New Application of Polymeric Microfluidic Chip

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Why polymeric microfluidic chip ?

Molecular biology, Biochemistry, Cell biology

- Gene Treatment
- Cloning
- Drug Discovery
- Mass Production of Livestock
- Etc.

Technology

- Chemical Assay
- Transgenesis
- Drive of Stem Cell
- Single Cell & Molecular Handling
- Etc.

Limit !! ⇒
- Time consuming (Low throughput)
- Micromanipulation (Skill dependent)
- Microvolume of sample

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Solution !! ⇒ MEMS (or MicroFabrication)

What is MEMS (traditional) ?

MicroElectroMechnical System

The fabrication of devices with at least some of their dimensions in the micrometer range

NanoElectroMechnical System

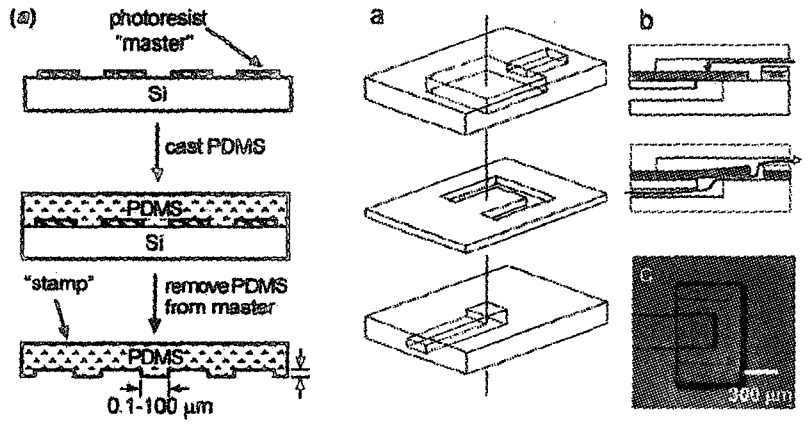
In the submicron range

Limits in Traditional MEMS for the Bio-Application

1. **Hard material (Si, GaAs, Metal, etc.) ←→ Tissue, Cell, Fluid, etc**
2. **Complicated Fabrication (Mass Production) ←→ Diversity**
3. **High Investment**
4. **Time Consuming**
5. **Non-biocompatible**

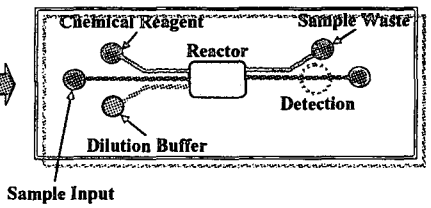
Softlithography

George M.Whitesides



Microfluidics/ Lab on a Chip/ Micro TAS

Fluid Handling, Amplification, Derivatization, Lysis of cells, Concentration, Extraction, Centrifugation



Fluorescence, UV/vis Absorption, Amperometric, Conductivity, Raman

Sample Prep

Reaction

Sample Detection

Advantages of Polymeric Microfluidic System

- **Very small volume of fluid is necessary**
- **Simple and inexpensive**
- **Highly integrated device**

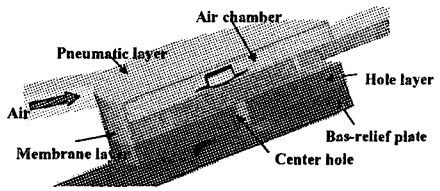
Major applications

1. Passive components
   Separation
   Mixing
   Transport (channels)
   Reservoirs
2. Actuator
   Passive Valve
   Pump
3. Sensor
   Bio-sensor
4. Microreactor

