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MICROMACHINE CENTER

MICROMACHINE

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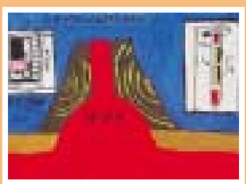

MICROMACHINE CENTER

No 38

New Year's Greeting

Iwao Okamoto
Director-General,
Manufacturing Industries Bureau, Ministry of Economy, Trade and Industry

I am very pleased to welcome you all to the New Year, 2002.

Looking back over the past year, the opening year of the 21st Century can only be described as a turbulent one. Despite of all the somber news, such as the simultaneous terrorist attacks on America and the outbreak of Mad Cow Disease in Japan, there was also much encouraging and cheerful news, including the birth of Princess Aiko, the success of baseball player Ichiro in America, and the awarding of the Nobel Prize in Chemistry to Dr. Ryoji Noyori, who became the second successive Japanese winner after Dr. Hideki Shirakawa.

With the effects of the IT recession in America and the terrorist attacks added to the problem of Japan's slumping economy, Japan is now facing fears of deflation, a deteriorating employment situation, and the problem of disposing massive amounts of bad loans. In light of this situation, the administration has come together to incorporate a series of structural reforms however, manufacturing industries are primarily concerned about the rapid shifting of production bases overseas, or what could be called the "second hollowing of industry." Manufacturing industries account for one-fourth of Japan's GDP, while foreign acquisition from their exports forms the heart of a processing trade country. Moreover, manufacturing industries comprise more than 90% of private R&D resources and industrial technologies cannot be developed when isolated from the manufacturer's worksite. Therefore, manufacturing industries literally make up the foundation of a country that creates science and technology. One after another, these industries have been shifting production bases to China, which has held a great attraction recently due to its low business costs and rapid market growth. Moreover, recent events have taken on a new aspect in the hollowing of industrial roots, wherein factories shifted overseas include not only those producing the finished product, but also those involved in parts and raw materials.

Last November Minister Hiranuma organized a conference to discuss strategies of industrial competitiveness. The principle themes evolving from this conference that we are considering for future studies are to review the exchange rate with the Chinese yuan, improve productivity through further selection and concentration of management resources, improve business efficiency through applications of IT, promote the development of industrial technology and improve strategies for intelligent properties, correct high-cost structures, and further diversify foreign trade strategies that include the WTO and FTA.

The Manufacturing Industries Bureau intends to participate actively in a series of discussions, while coming into direct contact with people in the industrial world to get their unreserved opinions. To mark the beginning of the new year, I would like to emphasize the following two points from this standpoint.

The first point is to further intensify efforts at selecting and concentrating management resources, not just in individual firms, but also as far as industrial restructuring. While it was encouraging to see great progress made in the steel and chemical industries last year, we hope to search for more potential in a wider range of fields. It goes without saying that firms interested in integrating and merging businesses should be entrusted to make their own management decisions. However, I believe that it is becoming increasingly urgent to decrease costs while investing bundled resources into strategic business areas, including R&D. As a branch of the government, we intend to push a series of reforms on corporate legislation and taxation and the constitution the industrial revitalization law to create a better environment for enabling related firms to reconstruct their businesses. We also intend to support the efforts of everyone in performing the correct operations.

Secondly, is it not time to shift toward "grow" in the "shrink to grow" philosophy? Everyone in the industrial world has strived these past few years to incorporate restructuring during our lingering recession even with the stiff international competition. Under the philosophy "shrink to grow," we were to endure many hardships of restructuring in order to establish a foundation from which we could build on for tomorrow. Creating demand through innovation is even more necessary now that demand is low throughout Japan's entire economy. In order to combat the hollowing of industry, I believe that we must develop products and processes a step or two ahead of China and other countries and put these results in operation domestically as a standard approach. I am confident that our manufacturing industries possess the potential to become a central leader in innovation. Is this not the time to move toward growth by accelerating R&D investments in order to boldly implement existing seeds and search for future seeds?

