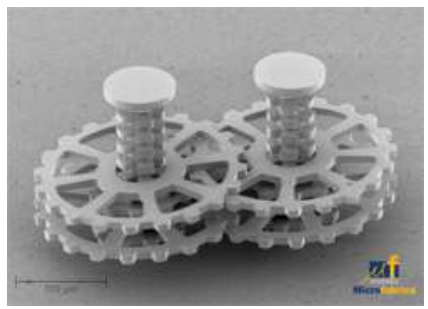
Tricumed Medizintechnik GmbH

Micro-diaphragm pump

ThinXXS Microtechnology

Micropump

Bartels Mikrotechnik



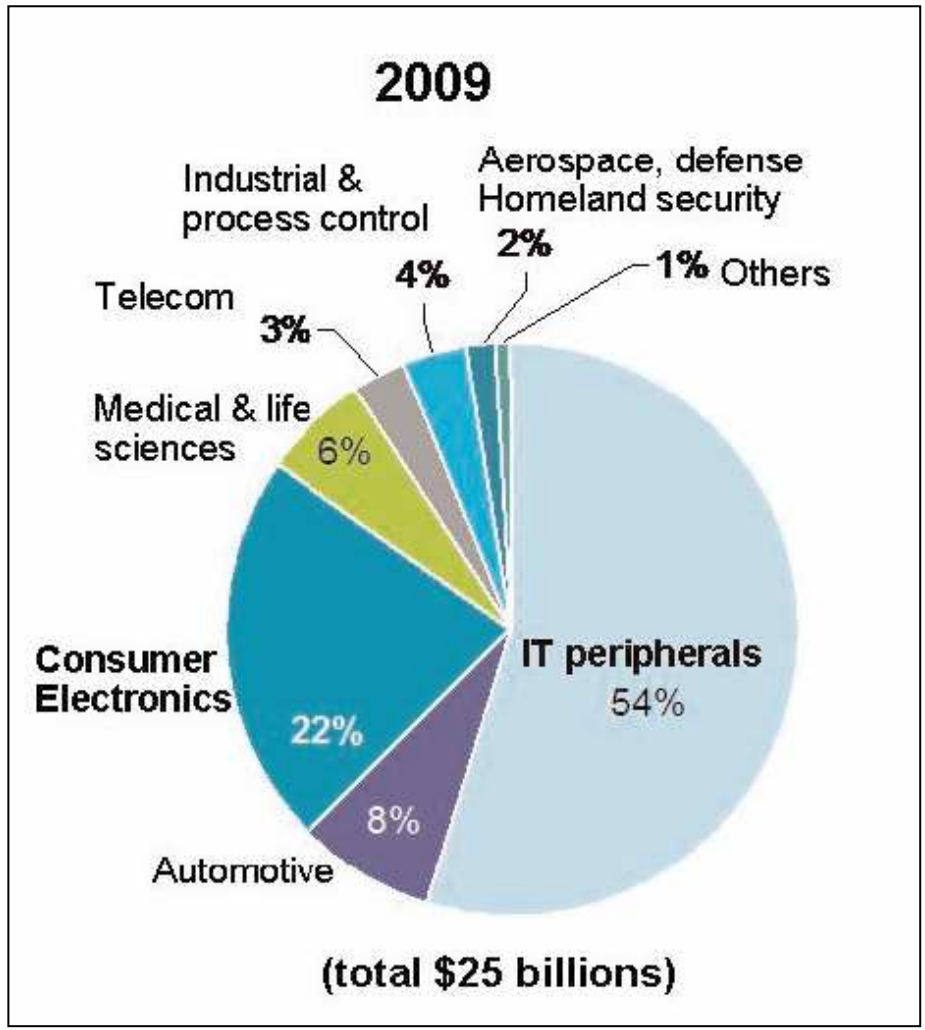
Microfabrica Inc.

Microsystems Market

Year	Market (Billions)
2004	12
2009	25

16% Growth

New products in 2009 will include micro fuel cells, MEMS memories, chip coolers, liquid lenses for cell phone.



