Manipulation in the Micro and Nano Domains: New Materials and Technologies

Research activities in micro- and nano-scale manipulations have become prevalent in the Robotics and Automation community in the last few years. The main goals for micro- manipulation are to allow researchers to assemble and build 3D MEMS or micromechatronic systems, to manipulate biological samples in the micro domain, or to move micro robotic systems through environments that are not accessible by macro-scale technologies. The objectives of nano-manipulation, on the other hand, include the enabling of 3D manipulation of chemical moieties to build molecules and then assemble them into larger devices, or to manipulate nano-scale biological entities such as DNAs and proteins for scientific analyses. In this workshop, a comprehensive survey of micro- and nano-manipulation technologies in the past 10 years will first be presented. The importance and key difficulties of micro/nano manipulations in science and engineering applications will then be presented. Then, we will focus on disseminating information on some of the recent developments in materials and manipulation techniques that should play major roles in advancing micro- and nano-manipulations technologies in the near future – these new materials and novel techniques are expected to increase the level of sophistication of handling micro- and nano-scopic objects. Specific examples of applications discussed at this workshop include micro actuators for aqueous environment, precision handling of biological specimen, carbon nanotube manipulation, and DNA stretching. This workshop strives to give participants a fundamental understanding of the scientific and engineering issues of micro- and nano-manipulation; and will also offer the attendees a glimpse of the global research activities in these exciting fields.

May 12, 2002 8:30am to 5:30pm

Time period listed for each session includes presentation+questions/answering

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8:30 to 9:00am

Introduction to Micro and Nano Manipulations

Wen J. LI
Department of Automation and Computer-Aided Engineering
The Chinese University of Hong Kong, Hong Kong

The importance and key difficulties for micro and nano manipulations will be introduced in this presentation. A comprehensive survey of micro and nano manipulation technologies will also be presented.

9:00 to 9:30am

Manipulation Technologies of Micro-objects for BioMEMS

Fumihito ARAI and Toshio FUKUDA
Department of Micro System Engineering
Nagoya University, Japan

Several manipulation technologies of micro-objects for BioMEMS will be introduced. At first, manipulation methods of micro-objects in liquid are classified and briefly reviewed. Mechanical micromanipulation, non-contact micromanipulation using laser trap or dielectrophoresis, and self-assembly of the micro-objects are introduced. We will also explain the recent development of the minimum invasive micromanipulation of the microbe using laser trapped micro-tools. We will see the non-contact micromanipulation is suitable for BioMEMS applications. Finally we introduce application example of these methods to the selective separation of microbe with the microchip fabrication technology.

9:30 to 9:45am Break

9:45 to 10:00am

Polymer-based Micro Actuators for Micro Manipulation: an Introduction

Wen J. LI
Department of Automation and Computer-Aided Engineering
The Chinese University of Hong Kong, Hong Kong

Several novel and different polymer-based micro actuators will be presented in this presentation: polypyrrole, parylene, and ICPF micro actuators. In general, polymer-based micro actuators give much more displacement compare to silicon- or metal-based micro actuators. And unlike conventional MEMS actuators, polymer-based actuators are also capable of working in aqueous environments. These qualities will enable them to

manipulate biological samples such as cells, proteins, or DNAs – if the actuators are built small enough. The intent of this presentation is to disseminate our design and fabrication techniques to build various micro polymer actuators to the participants.

10:00 to 11:00am

Development of Underwater Microrobot and New Type of Micropumps Using ICPF

Shuxiang Guo[1] and Kinji ASAKA[2]
[1] *Dept. of Intelligent Mechanical Systems Eng'g, Kagawa University, Japan*
[2] *Osaka National Research Institute, AIS, Japan*

ICPF (Ionic Conducting Polymer Film) actuator is made from a film of perfluorosulfonic acid polymer chemically plated with platinum on both sides. ICPF actuator is superior to typical polymer gel actuator because it has fast response, able to be driven by low voltage (about 1.5V) in wet condition without electrolysis, and it is safe to use in a human body. We have shown that it is now possible to replicate the undulating motion of marine animals using ICPF actuators. In this presentation, we will show our development of an underwater microrobot that has the characteristics of flexibility, driven by a low voltage, good response, and safely operated in a human body. In addition, we will also show a new type of micropump that can supply micro liquid flow, and can be potentially used for medical applications. This micro pump consists of two active one-way valves that make use of the same ICPF actuator. The overall size of this micro pump prototype is 12mm in diameter and 20mm in length.