To achieve this, I think we must seriously investigate the expansion of government support for R&D investments, restoring financial intermediation functions of banks and the like, and maintaining the capital market. Do we need to reevaluate this viewpoint of marketing workers given only to shrink, i.e. reducing the number of employees to such and such a number and the balance of interest-bearing debt to such and such dollars? What about the views of managers reluctant to shift to a strategy of growth in accordance with this viewpoint? While realizing that it is not easy to shift toward growth when considering the current business situation of progressing deflation and the problem of bad debts, could we ever expect to emerge from this deflationary depression, during this type of period, if all economic players moved in a direction toward diminishing equilibrium? It is my fervent hope that this year we will find bright spots in these dark times and have as many chances as possible to discuss the way to act on them positively and aggressively.

In conclusion, I would like to wish you happiness in all of your endeavors in 2002. Happy New Year!

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 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.

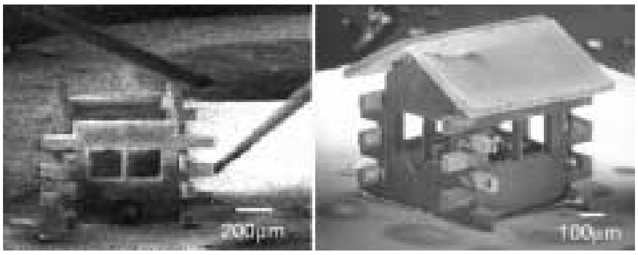

Fig.1 Manufacturing a micro-house

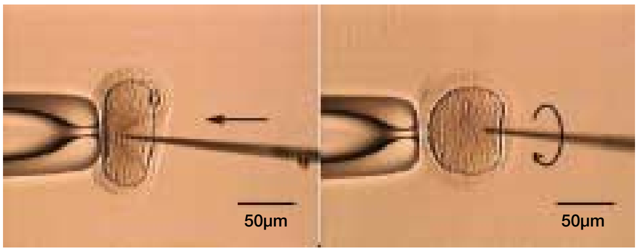

Fig.2 Micro-insemination employing rotation (right)

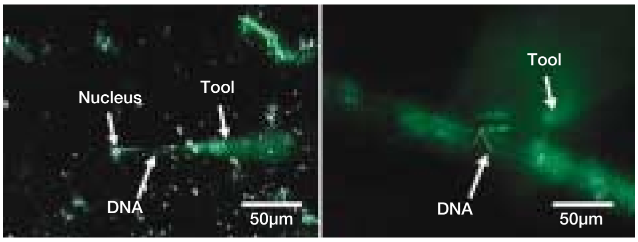

Fig.3 Handling DNA

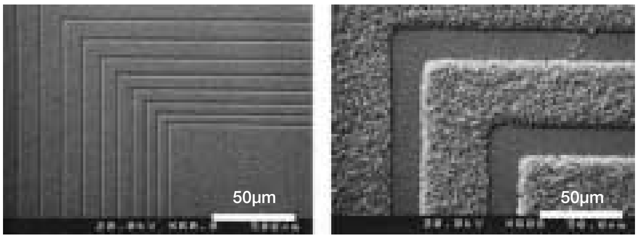

Fig.4 Microchannel press-molded on a glass substrate

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

SEM image

AFM image

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

Micromachines and Business Models

Fumio Kodama
Professor,
Research Center for Advanced Economic Engineering, The University of Tokyo

Introduction

Thank you for the introduction. I am Fumio Kodama. Today I would like to focus my discussion on two topics: micromachines and business models. You are probably thinking that I am drawing a connection between two wholly unrelated terms. Well, I believe I have been associated with the Micromachine Center now more than five years, where experts in many fields are tackling various technical issues related to micromachines, and questions on demand forecasts, economic effects, and so forth have eventually found their way to me.

If you think back to five years ago, it was extremely difficult at that time to scientifically analyze potential markets for this type of technology. At first we tried to predict new markets, and by doing so came up with some sort of statistics, but the grounds for these numbers were somewhat dubious. We wondered if considering only new markets was enough. Then we wondered if we should consider the creation of new industries and begin to look at the relationships of these new industries, which became a popular buzzword at that time. While all this seemed to look good on paper, in fact it was extremely difficult to analyze.

While I realize that there are many types of micromachines, I believe that by considering them as basically element technologies we can look at their various uses, particularly new uses. Therefore, we considered the development of new uses, even though we did not know whether they would actually be used as such. Essentially it is necessary to link these uses with a system of use that can be established as a business. Or assuming this micromachine technology is of tremendous proportions, we must create a separate business model. However, the term business model sounded very small. We wanted a business model for establishing an industry. So ultimately we began creating peculiar terms, such as "industrial business model," resulting in the title of my presentation, "Micromachines and Business Models." This information is described in much more detail in our report, which is the result of experts in various fields joining forces to analyze each sector of the market. But rather than describing that here, I think you would understand it much quicker by reading the report.