Source: NEXUS (The Network of Excellence in Multifunctional Microsystems)
Market Analysis for MEMS and Microsystems III, 2005-2009

Microassembly

- Assembly of objects with microscale/mesoscale features under microscale tolerances
- Assembly of microcomponents/microsystems where contact and surface forces dominate over the volume related properties (gravity) affecting:
  - Handling
    - pick, place, release
  - Accuracy of Placement
    - move, rotate, orient, mate
- Microassembly can account upto 80% of total production cost
- More expensive as parts become smaller

Why Microassembly?

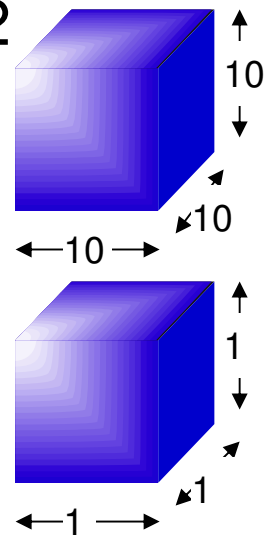
- To integrate heterogeneous micro components and microsystems into hybrid functional devices/3D structures.
- Choice of materials: Components can be made using non-semiconductor materials
- Diverse manufacturing processes can be used for making components
- Microparts with a range of geometrical shapes and sizes can be assembled.

Major Issues: Microcomponent Handling

Scaling effect creates problems for handling:

- Stiction due to surface tension and intermolecular forces
- Mechanical Clamping
- Repulsion/attraction due to electrostatic forces
- Careful handling to avoid damage

- Volume $\propto$ L3
- Surface Area $\propto$ L2
- Part1:
  - Volume: 1000
  - Surface area: 600
- Part2:
  - Volume: 1
  - Surface area: 6
- The surface area went down by 100 but the volume by 1000



Microsystems in Medical & Life Sciences - Assembly Required

- Lab on a chip
- Components for catheter systems
- Micro surgical instruments
- Implants (micropumps, microvalves, sensors)
- Drug atomizers
- Endoscopes
- Cell separation systems
- Components for non-invasive power transfer
- Electrodes for nerve stimulation
- Hearing aids

Key Processes for Microassembly

- Part feeding
- Handling of microcomponents including grasp and release
- Precise positioning
- Precise manipulation to align and mate parts
- Sensing for finding parts position and orientation
- Verification for quality control
- Joining or Bonding
- Programming of robotic system

Current Status

Manual

- Tedious
- Tiresome
- Very low repeatability
- High flexibility
- High rejection rate
- High operational costs

Automation

- Specific to product type
- High accuracy and repeatability
- Low flexibility
- High capital costs
- Suitable for very high production volumes

The Future Needs

"There is an urgent industrial need for re-configurable, easily deployable, cost-effective, micro assembly system solutions with a supportive application methodology" European Precision Assembly Roadmap 2010

Most of the Nanotechnology products will require microtechnology based constructs to provide interface to real (macro) world

Technology Trend

- Microcomponent manufacturing
  - Lower costs
  - Better tolerances
  - Choice of materials
- Decreasing cost of robotics, machine vision, and systems integration
- Microdispensing

