System Integration Based on Micro-Nanotechnology and Biomedical Applications

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1. Introduction of Mechano-Bio Systems

Biomedical engineering attracts lots of attention in an aged society. Mechano-bio systems play an important role to supply advanced devices and equipments for biomedical engineering. The need of the mechano-bio systems is increasing for technological innovation and micro-nano technology is indispensable for miniaturization as well as functionalization. In this project, we study on mechano-bio systems integrated by using micro-nanotechnology.

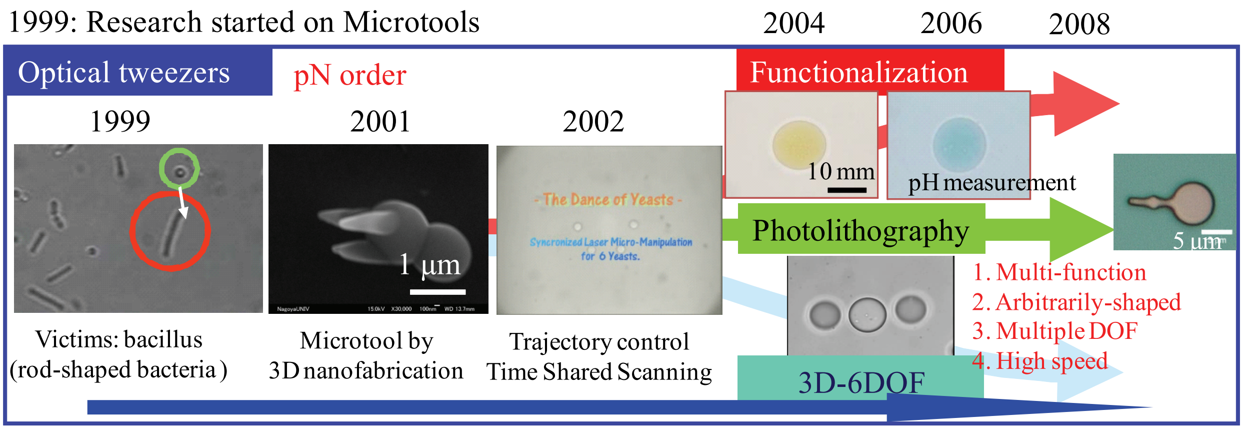
Mechano-bio systems are defied as (1) the systems which deal with the molecules, cells, and tissues mechanically, (2) the artificial systems which mimic the biological elements or life itself, and (3) the hybrid systems or devices which introduce the biological elements or life into the artificial devices or the biocompatible systems which are taken into the biological object.

Common technical interest will be the micro and nanotechnology in designing and producing the system and bio-compatibility of the system. Micro-nanotechnology plays an important role for system integration. Here we introduce our recent works.

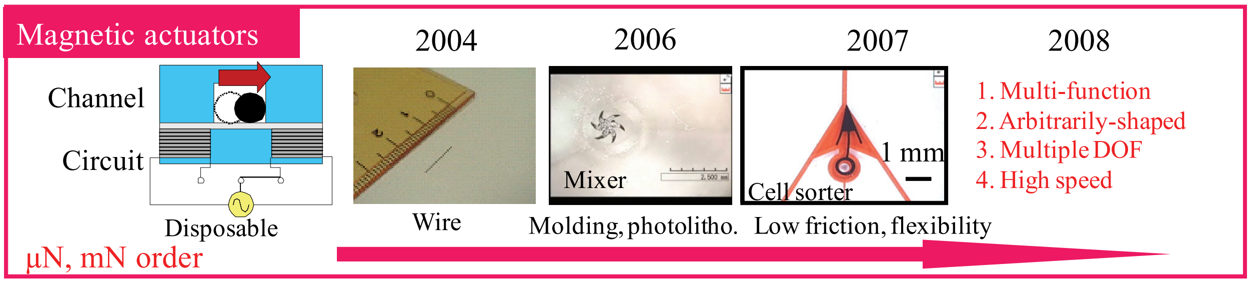
2. Manipulation of Micro-nano Scale Biological Objects

2.1. Noncontact manipulation in a chip by optical tweezers

On-chip single cell analysis is an important approach for research and development in life science, pharmaceutical industry, livestock agriculture, and so on. Optical tweezers are well known as one of the noncontact manipulation methods used in a closed space and much has been reported. Optical tweezers are suitable to manipulate a single micro to nano scaled



(a) History of microtools for optical tweezers



(b) History of microtools for electromagnetic manipulation

Fig. 1. Transition of microtools

particle. Direct laser manipulation is not recommended for cell manipulation and advantage of using microtools was shown by the author [1]. Figure 1 (a) shows history of microtools for optical tweezers. We achieved three-dimensional 6 DOF manipulation of the laser trapped object [2]. Recent research attention has been gathered dexterous manipulation.