Today I would like to talk about the background and process at which we arrived at the conclusion described earlier, through much trial and error, namely that it is necessary to create a business model. As one might expect, great changes in the direction of technological innovation occurred during this process. We see many changes particularly in technological innovation and the generation of industries, or the industrial structure. Alternatively, the creation of industries changes the industrial structure, causing the direction of technological innovation to change. I believe there is a strong interaction between innovation and the industrial structure. Today I would like to tell you about our research findings and views on this topic.

Micromachine Systems

The reasons why Japan could create a new industry and take control of its creation, and why Japan is regarded as the home of micromachines is due to the "mechatronics revolution" in the background. In fact, the word "mechatronics" was coined by a Japanese, which leads one to believe that Japan seized the initiative in this technological revolution. The essence of mechatronics and optoelectronics is the skillful combination of technologies thought to be of completely different types belonging to different fields for the purpose of exhibiting effects greater than the combination of its parts. In this sense, we created a new concept called "technology fusion," meaning the combining of different technologies.

Hence, technologies have advanced in this pattern. While industries had been progressing in a direction that emphasized total integration, the PC revolution brought about a state in which a manufacturer supplying a single element called a microprocessor unit, specifically Intel, has taken complete control of all industries. By looking at this situation, however, I believe a major change has occurred in technologies; in other words, a phenomenon called digital convergence has progressed. Digital convergence is a phenomenon peculiar to the PC industry. With the advance of modularization, module suppliers seized leadership in technological development, and final products are obtained by combining these modules. This is what has occurred in the PC industry.

While there are varied opinions on whether this phenomenon has occurred in the mechanical industry as well, indeed we can find the same phenomenon by looking at the automotive industry and the like. There are some differences in how the progression of this phenomenon is occurring in the automotive industry from how it is progressing in the PC industry, but modularization is also taking hold in mechanical systems. Accordingly, the term micromachine-based system was coined when considering the micromachine market to mean a new system based on micromachines. Much research has been conducted under the belief that it would be better to consider things under that system.

Hence, the idea is to predict the future. For example, if we tried to predict what will occur in the year 2010 and the year 2025, we know that while the current pattern may hold through 2010, it is almost impossible to predict what will happen in 2025 without considering a completely different type of usage pattern. Business models are used to consider new industries that use micromachines.

Technology Fusion

To begin with, "mechatronics revolution" is a term coined by a Japanese person in 1975. There was another significant movement occurring at this time. Despite a steady increase in Japan's competitiveness in the international market, doubts were raised at this time concerning what original contributions Japan had made. The U.S. administration in particular initiated several comparative studies to determine which country had the most technological innovativeness. The first study, called the Gellman Survey, evaluated the innovativeness of each country. The method of this survey was to list one hundred examples of radical breakthroughs in technology over the period from 1953 to 1973 and determine which countries brought about these breakthroughs. America was responsible for 65, Japan for a mere 2, and England for 25. Hence, although Japan's competitiveness in the market was strong, from the viewpoint of radical breakthroughs it was responsible for only 2 of 100, leading to the conclusion that Japan is merely a country that imitates.

With the purpose of conducting a slightly more objective survey, Francis Narin was commissioned to conduct a survey in which he stored all patents registered in America between 1975 and 1985 in a database. When checking the percentage of patents for each country, Japan's share had increased steadily during this period. Japan clearly demonstrated enormous strength in high-tech oriented patents. When looking at the quality of patents at this time, it was found that the U.S. carefully manages citations of patents. All citations were fully listed on the front page of each patent. By using this data, it was possible to determine how many patents cite a particular patent. If a patent is cited numerous times, that patent can be viewed as a basic technology. The chance of patents submitted by Americans being in the most cited patent group, for example the top ten percent, was completely random. It turns out that, rather than being completely random, patents published by Japanese had a higher probability, by 37 percent, of belonging to the most cited patent group. Hence, many patents filed by Japanese belonged to the patent group that is most frequently cited, thereby making them basic technologies. As a result, in only ten years, Japan jumped from the bottom rung in the Gellman Survey to the very top rung in the Narin Survey.