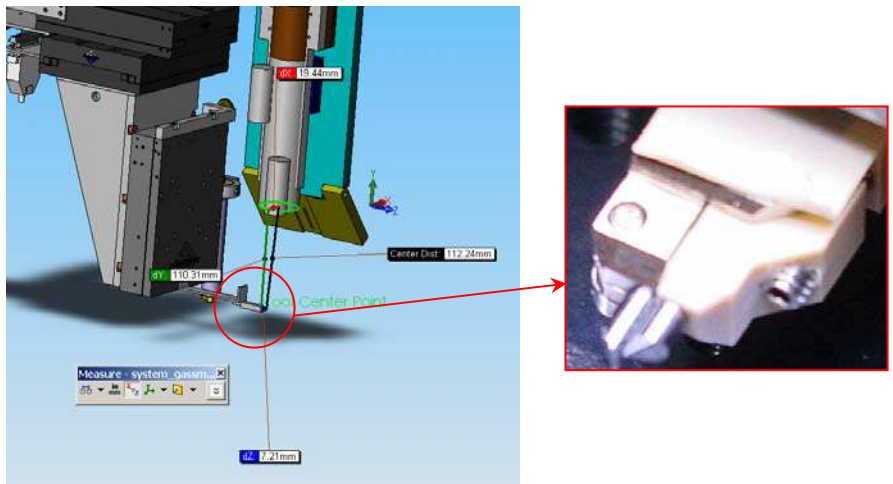
Future Research Direction

- Improved gripper design –
  - fast and accurate grip
  - rapid release
  - force feedback
  - volume production
- Integration of micromanipulation and gripper function
- Micro level sensing
- Micro Metrology
- Tool changers – quick change of grippers
- Development of VR environments coupled with Physics based analysis tools
- Parallel Microassembly
- Micro factories
- Mechanical Fasteners

Micromanipulation and Microgrippers

- Precision micropositioning stages
- Microgrippers used in conjunction with positioning stages
- Integrated functionality of gripping and positioning in a single device

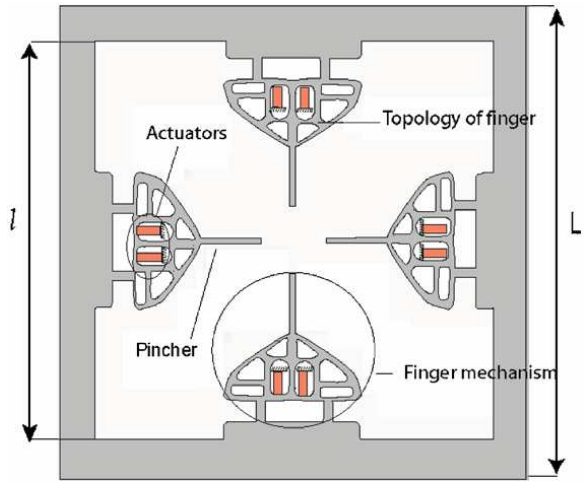
Microgripper plug-in mounted on MMA micromanipulator (3DOF) by Kleindiek Nanotechnik

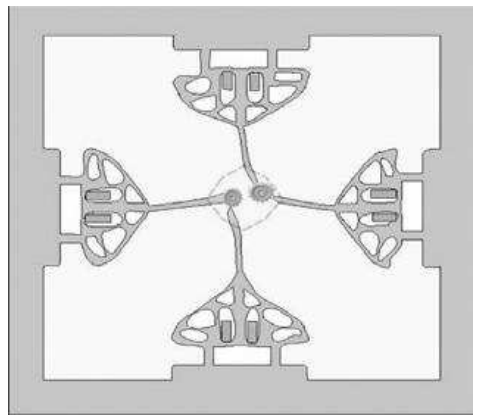


Gassman microgripper mounted on XYZ micromotion stages at NRC-IMTI's microassembly workstation

Integration of micromanipulation and gripper function

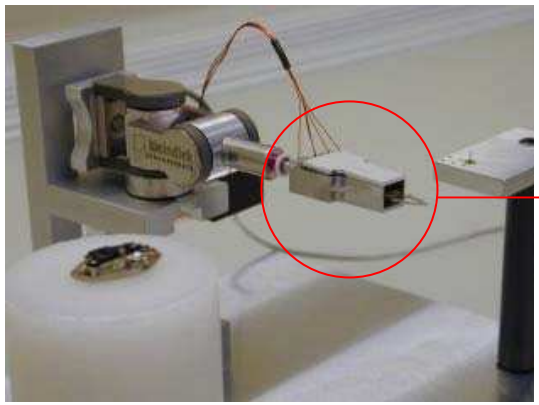
- One-square centimeter proof of concept device "micromanipulator station"
- Has multiple, coordinated fingers that grips an object and take it from one given position to another
- Fabricated on the silicon wafer
- Developed by Saggere and his graduate student Sandeep Krishnan at the University of Illinois



