Creative Designs for Microfabricated Information-Processing and Medical Equipment

Masayuki Nakao
Professor,
Engineering Research Institute, Faculty of Engineering, the University of Tokyo

Forming teams with professional designers and researchers of different fields in our laboratory, we ascertain functions required in new devices and design microfabrication methods for achieving those functions. Primarily, we are targeting fields of information-processing and medical equipment by applying many microfabrication techniques aimed at concocting new and creative prototypes through repeated attempts and failures. In these attempts, we develop an upper level concept based on a designer's thinking process diagram and accumulate the results as explicit knowledge, as defined in knowledge management. When failures occur, we take up the situation at the occurrence of the failure in order to get further use from the design attempt as a case study on design failure. In short, by conducting creative designing alone without imitating others, we can obtain the most thorough research data without regard for success and failure of the research.

In our research laboratory, we use so-called micromachine manufacturing technologies without thinking of them as new techniques, but rather as potential manufacturing methods as obvious as cutting, casting, and other age-old technologies. Micromachine technology has been present in Japan for more than a decade and now enjoys widespread use. However, in the future I believe we must bring micromachine experts together with experts of conventional mechanical engineering. People desire products, not manufacturing techniques. I do not believe the public cares what methods are used to create a product, providing the required functions are achieved.

Here, I introduce methods of assembly and reproduction only attempted by a few researchers in shaping processes.

The right diagram in Fig. 1 shows a micro-house that has appeared many times on television and in newspaper articles. While we have accumulated many other achievements in our laboratory besides this and have made painstaking efforts to describe them to media personnel, the media still focuses only on the micro-house. Perhaps this is because the micro-house can be readily understood just by looking at it and does not require a complex technical explanation. However, it took four years to be able to develop this micro-house. As shown in the left diagram, the micro-house is assembled and bonded under a scanning electron microscope using an electrostatic tool having

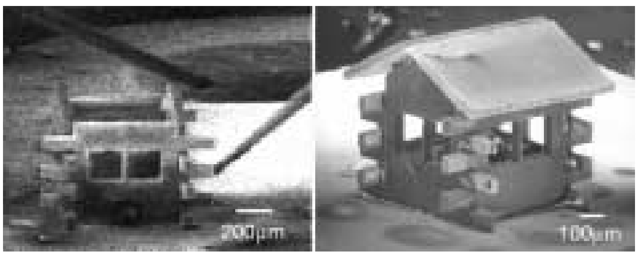

Fig.1 Manufacturing a micro-house

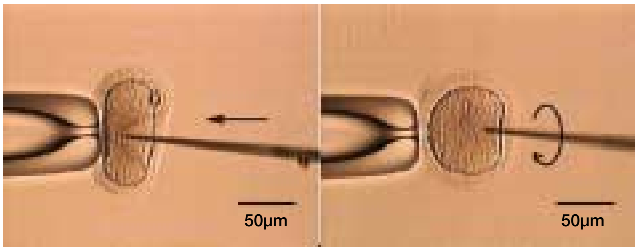

Fig.2 Micro-insemination employing rotation (right)

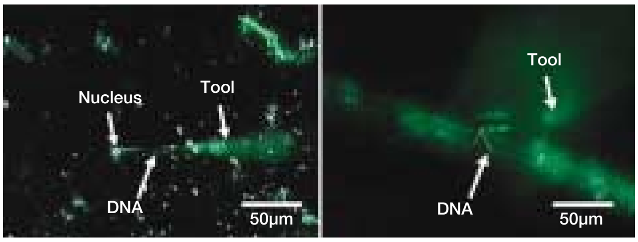

Fig.3 Handling DNA

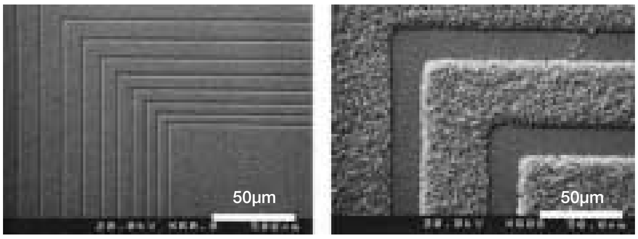

Fig.4 Microchannel press-molded on a glass substrate

a diameter of 15μm and a semiconductor laser with an output of 1.6 W that are moved with a total of 20 degrees-of-freedom.

While, in an engineering sense, the micro-house can be created if one has a mind to, such construction is not a profitable enterprise. Since the microassembly of cell phone components and magnetic heads has less than one cent of added value, it is obviously more advantageous to have the work performed by cheap laborers with 20/20 vision.

