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Micro-Nanorobotic Manipulation Systems and
Their Applications

Toshio Fukuda Fumihito Arai Masahiro Nakajima



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《纳米科学与技术》丛书序

在新兴前沿领域的快速发展过程中,及时整理、归纳、出版前沿科学的系统性专著,一直是发达国家在国家层面上推动科学与技术发展的重要手段,是一个国家保持科学技术的领先权和引领作用的重要策略之一。

科学技术的发展和应用,离不开知识的传播:我们从事科学研究,得到了“数据”(论文),这只是“信息”。将相关的大量信息进行整理、分析,使之形成体系并付诸实践,才变成“知识”。信息和知识如果不能交流,就没有用处,所以需要“传播”(出版),这样才能被更多的人“应用”,被更有效地应用,被更准确地应用,知识才能产生更大的社会效益,国家才能在越来越高的水平上发展。所以,数据→信息→知识→传播→应用→效益→发展,这是科学技术推动社会发展的基本流程。其中,知识的传播,无疑具有桥梁的作用。

整个 20 世纪,我国在及时地编辑、归纳、出版各个领域的科学技术前沿的系列专著方面,已经大大地落后于科技发达国家,其中的原因有许多,我认为更主要的是缘于科学文化的习惯不同:中国科学家不习惯去花时间整理和梳理自己所从事的研究领域的知识,将其变成具有系统性的知识结构。所以,很多学科领域的第一本原创性“教科书”,大都来自欧美国家。当然,真正优秀的著作不仅需要花费时间和精力,更重要的是要有自己的学术思想以及对这个学科领域充分把握和高度概括的学术能力。

纳米科技已经成为 21 世纪前沿科学技术的代表领域之一,其对经济和社会发展所产生的潜在影响,已经成为全球关注的焦点。国际纯粹与应用化学联合会(IUPAC)会刊在 2006 年 12 月评论:“现在的发达国家如果不发展纳米科技,今后必将沦为第三世界发展中国家。”因此,世界各国,尤其是科技强国,都将发展纳米科技作为国家战略。

兴起于 20 世纪后期的纳米科技,给我国提供了与科技发达国家同步发展的良好机遇。目前,各国政府都在加大力度出版纳米科技领域的教材、专著以及科普读物。在我国,纳米科技领域尚没有一套能够系统、科学地展现纳米科学技术各个方面前沿进展的系统性专著。因此,国家纳米科学中心与科学出版社共同发起并组织出版《纳米科学与技术》,力求体现本领域出版读物的科学性、准确性和系统性,全面科学地阐述纳米科学技术前沿、基础和应用。本套丛书的出版以高质量、科学性、准确性、系统性、实用性为目标,将涵盖纳米科学技术的所有领域,全面介绍国内外纳米科学技术发展的前沿知识;并长期组织专家撰写、编辑出版下去,为我国

纳米科技各个相关基础学科和技术领域的科技工作者和研究生、本科生等,提供一套重要的参考资料。

这是我们努力实践“科学发展观”思想的一次创新,也是一件利国利民、对国家科学技术发展具有重要意义的大事。感谢科学出版社给我们提供的这个平台,这不仅有助于我国在科研一线工作的高水平科学家逐渐增强归纳、整理和传播知识的主动性(这也是科学研究回馈和服务社会的重要内涵之一),而且有助于培养我国各个领域的人士对前沿科学技术发展的敏感性和兴趣爱好,从而为提高全民科学素养作出贡献。

我谨代表《纳米科学与技术》编委会,感谢为此付出辛勤劳动的作者、编委会委员和出版社的同仁们。

同时希望您,尊贵的读者,如获此书,开卷有益!



中国科学院院长

国家纳米科技指导协调委员会首席科学家

2011年3月于北京

Preface

Micro-Nano robotics and automation technologies have rapidly been grown by associated with growth of Micro and Nanotechnologies. This book represents a summary of principals in micro-nano scale engineering and the current state of art of related technologies.

Currently, in our daily life, "Microtechnology" is commonly used and embedded for various devices and systems, such as automobiles, computer peripheries, printers, cameras, amusements, robotics, automation, environmental monitoring, energy resource, and biological-medical treatments to increase their performance, accuracy and to improve energy consumption, cost performance and so on. "Micromechatronics" came up as the one of the important technology by miniaturizing the elemental devices on sensors, actuators, and computers in micro-scale. Recently, "Nanotechnology" comes up to have an important role in the industrial applications as an advanced field of mechatronics named as "Nanomechatronics".