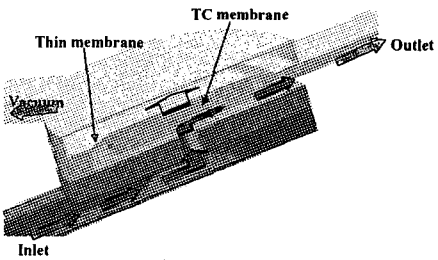
New Applications

1. Active Polymeric Micropump
2. Factory on a Chip

Schematic and Operation

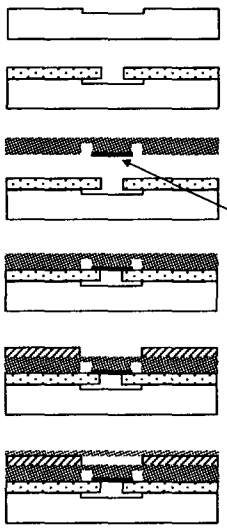


(a) Closing of valve by compressed air



(b) Opening of valve by vacuum

Process of valve fabrication



Patterned PDMS bas-relief plate with access hole for fluidic network

Bonding with hole layer by exposing to the oxygen plasma

Masking with WS mask onto the rigid centered area *and regional exposition to the oxygen plasma.*

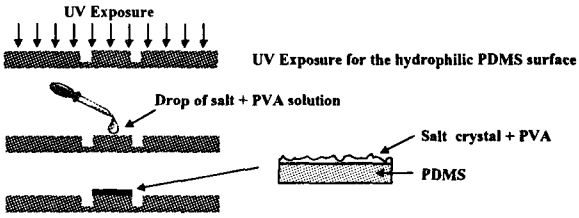
WS Mask

Bonding of membrane layer

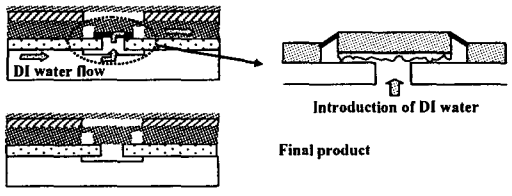
Bonding with pneumatic layer

Bonding with cover glass

Process of valve fabrication

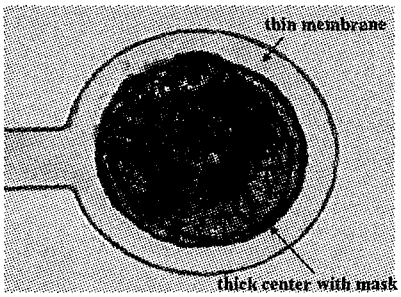


(a) Masking process with salt and PVA solution

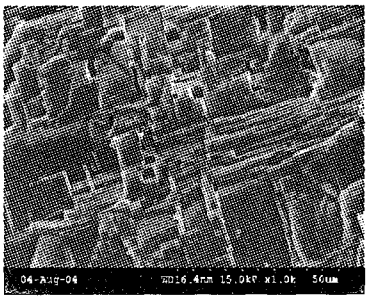


(b) Development process with DI water

Optical and SEM micrograph of WS mask

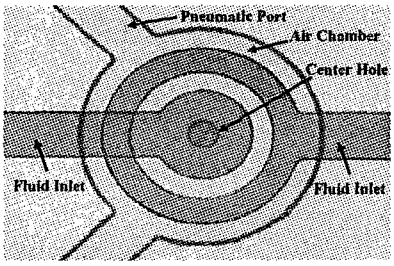


(a) Micrograph of WS mask

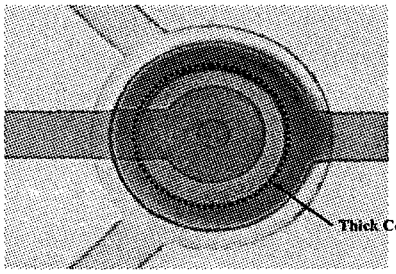