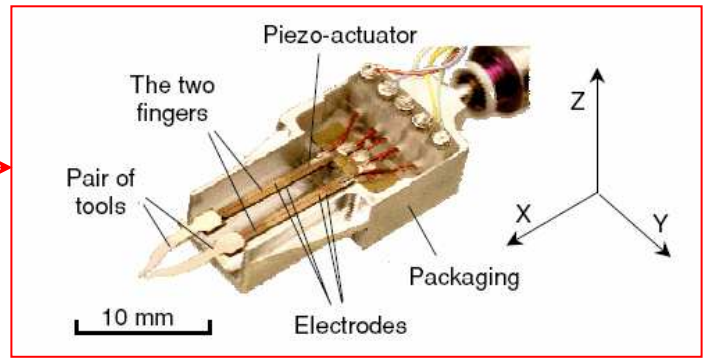


A multi-fingered micromechanism for coordinated micro/nano manipulation. Krishnan-S; Saggere-L, Journal of Micromechanics and Microengineering. March 2007

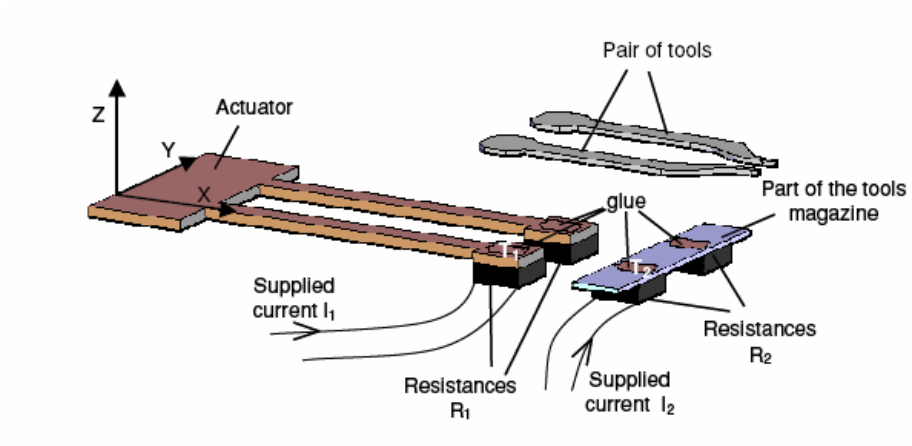
Microgripper with tool changer (1)



Microgripper mounted on MM3A micromanipulator
Laboratoire d'Automatique de Besancon, France

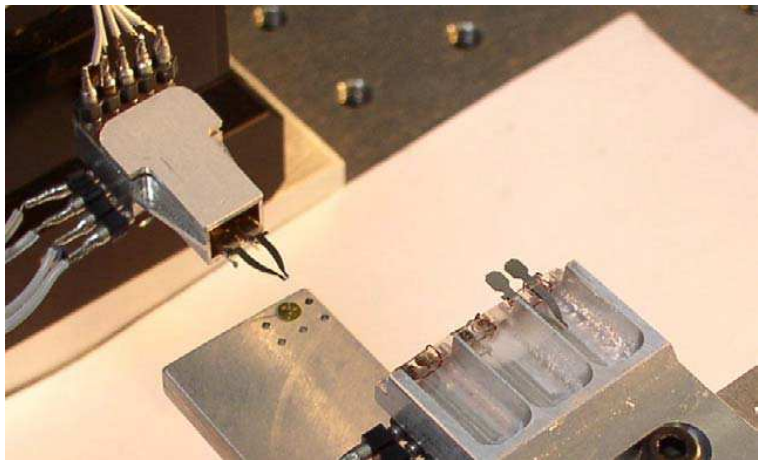


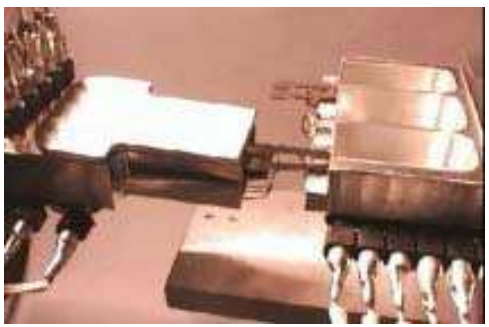
Piezoelectric Microgripper with changeable nickel tips