It is conceivable here that this came about due to a new technological concept. I think this is basically due to the mechatronics revolution. For example, Japan began in fourth place in the number of machine tools manufactured and jumped to an overwhelming first place in just ten years. As you are aware, such a large change in only ten years was brought about by the great progress made in the numerical control of machine tools. Hence, Japan made this great jump due to the advance of the mechatronics revolution.

Optoelectronics is a term for a similar technology, also formed by fusing different technologies. In 1986 Fortune magazine published a scoreboard indicating which countries were the strongest in various fields. As you can imagine, the U.S. was the top in most fields, but Japan was stronger in one: optoelectronics. Japan had 9.5 points to America's 7.8, a difference that cannot be ignored. While we found a major change over a ten-year period when evaluating the quality of patents earlier, behind this change there has emerged new technological concepts called mechatronics and optoelectronics that conceivably brought about this change. I propose that we combine these conceptions into the term "technology fusion." Technology fusion is not simply the combination of different technologies, but rather the addition of one technology to another to provide a solution greater than the sum of its parts. In other words, one plus one equals three. This I have cited from the Harvard Business Review, a magazine written for business managers, which emphasized in rather severe language that this is a new concept.

Modularization

Subsequently, considerable changes occurred. Around 1980, for example, the computer industry was composed of vertically integrated firms. Companies like IBM, TEC, Fujitsu, and NEC were competing with each other making their own chips, their own platforms, their own software, and their own applications, and selling them at their own distribution outlets. Hence, the industry had an extremely vertically integrated structure.

Around 1995, the industry shifted to a horizontal competition. Intel and Motorola were competing in the silicon industry; Sharp, NEC, and DTI in the matrix display field; and so on. Great changes in the industrial structure occurred when computer manufacturers began to obtain various components and combine them. In 1999 Newsweek magazine did a feature asking experts what they felt the major changes of the next century would be. I was also interviewed, at which time I commented that it is not easy to link things in the analog world, while things can be joined in every possible combination in the digital world, demonstrating results greater than the sum of their parts. Hence, digitization has come charging into the current age, I commented, and we will see a change from technology fusion to digital convergence.

In my laboratory, we attempted to measure how much modularization had developed. While there may be several methods for measuring this, ours was to search patent applications on a patent database called PATORIS for four different computer fields: CPUs, memory, discs, and I/O devices. We measured the percentage of patent applications filed to determine how much leadership the assemblers (not component suppliers) had seized in the technological development of each field. The assembler shares in each field had all dropped, indicating that modularization has progressed in the personal computer field, shifting control of technological development to the individual module providers. This shift reflects the change in industrial structure indicated above from a vertical to a horizontal structure.

Many in the mechanical industry felt that compromise between companies was necessary and that modularization would not be easy to implement. We attempted the same analysis on the automotive industry. We divided up control-related areas of the automotive industry into four fields, checked the patent filing percentage for each and measured the ratio of automotive assembly manufacturers, or so-called automobile manufacturers, therein. While the trends here were slightly complex, we divided the industry into four fields: engines, chassis, safety systems, and communication systems including navigation. Although the share of automotive assemblers rose in most fields up to around 1980, they all dropped in the 1990s. Hence, we must acknowledge that modularization had progressed. While all fields in personal computers dropped, there were some differences in the mechanical industries. Only one field, engines, rose in the automotive field. We can say that the proportion of automotive manufacturers in engine control increased, that is, their leadership strengthened - a trend different from the personal computer manufacturers.

In general terms, I believe that the promotion of modularization is electronification. Determining the share of production volume for electronic control units in the overall production of parts of each automotive field and determining how much weight each has in terms of monetary value is one index for indicating how much digitization and electronification has advanced in each field. Based on this index, we learned that digitization in the field of engine control has not advanced, or rather is in a declining trend. Since the ratio of patent applications supplied from automotive manufactures has risen slightly in the category of engines only, the strategy of automobile manufacturers is being watched. This strategy is reflected in the pattern of concentrating all efforts in developing engines and outsourcing parts in other fields as much as possible. As a result, modularization in the automotive industry is advancing.