(b) SEM image of the mask surface

Operation of fabricated valve

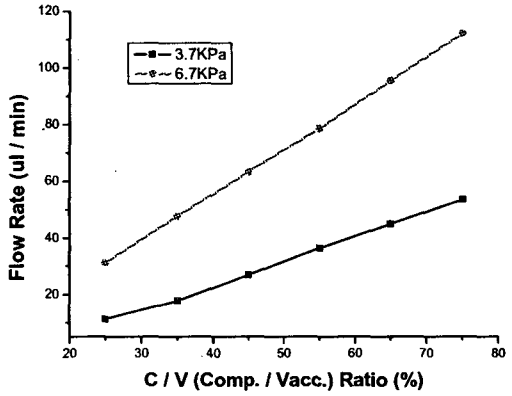


(a) Close of valve

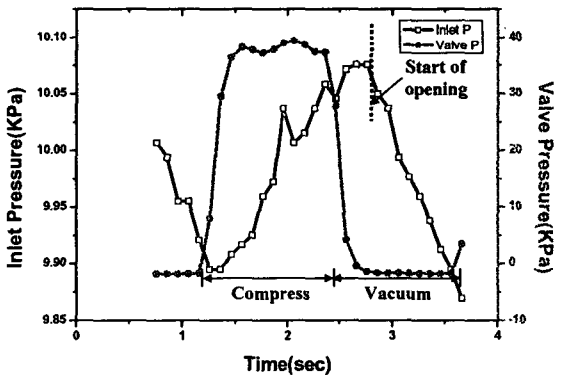


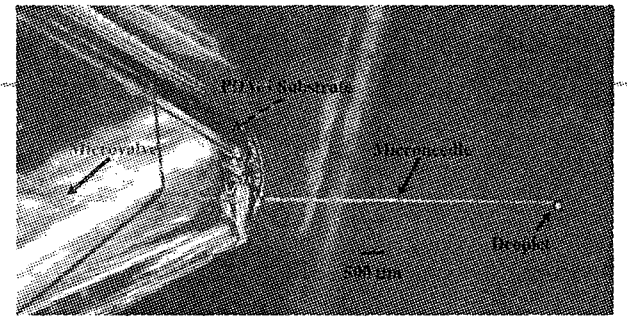
(b) Open of valve

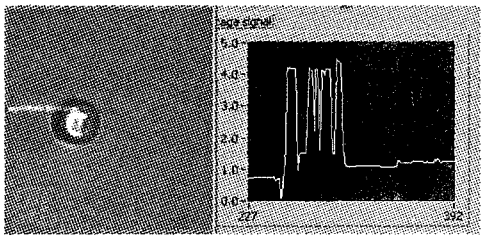
The change of flow rate to the C/V ratio and inlet pressure



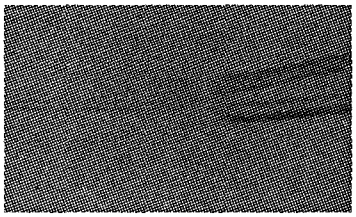
Response of valve operation







At the Tip of Needle and Applied Pressure



Lab on a Chip(Sep. 2003)

New Applications

2. Factory on a Chip

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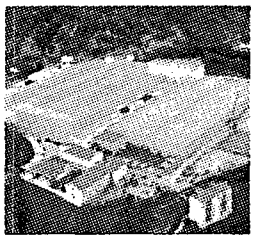
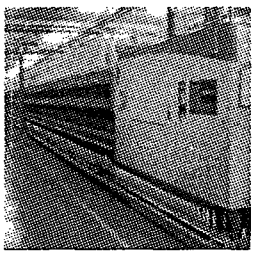
How to create micro curved structure in continuous way ??

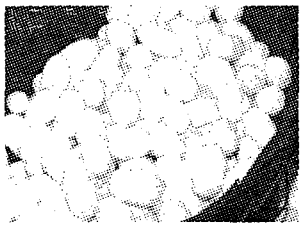
In industry



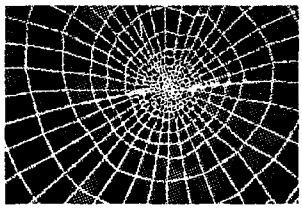


- Effective
- No pollution
- Microstructure

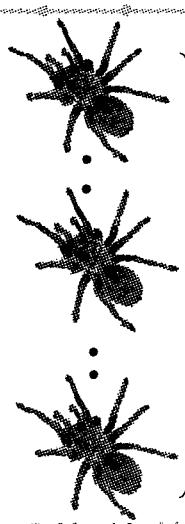
In nature



Cocoon

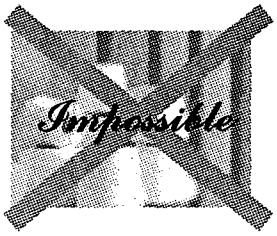


If the mass production of spider silk is possible ...