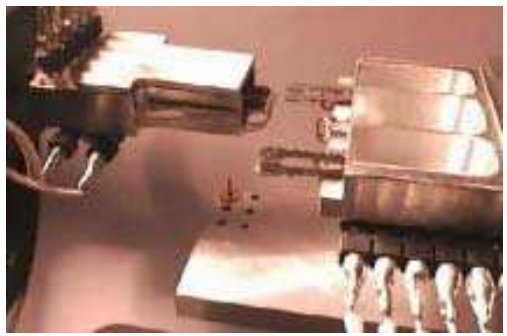
A micromanipulation cell including a tool changer, C´edric Cl´evy, et.al. J. Micromech. Microeng. 15, 2005

Microgripper with tool changer (2)





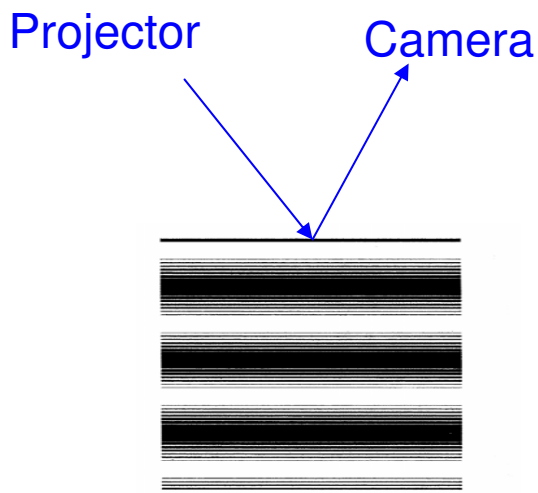
Release of first pair of tools



Actuator approaching
second pair of tools

Micro metrology

- Inspection of micro scale parts and features has not kept up with micro manufacturing capabilities
- Fringe Projection/Structured Light suitable for on machine measurement of micro/meso-scale parts
  - Non-contact measurement
  - Large field of view
  - System components are compact
  - High speed measurement



An Overview of Micro/Meso-Scale Dimensional Metrology, Shawn P. Moylan, NIST. SME MIcromanufacturing Conference, 2007, Chicago.

VR Environment couple with Physics based Simulation

Simulation drives hardware

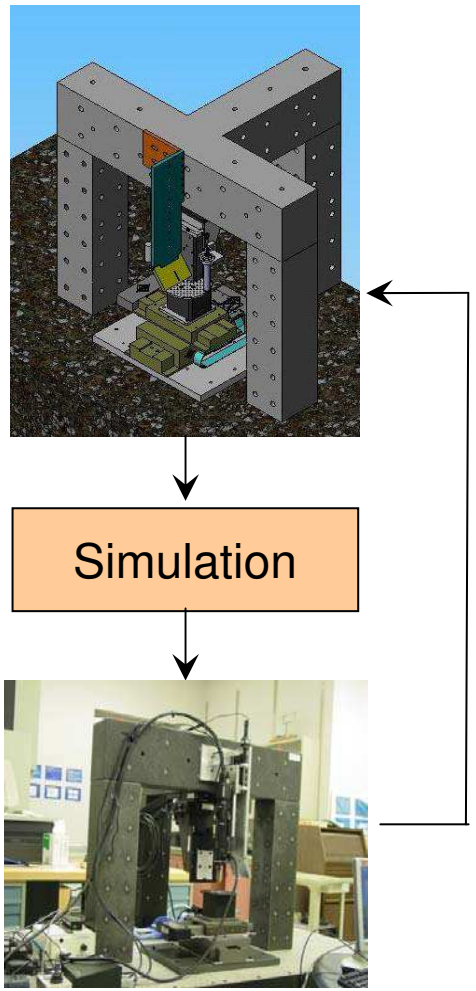
Model hardware and physics of assembly

Simulate and analyze assembly plan

- Pick, position, orient, and release
- Mating strategies
- Task sequencing
- Collision avoidance
- Tolerance stackups