On the other hand, a manipulation technology enables us to control the small objects locally or individually. For industrial applications, automation technology is important to improve efficiency for the creation of large-scale structural devices from small scale based on the micro-nano manipulation techniques.

In this book, we summarize some major techniques which are related with micro-nano robotics and micro-nano manipulation technologies, such especially micro-nano fabrication, micro-nano assembly, micro-nano control techniques, micro-nano materials, micro-nano evaluation techniques and so on. It is Various devices are investigated based on the micro-nano mechatronics technologies to realize high-efficiency, high-integration, high-functionality, low-energy consumption, low-cost, miniature, saving material usage and so on.

One of the application field is the "system cell engineering" which is a new a new academic field aiming at synthetic understanding of cell function using engineering (Fig. 1). The manipulation techniques are one of the key factors to analyze/control to reveal the functions of biological cell system. Recently, the research direction is moving to synthesis from analysis of biological cells based on the system cell engineering.

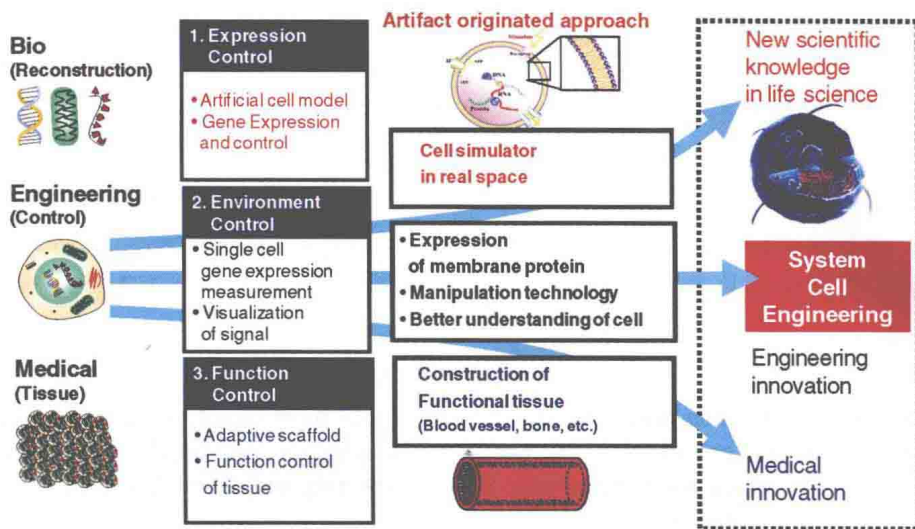


Fig. 1 System Cell Engineering by Micro-Nano Robotics and Automation

Through the micro-nano robotics and automation technologies, various research fields are investigated to achieve the next-generation science and engineering applications as shown in Fig. 2. In robotics field, the soft and wet robotics is key technology to mimic the biological system or combine the biological and artificial systems for example. The importance of micro-nano manipulation is that this technology is placed on the borderline between bottom-up and top-down fabrication and assembly technologies as shown in Fig. 3.