Bio-factory

Spider Machine



Biomimetic Factory

Microfluidic Chip

?

Objective

Development of a PDMS based micro-chip for the continuous fabrication of curved microstructure such as microfiber or microtube like mass production-machine in the factory.

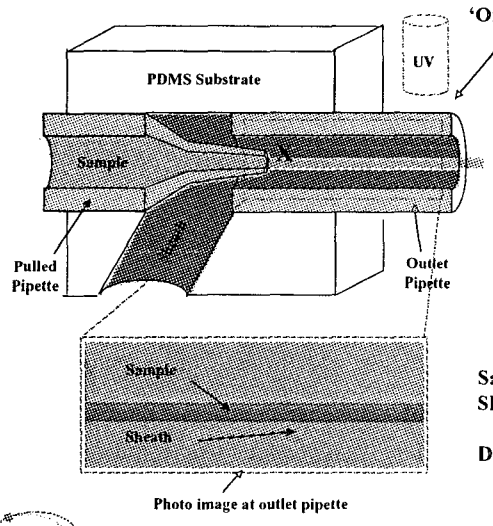
Artificial Spider

Is it Possible ? ⟹ **'Yes'**

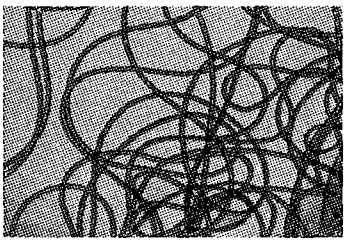
How ?

- **Laminar flows in micro worlds**
- **'On the fly' Photopolymerization**

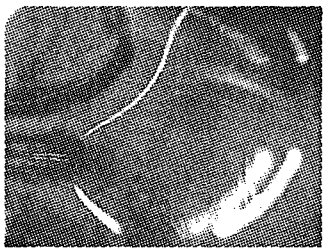
Fabrication of Microfibers



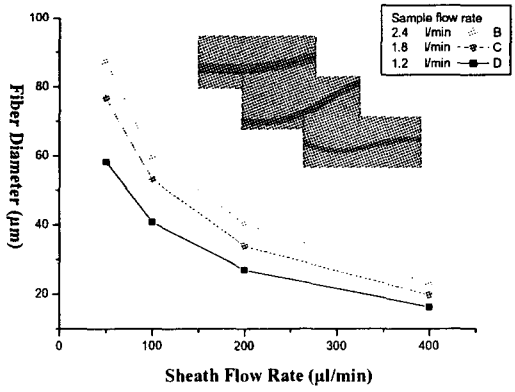
'On the fly' Photopolymerization

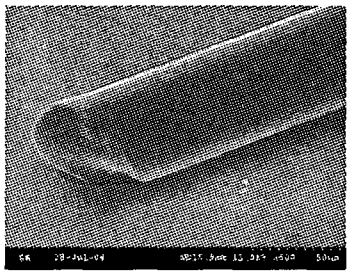


Sample: 4-Hydroxybutyl acrylate (4-HBA)
Sheath: 50 Vol% Polyvinylalcohol (PVA) + 50 Vol% DI water
Dye: Rhodamin B