Control actual cell based on simulation

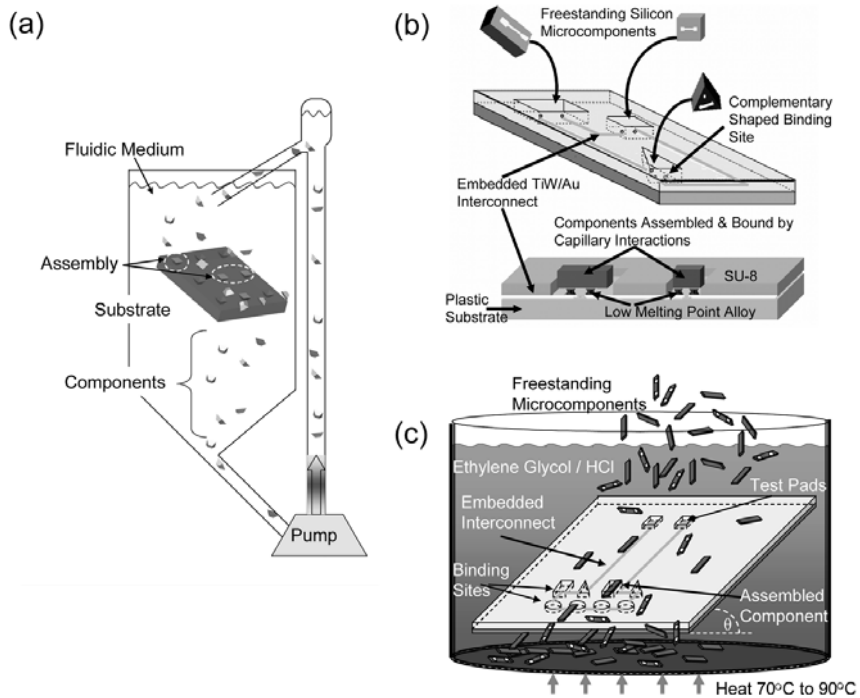
Update virtual cell using actual cell



IMTI's Microassembly station

Parallel Microassembly

- Surface mount machines are fast, capable of handling:
  - ~ 26 000 electrical parts per hour
  - ~ Part sizes as small as 300 microns
- Assembly rates depend on the component size
  - Increases as the size decreases from meters millimeters.
  - Decrease when components size is less than 300 microns (Difficult to handle and position)
- Self assembly has advantages when
  - Large number of parts
  - Parts smaller than 300 microns
  - 3D assembly



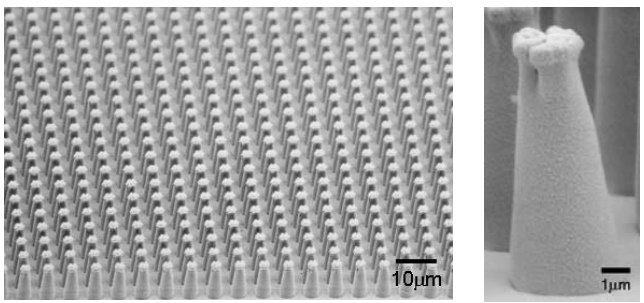
Self-Assembly for Microscale and Nanoscale Packaging: Steps Toward Self-Packaging, Christopher J. Morris, IEEE Transactions on Advanced Packaging, VOL. 28, NO. 4, NOVEMBER 2005

Micro and Nano Velcro

Enable assembly without adhesive or solder at room temperature

Micro Velcro

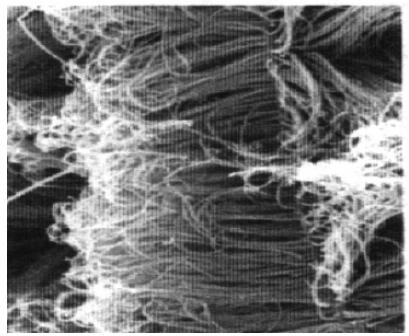
- fabricated on standard silicon wafers
- Or, high-aspect-ratio arrays of metal posts fabricated with density of ~ 2,700,000 per cm2.



MICRO-BRUSH PRESS-ON CONTACT: A NEW TECHNIQUE FOR ROOM TEMPERATURE ELECTRICAL AND MECHANICAL ATTACHMENT, Sang-Hyun Lee, IEEE, MEMS, Istanbul, 2006