Generally speaking, modularization is also advancing in mechanical industries. Hence, if micromachines are provided in modules, it is sufficient to simply consider the design of the overall system. So what type of strategy do we use? Two scholars that popularized the term "core competence" say this strategy comes in the form of first acquiring the necessary technologies, integrating these technologies, and then competing for the core intermediate product. Ultimately the intention is to maximize shares in the final end product. An example of this strategy was adopted by Canon, and maybe some of the people related to this project are here today. Canon even sells laser printer engines to its competitors, including Apple. Ultimately they sold their core product to competitors in order to obtain a larger market share in the field. "Virtual market share" is a term being used today. This is a competitive strategy for controlling the entire market by seizing the initiative in module development, as modularization increases.

Creating a Business Model

So what strategies will be used for micromachine technology? Micromachines should be thought of as core components of systems rather than core products. Therefore, I think that the problem lies not in the end product, but in how systems can skillfully use inventive micromachines, in other words, how micromachines can be used in a virtual system. Hence, we considered micromachine-based systems or systems of use that are only possible with micromachines. Actually, two years ago I spoke at this very symposium on "Micromachines and the Market," and today I am talking to you about "Micromachines and Business Models," so I have progressed a little. This table lists the ideas that we came up with at our research conference (see Table 1). Experts in various fields came up with the details, so I believe the table is reliable. We considered, for example, data storage systems, printing systems, optical communication systems, wearable systems, and micro-inspection systems. Regarding printing systems, we

Industries	Micromachine-based systems
Information Technology	Data-storage system Printing system
IT Infrastructure	Optical communication system
Precision Instrument	Wearable system
Measurement Instrument	Micro inspection system
Micro Factory	Micro factory system
Maintenance	Maintenance system
Medical and Health	Medical Endoscope and catheter system Personal health support system
Bio Technology	Genetic and DNA analysis system
Environment	Environmental inspection system
Automotive applications	Automotive related system
Life and Household	Electric household appliances system

Table 1 Micromachine-based Systems

viewed the development of new printers as an opportunity. We could come up with various wearable systems, but here we will take up cellular telephones. Therefore, we selected printers and cellular phones and then quantitatively analyzed what form of market had been created, what industries had been created, their differences, whether they were a new type of usage, or what part they played in the creation of a business model.

Specifically, while the facsimile machine was a substitute for conventional communication means, a liquid crystal display (LCD) expanded the number of applications. As you know, the PC of today began from a computer and later a word processor, and then was developed with a new use as an Internet terminal. Clearly, we can say that a business model had been developed. I would like to study each of these technologies in more detail. As you know, a logistic model is used to determine how large a new market has grown. Over time, the size of the market (production volume) approaches an upper limit, that is, an ultimate potential demand. This is a substitute market, wherein a new product is used as a substitute for an existing conventional function.

We can also consider the occurrence of an extremely major technological invention that greatly expands the scope of users. Since the logistics of this scenario take place in two stages, its model is called a two-stage logistic model. As the market size of the product nears an upper limit during a certain time period, a major technological innovation occurs, causing the market size to leap suddenly. The printer is one example that comes to mind immediately. Inkjet, bubble jet, or laser printers and particular inkjet are a good example of a product designed for office use that suddenly became useful in the home, and moreover could print photos or other pictures. Instead of just printing conventional text, it is now conceivable to print pictures.

Next is an example of the upper limit itself growing according to a logistic function. This is called a double logistic model. In short, new usages are being created constantly, increasing the production volume more and more. The cellular telephone fits this description, in which new business models were created continuously.

We talked about analyzing each one individually. The facsimile is a simple logistic model in which the production number approaches a fixed value. Printers follow more of a two-stage logistic curve. As you know, printers were used to print characters and were limited to use in the office. However, laser and inkjet printers came out around the mid-80s. At the same time, printing precision improved and the ability to print in color was also added, clearly causing production to jump a step.

If we assert that micromachine-based systems will create new business models, I think they must continually create new business models. A very recent example that follows the double logistic curve can be seen if we look at the actual production data for cellular telephones. In other words, the upper limit is increasing constantly and the market size is continually expanding. In a sense, I suppose business models are also constantly being created.