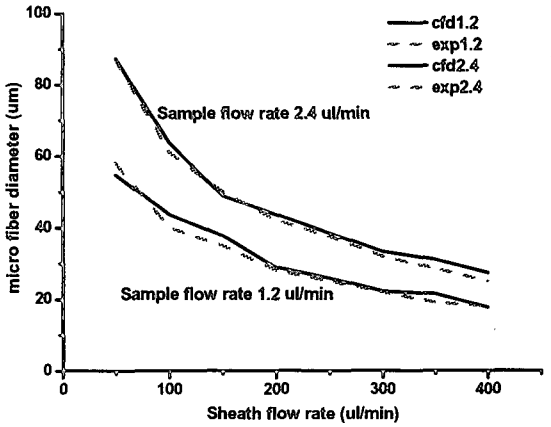


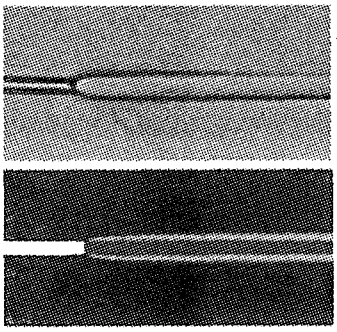
Flow Rate vs. Diameter





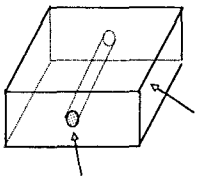
CFD-based Diameter Prediction





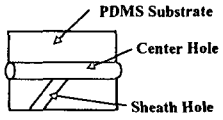
Sample flow: 1.2 ㎕/min, sheath flow: 100 ㎕/min

Construction of Apparatus

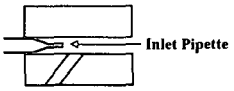


Center hole

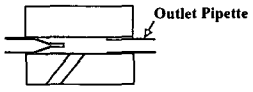
PDMS substrate with center hole



- Puncture hole for sheath flow



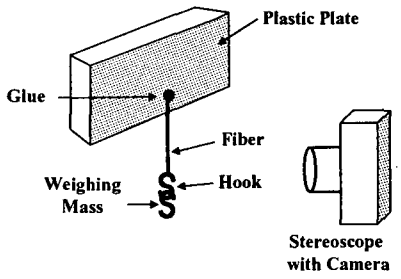
- Insertion and bonding of inlet pipette

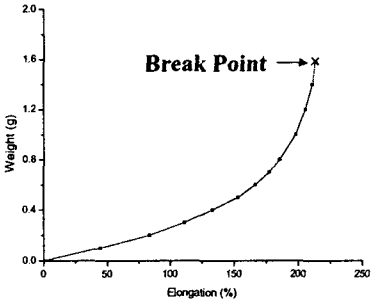


- Insertion and bonding of outlet pipette

Stress-Strain Curve

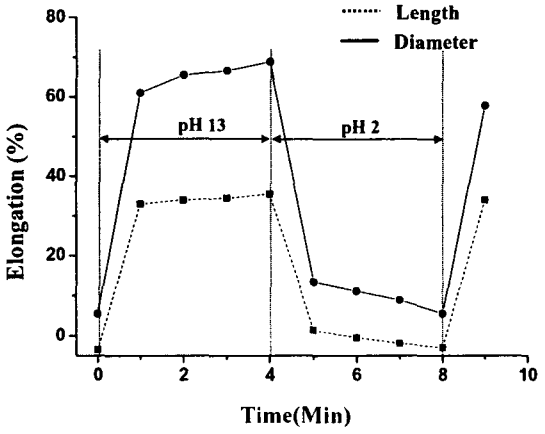
Experimental Setup



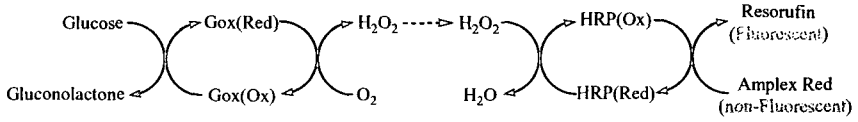


pH-Responsive Property

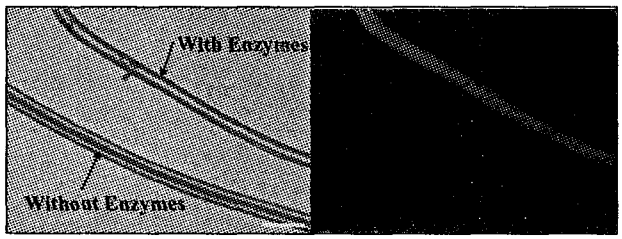
Swelling and shrinking motion of microfiber in response to a step change in pH