However, there exists some microassembly work that has an added value of more than one-hundred dollars, such as work in biotechnology including the micro-insemination of sperm, electrical stimulation of specific cells, and isolated cultivation of specific chromosomes. The right diagram in Fig. 2 shows an operation of introducing sperm into the cell membrane of an ovum while the tool is rotated. The left diagram shows the same operation performed by simply pushing in with the tool. Here, the ovum deforms much more than that in the right diagram, risking injury to the DNA. Fig. 3 illustrates an operation of extracting DNA from a chromosome, then isolating, stretching, and cutting the DNA strands. While DNA strands 2 nm in diameter are flowed, fluorescent molecules are attached to

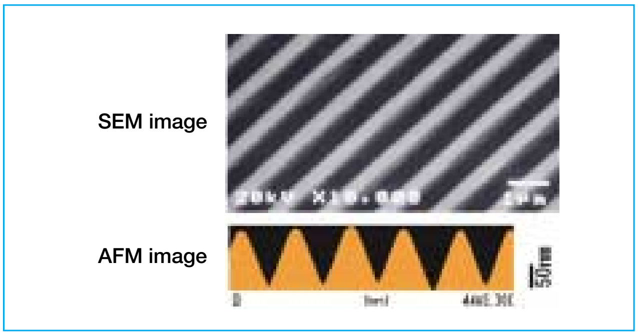

Fig.5 Triangular grooves formed through polystyrene injection molding

specific parts of the DNA, then a DNA strand is handled briefly relying on the fluorescent light. This type of microassembly can be achieved with the proper micro-tools.

Next, I will describe reproduction assembly. Fig. 4 shows an L-letter patterned groove having a width of 20μm and a depth of 2μm that is reproduced by press-molding on glass. After masking a carbide die with resist, the die is formed by blasting and reproduced to the glass under a temperature of 530℃. Fig. 5 shows triangular grooves formed at a pitch of 1μm by injection molding on plastic. To obtain an accurate reproduction, we pressed only on the core portion of the triangular groove twice using a piezo element. Hence, it is possible to accurately reproduce a micro-shape, such as a groove, up to about a 30-nm width.

However, the problem is attempting to reproduce a workpiece several millimeters square without bending the workpiece. Wavefront aberrations are a problem in optics. For example, a 20-nm flatness and parallelism is necessary in a 2-mm square diffraction grating. In this case, it is not enough simply to create the micro-shape of the die, but also it is necessary to analyze physical phenomena that occur during the reproduction and to control cooling and the distribution of pressure and deformation to prevent residual stress.

In addition to assembly and reproduction, other general methods of shape formation include removal, addition, and deformation. I believe that methods of shape formation, such as "growth" known in reproductive medicine will emerge from nanotechnology in the future. At that time, we will be able to produce anything by preparing the proper DNA father and culture medium mother. Perhaps this is what has conventional designers paralyzed with fear.

MMC Activities

The 7th International Micromachine Symposium

The 7th International Micromachine Symposium was held at the Science Museum in Kitanomaru Park, Tokyo, on October 31 and November 1, 2001.

On the first day, the symposium program began with an opening address by Mr. Toshiro Shimoyama, Chairman of the Micromachine Center, followed by guest speeches by Mr. Iwao Okamoto, Director-General of the Manufacturing Industries Bureau, METI, and Mr. Keiichi Aoyagi, Executive Director of NEDO with words of expectation to micromachine technology and encouragement for the efforts to concerned persons.

The symposium was very successful, despite the participants from overseas were greatly reduced as a result of the September 11 terrorist attacks in New York. The venue packed with participants to almost full capacity on both days,total participants for the two-day program numbered 380, including 267 registered participants, presenters, and members of the press.

On the first day, Prof. Fumio Kodama of The University of Tokyo Research Center for Advanced Economic Engineering gave a special lecture entitled "Micromachine and Business Model," exploring the topic which is currently of greatest interest to those within the industry.

Other program items on the first day included sessions entitled "The Path to Micromachine Industries in the 21st Century," "Overseas Activities," "Innovative R&D," and "Micromachine in the Last Decade and Future Outlook". A total of 16 invited lecturers, including 4 from abroad, made presentations during these sessions.

The second day of the program began with a speech by Mr. Yukihiro Hata, Director- General of the Industrial Technology Development Department of NEDO. After this, researchers representing 23 enterprises and organizations that had participated in the "Micromachine Technology Project" (completed in March 2001) - part of the Industrial Science and Technology Frontier Program by MITI- each presented the results of their team's research results, as a summary of the project.

The scheduling and content of the presentations in this symposium were regarded highly by participants, as showed by the comments for the questionnaires submitted after the of the entire program.

The schedule for the next symposium is shown below.

The 8th International Micromachine Symposium
Period: November 14 (Thu), 2002
Place: Science Hall, the Science Museum in Kitanomaru Park, Tokyo

View of Symposium Hall