11:00am to 12:00pm

Micro Tweezer for Micro and Nano In-Situ Manipulation of SEM Operation

Chang LIU
Department of Electrical and Computer Engineering
University of Illinois, Urbana-Champaign, USA

This presentation will discuss a micro tweezer and a three-axis motion stage for in-SEM operation. The tweezer is made by using MEMS technology and operates on thermal actuation principle and electrostatic actuation principle. The tool is expected to increase the level of sophistication of handling micro- and nano-scopic and objects.

12:00 to 2:00pm Lunch Break

2:00pm to 2:50pm

3D Nanoassembly of Carbon Nanotubes through Nanorobotic Manipulations

Fumihito ARAI and Toshio FUKUDA
Department of Micro System Engineering
Nagoya University, Japan

Nanometer scale building blocks of multi-walled carbon nanotubes (MWNTs) with desired properties are prepared by picking up them from raw material (pre-selection), observing and *in situ* measuring their geometries (diameter, length, etc.), mechanical properties (flexural rigidity), and modifying their geometries and hence their mechanical and/or electronic properties through destructive fabrication as needed. Nanoassembly of MWNTs in three-dimensional space is realized by positioning these building blocks with nanometer order accuracy, and joining them together through van der Waals forces, electron-beam-induced deposition (EBID), and/or covalent keys through mechanochemical nanorobotic manipulations. MWNT I-junctions and Y-junctions are constructed For parallel nanoassembly, concept of parallel EBID is presented, MWNT electron-beam emitter is prepared through nanoassembly of MWNTs onto commercially available atomic force microscope (AFM) cantilevers, and feasibility of using them for parallel EBID is investigated.

2:50 to 3:30pm

Direct Manipulations of DNA Molecules using Hydrodynamic Force

Pak Kin WONG, Tza-Huei WANG, and Chih-Ming HO
Department of Mechanical and Aerospace Engineering
University of California, Los Angeles, USA

In this talk, direct manipulation of DNA molecules using hydrodynamic force is discussed. The fundamental issues and challenges of micro/nano manipulations of biomolecules are presented. Methods for visualization of single molecules such as video fluorescence microscopy are reviewed. Various micro-machined fluidic devices are designed and fabricated for manipulating DNA molecules. Flow field characterization techniques, which are critical for effective handling of the molecules inside microchannels, are done via micro particle image velocimetry (μPIV) and computational fluid dynamic (CFD). Stretching of DNA molecules was demonstrated under steady shear and homogeneous extensional flow, which are velocity gradients along spanwise and streamwise directions respectively. The flow was suddenly stopped to observe the relaxation of stretched molecules. Longest relaxation time of DNA can be determined experimentally. The result is in reasonable agreement with values obtained from other molecular manipulation techniques and theoretical prediction.

3:30pm to 3:50pm Break

3:50pm to 4:50pm

Landmark-based Control for Precision Handling of Biological Specimen

Fathi M. Salam and Virginia Ayres
Department of Mechanical and Aerospace Engineering
Michigan State University, USA

We will present our recent research on the development of systems and enabling technologies for precise and controlled handling and manipulation of micro and nano

biological cells, molecules and tissues, down to the DNA level. The research seeks to *understand* and *exploit* the interaction forces between nano-probing mechanism, the bio-samples, and their environment. The outcome of this research will enable biologists and medical scientists to perform precise and controlled transport, positioning, insertion into and site-specific modification of bio-cells and related samples.

4:50pm to 5:20pm

Electrical Molecular Focusing for DNA Based Diagnostic

Pak Kin WONG, Tza-Huei WANG, and Chih-Ming HO
Department of Mechanical and Aerospace Engineering
University of California, Los Angeles, USA

Direct manipulations of biological objects using electrical forces in micro/nano domain are beneficial because biomolecules are usually charged. Electrophoretic force can be applied by taking advantage of the charge properties of the molecules. In addition, the length scale between electrodes is small in micro/nano domain. Therefore, even when the applied voltage is small, the generated electric fields can be as much as hundreds volt per centimeter. This allows effective manipulation of biomolecules with electrophoretic force. In this talk, manipulations of DNA molecules using electrical forces are discussed. An electrokinetic focusing technique that significantly enhances the detection efficiency for laser induced fluorescence based molecular sensing by concentrating fluorescence labeled molecules to the tiny detection region is presented. 3-D electrodes were designed and fabricated to generate uniform and strong electric field toward the probe region in the microchannel. Negatively charged DNA molecules are driven by electrophoretic force and focused in the probe region; therefore, significant enhancement of detection efficiency can be achieved by our electro-molecular focusing technique.

5:20pm to 5:30pm

Concluding Remarks

Wen J. LI
Department of Automation and Computer-Aided Engineering
The Chinese University of Hong Kong, Hong Kong