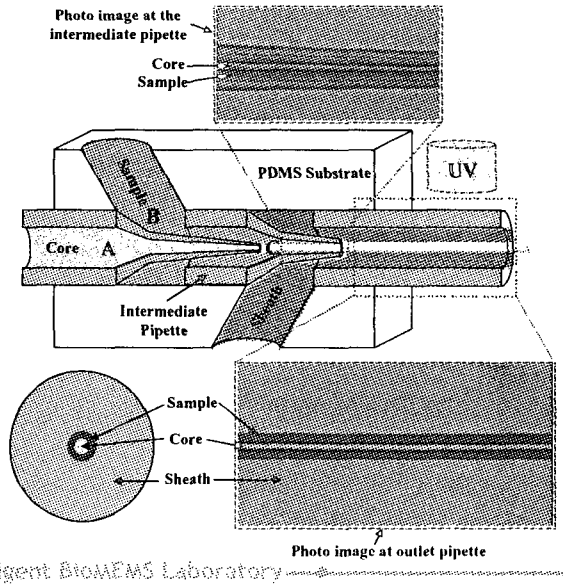
Enzyme Immobilization - Biosensing



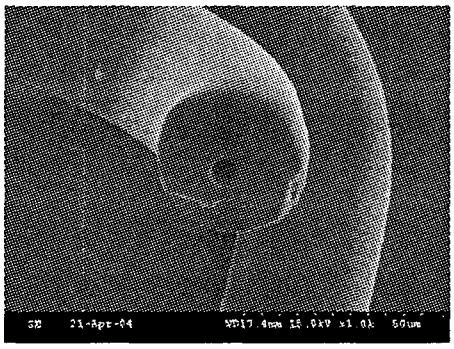
Scheme of glucose-enzyme reaction



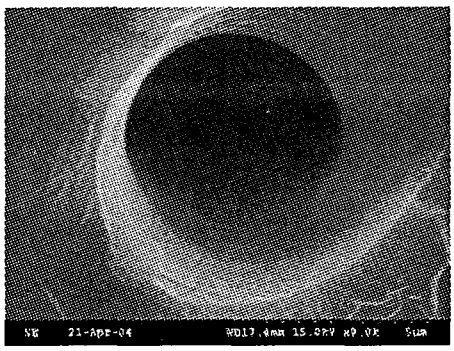
Fabrication of Microtubes



SEM Images of Microfiber

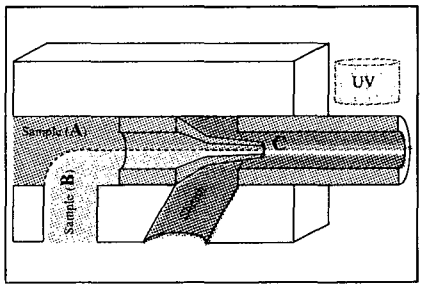


Outer dia.: 35μm, Inner dia.: 7μm

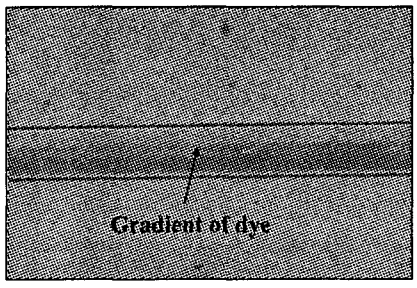


Lumen of Microtube

Control of the Local Fiber Properties via Laminar Flow

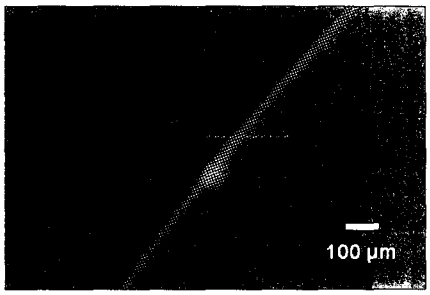


Schematic of Apparatus

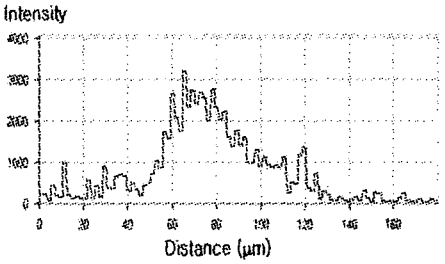


Produced Fiber with Different Color

Fluorescence Micrograph of the Dual-sensing Microfiber



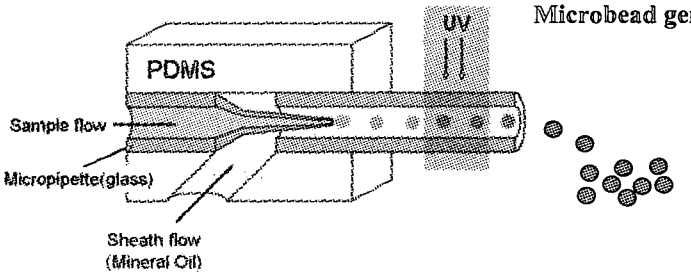
Fluorescence micrograph of the dual-sensing microfiber

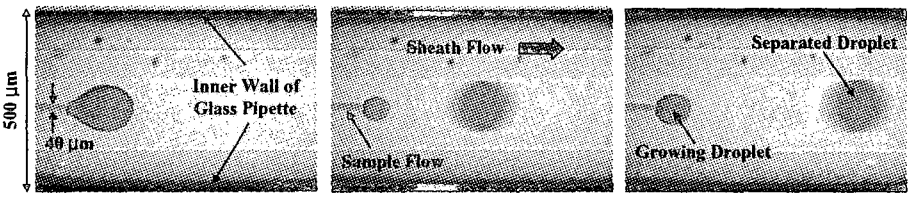


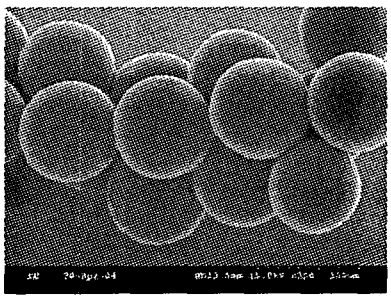
Fluorescence intensity curve across the microfiber

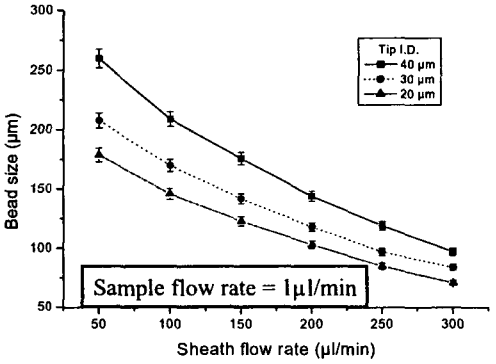
Further Applications → Microbead Production

Microbead generation apparatus









Advantages

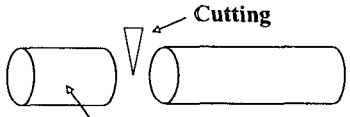
Fabrication process