Conclusion

At the research conference, we studied various micromachine-based systems, such as printers using micromachines. We considered a business model of on-demand printer systems that can be used in the home and print when the user requests it (see Fig. 1). Next, we considered a business model for order made printer systems in 2025, wherein users can custom order printers with a desired design and shape and the capability of printing on anything, not just paper. The members at the research conference considered what systems would be necessary to achieve this and what technologies must be developed. When considering future technological development, the members concluded that it would be beneficial to promote the development of micromachine technology in particular, which is capable of changing the world. Such being the case, if you can imagine an industrial business model, such as that shown in Fig. 2, extract the technological issues from this model and attempt to resolve them, I believe that there is potential and validity in taking that future direction. Thank you all for your attention today.

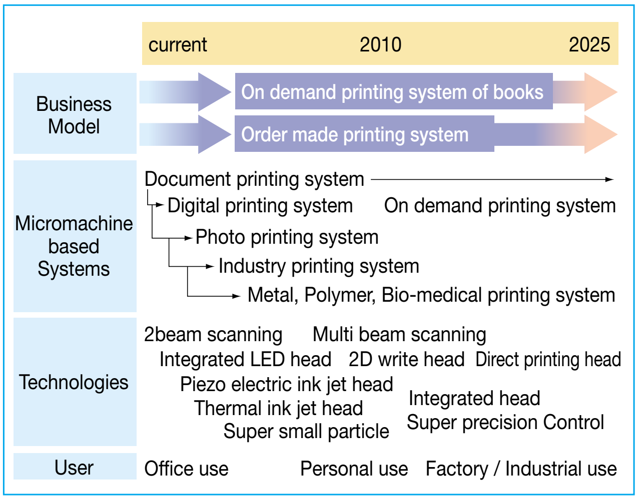

Fig.1 Micromachine Technologies for Printer Systems

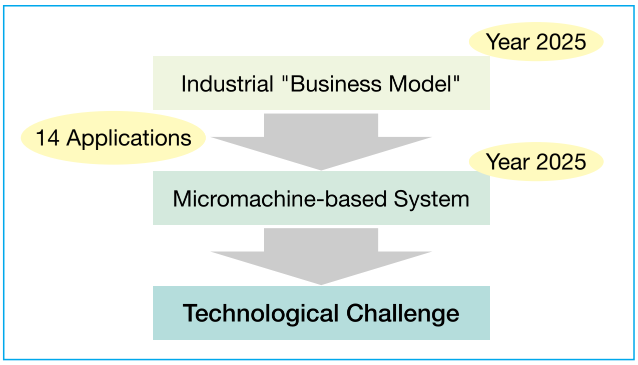

Fig.2 What is technological innovation in future?

Fuji Electric Co., Ltd.

Akira Takai
General Manager
Corporate Technology Planning Office and Corporate R&D Center

1. The Challenge of Micromachine Technology

Micromachine technology at Fuji Electric Co., Ltd. began with the development of sensors. Examples of our current products include accelerometers for activating automobile airbags, pressure sensors for plant monitoring, and gas leakage sensors for domestic use.

In a government research program called "Research on Hazardous Environment Robots," we developed 3-axis tactile sensors to be fitted in the fingertips of robots. Here, multiple micromachined strain sensors are mounted on a silicon substrate to detect three-dimensional force components. Robots equipped with these sensors are now able to grip soft objects, like a rubber ball.

2. Development of Micromachine Technology

Fuji Electric Co., Ltd. took part in the Micromachine Technology Project of the Industrial Science and Technology Frontier (ISTF) Program from the beginning, studying primarily the manufacture of micro-actuators. In Phase I of the project that began in FY 1991, we pursued the feasibility of such micro-actuators as an electromagnetic motor with a rotor diameter of just 1 mm.

Phase II, which began in FY 1996, saw seven companies collaborate to develop a "microfactory." The microfactory was an attempt at extreme size-reduction of manufacturing equipment, shrinking processing and assembly units to fit into a space about the size of a desktop. In Phase II, we were responsible for a two-dimensional micro-conveyor used to convey parts and finished products between operating units.

Fig. 1 shows an external view of the micro-conveyor, the surface of which is lined with square coils having a side length of 1 mm. By controlling an electric current supplied to each coil separately, it is possible to move a carrier with a permanent magnet in a desired direction.