Nano Velcro

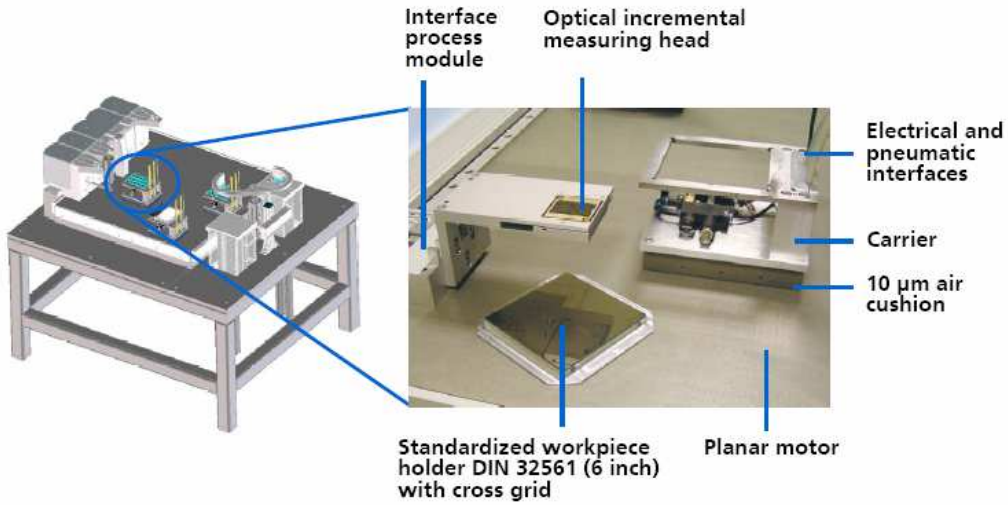
- Carpeted with hook-ended carbon nanotubes (1 E -8).
- ~ 30 times stronger than conventional epoxy adhesives
- Many times stronger than a microscopic microvelcro



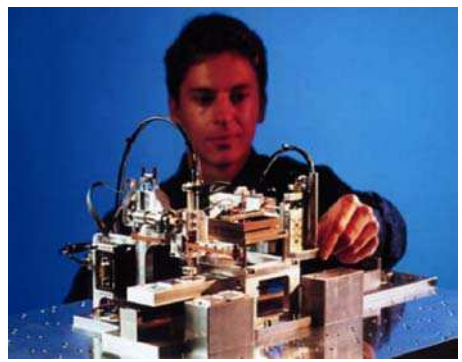
Berber, Kwon, and Tomanek, *Physics Review Letters*, Vol. 91, No 16

Micro factory

- Increasing gap between the size of the product and the size of the machine
- Assembly lines for microproducts
  - Often many meters long
  - Expensive
- Micro factory
  - Economic benefits
  - Technology benefits



Miniaturized reconfigurable Micro-assembly System
MiniProd - Miniaturized technology building kit



Cost-effective Assembly of Microsystems

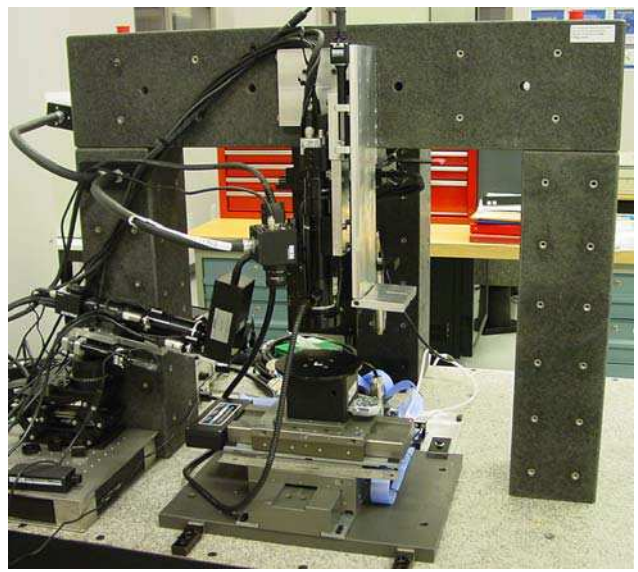
Project Goal

- Develop cost effective, flexible, modular, microassembly cell & processes:
  - High product yield
  - Co-existence of manual and automation
  - Incremental step-wise automation
  - Easy operator interface
  - Able to handle large product variety

Motion stages, robots, vision system, vibration isolation, etc.

$$\text{Flexibility} = \sum \frac{\text{Capital Costs}}{\text{Recurring Costs}}$$

Re-programming, new part handling new fixtures, new grippers



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