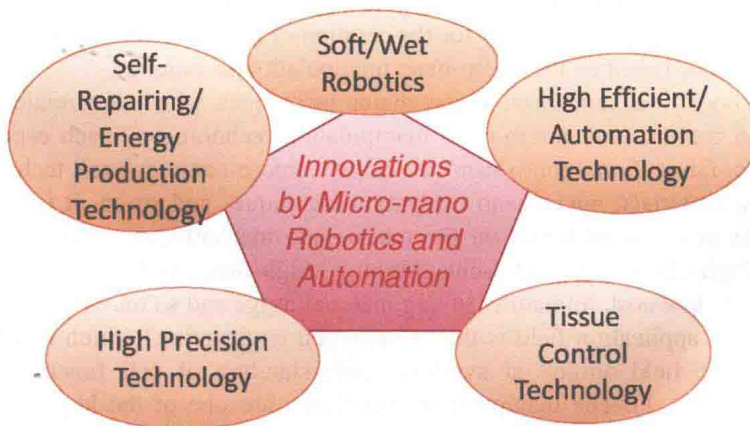


Fig. 2 Innovations by micro-nano robotics and automation

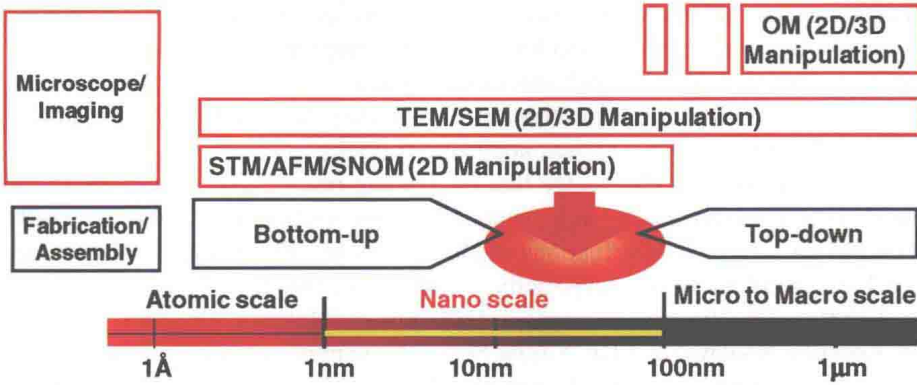


Fig. 3 Micro-Nanomanipulation based on imaging technologies for micro-nano fabrication and micro-nano assembly

In this book, we introduce the advanced technology from the basics and applications aspects of micro-nanorobotic manipulation system with their applications and related technologies. This book is organized as follows:

In Chapter 1, we introduce the overview and introduction of micro-nanorobotics and manipulation technology with some historical background and current achievements with related works.

In Chapter 2, the physics in micro-nano fields is explained in the scaling effects, mechanics, electronics, fluidics, surface interaction, and optical physics.

In Chapter 3, the related technologies in micro-nano scale are explained about the material and science, microscopes, fabrication technology, sensing and actuation, control techniques, and assembly techniques.

In Chapter 4, bio-manipulation system under optical microscope is explained under optical microscope by on-chip micro-fluidics devices, micro-tools, and laser micro-nano manipulations.

In Chapter 5, a rotational speed control of single bacterial flagellar motor is introduces as one of the applications of micromanipulation system under optical microscope.

In Chapter 6, nanomanipulation system is introduced under electron microscopes, with configurations of nano-robotics and manipulation system, hybrid nanorobotic manipulation system inside FE-SEM/TEM, nanorobotic manipulation system inside E-SEM, nano-tool exchanger system under hybrid microscope, automation of nanorobotic manipulation system inside E-SEM.

In Chapter 7, measurement, manipulation, and assembly of carbon nanotubes are explained under FE-SEM and TEM based on the nanomanipulation system. The techniques of picking up, cutting, peeling, bending, fixing of carbon nanotubes are presented as one of the applications of nanomanipulation system under optical microscope.

In Chapter 8, measurement and analysis of biological cells are explained under E-SEM for single cell nano-surgery system, especially mechanical property

characterization, adhesion force measurement, electrical measurement, and cutting of single cell using various nano-tools such as nanoprobe/ nanofork/ nanoputter/ nanopicker/ dual nanoprobe with automation system.

In Chapter 9, we give a description of summary and applications of micro-nanorobotic manipulation and their applications finally.

We would like to acknowledge that the leading researchers extensively in the world to evolve the micro-nanomanipulation and related fields. We especially thanks to the excellent contributions of all students graduated from our laboratory to achieve fabulous results, especially for Dr. Lixin Dong, Dr. Ahmad Ridzuan, Dr. Liu Pou, Dr. Hisataka Maruyama, Dr. Akihiko Ichikawa, Dr. Akiko Kawaji, Dr. Kousuke Nogawa, and Dr. Yajing Shen. We express our sincere appreciation for the publication of this book supported by Nagoya University, the 21st COE program "Micro- and Nano- Mechatronics for Information-Based Society", and the global COE program "COE for Education and Research of Micro-Nano Mechatronics". This book would not have been possible without these generous supports.

Nagoya, January 2012

Toshio Fukuda
Fumihito Arai
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