2.2. Noncontact manipulation in a chip by Magnetically Driven Microtools

It is desired to have actuators which have the ability of enough actuation force to manipulate cells as well as the softness enough to be harmless to actuate cells. We proposed a magnetically driven microdevice for making a disposable microchip with simple control. Figure 1 (b) shows history of microtools for electromagnetic manipulation. We reported novel polymeric magnetically driven microtools (MMT) for non-intrusive and no contamination experiments on a chip [3]. The composites were formed by suspending magnetite nanoparticles in polydimethylsiloxane (PDMS). In order to obtain precise and complicated pattern of microtools, a photolithography techniques has been applied.

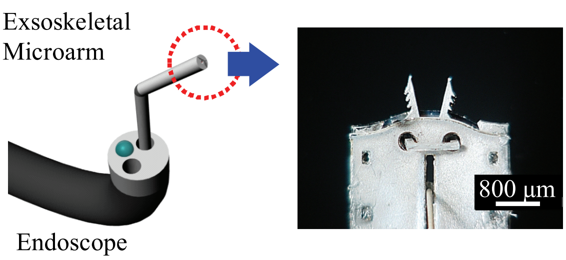


Fig. 2. Endoscopic micro-device for biopsy

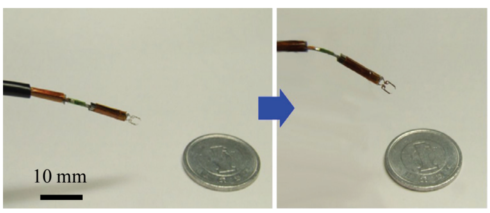


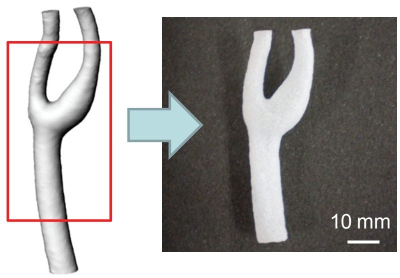
Fig. 3. Bilateral actuation of the microarm

3. Exoskeletal Microarm for Endoscopy

We proposed a new concept of endoscopic micro-device, which has a micro-scale manipulator to precisely control the positioning and insertion of the biopsy (Fig. 2). We also proposed an endoscopical tool to manipulate and peel tumor skin in ESD (Endoscopic Submucosal Dissection). This microarm will come out from the tip of an endoscope to help the manipulation of the tumor skin. The arm is fabricated by photolithography and electroplating and assembled by stacking up the layer of electroplated parts (STAMP: Stacked Microassembly Process)[4], thus mass-production with low cost is possible. This microarm has a joint as shown in Fig. 3. Measuring the angle of the joint can calculate the tip position of the microarm, thus being able to control the arm sicurely. The integrated control system is under development.

4. Tailored Human Models and Scaffolds

We have developed scaffolds of three-dimensional (3D) synthetic vascular prostheses in tailor-made. Figure 4 shows the patient-specific scaffold [5]. Artificial carotid artery was made by combining processes of rapid prototyping, lost wax, dip coating, selective dissolution and salt leaching. This scaffold is porous and made of biodegradable polymer. Human umbilical vein endothelial cells (HUVECs) are adhered to the inner surface of the scaffold for their anticoagulant effects.



(a) (b)

Fig. 4. Patient-specific scaffold. (a) Reconstructed 3D structure of targeted carotid artery. (b) Macroscopic image of a PLCL scaffold.

5. Summary

Mechano-bio systems play an important role to supply advanced devices and equipments for biomedical engineering. For future improvement, it is obvious that micro-nanotechnology plays an important role. Interdisciplinary education as well as research works between engineering, biological and medical fields are promoted.

References

[1] F. Arai, et al., High speed random separation of microobject in microchip by laser manipulator and dielectrophoresis, *Proc. IEEE Micro Electro Mechanical Systems Conf.*, pp. 727–732, 2000.

[2] F. Arai, et al., 3D 6DOF Manipulation of Micro-object Using Laser Trapped Microtool, *Proc. of 2006 IEEE Int'l Conf. on Robotics and Automation*, pp. 1390–1395, 2006.

[3] Y. Yamanishi, Y. C. Lin, F. Arai, Magnetically Modified PDMS Devices for Active Microfluidic Control, *μ-TAS*, pp.883–885, 2007.

[4] D. Azuma, K. Narumi, F. Arai, Fabrication of Articulated Microarm for Endoscsopy by Stacked Microassembly Process (STAMP), *IEEE MHS '08*, Nagoya, Japan, Nov., 2008. (submitted)

[5] T. Uchida, et al., "Development of biodegradable scaffolds based on patient-specific arterial configuration", *J. Biotechnology*, **133**, pp. 213–218, 2008.