- Conceptually simple
- Cost effective
- Flexibility in materials, geometries, and scales
- Parallel processing on one chip is possible

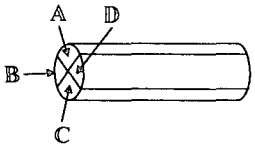
Fabrication environment

- No production of pollution
- High voltage electrical power is not necessary
- Fabricated under the room temperature and atmosphere
- Biological materials (e.g.: enzymes, DNA etc.) can be immobilized

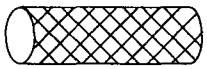
In Future



Biosensor or actuator micro-component which is integrative into the other microdevices



Multi-sensing fiber

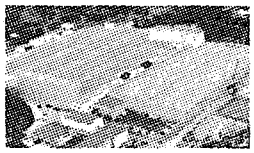


Responsive stent

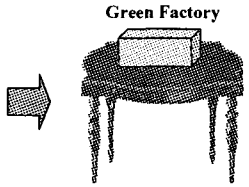
Conclusions

1. Advanced fabrication technology of polymeric devices
2. Diversity in materials
3. Extensive unknown applications and phenomena
4. Revolutions in the fabrication technology !!

Dream !!

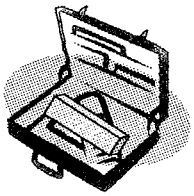


Factory



Green Factory

Mountable Factory
On the Table



Portable Factory

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Thank you for listening!

Intelligent BioMEMS Laboratory