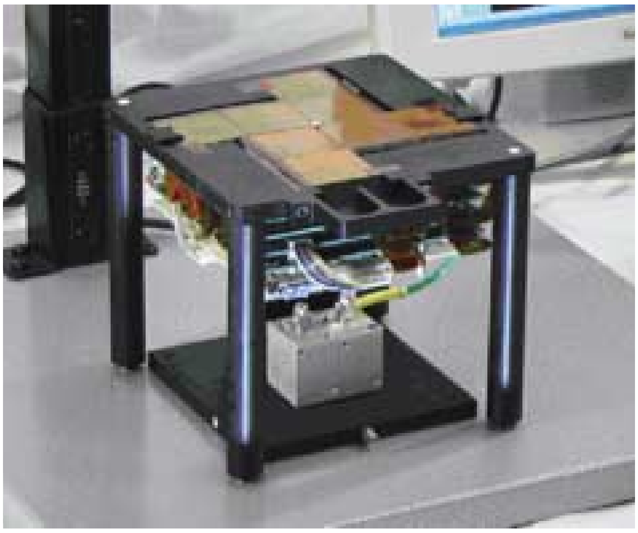

Fig.1 Micro-conveyor

3. Future Stance

While achievements from the ten-year ISTF Program range from actuator driving technology to micromachining/assembling technology, thin-film formation technology, and material technologies, we consider thin-film technology and micromachining technology to be the most promising areas for future development. In addition to actuators, we expect these technologies will be applied to a wide range of products, including sensors and electronic parts.

Fig. 2 shows a thin-film coil having sides 4 mm in length directly formed on the surface of an IC using thin-film formation technology. This process will be useful in manufacturing smaller power sources for portable equipment. In this way, we hope to apply technologies cultivated in the Micromachine Technology Project in the development of many products.

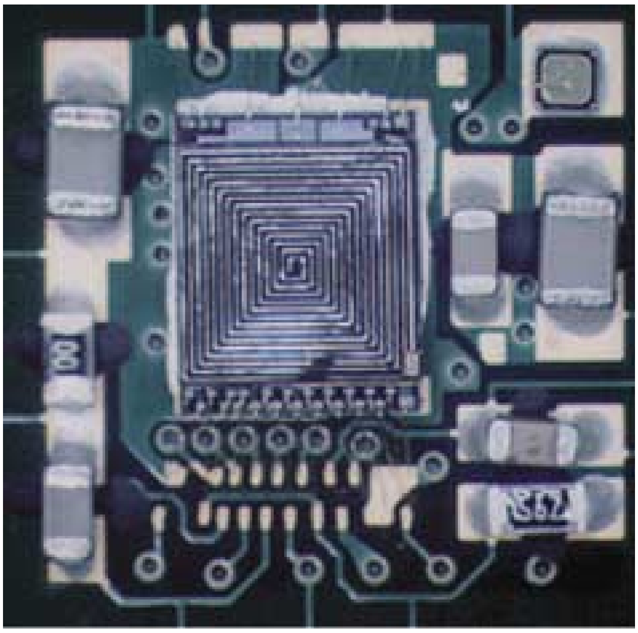

Fig.2 Thin-film coil formed on an IC (4x4 mm)

Matsushita Electric Industrial Co., Ltd.

Masaaki Adachi
Director
Advanced Technology Research Laboratories

1. Endeavors in Micromachine Technology

Matsushita Electric Industrial Co., Ltd. has been working toward establishing design technologies for micromechanisms, as well as micromachining, assembly, and evaluation techniques to cope with the increasing integration and size-reduction of information-processing equipment. We participated in the Industrial Science and Technology Frontier (ISTF) Program by conducting research on the system integration of travelling devices.

2. Development of Micromachine Technology

A travelling device developed by Matsushita Electric Industrial Co., Ltd. (Fig. 1) implements locomotive functions by rapidly decelerating the high-speed rotations (40,000 rpm) of a motor and increasing torque. We developed micromachine base and system integration technologies for developing micromechanisms by applying these integrated functions to a chain-type micromachine system for inspection of outer tube surfaces in cooperation with Mitsubishi Electric Corporation and Sumitomo Electric Industries, Ltd. In particular, we developed such element technologies as mechanical interfacing (a design technology for micromechanisms that involves tribology), high-precision micromachining and measuring technologies, and high-precision assembly technology. We manufactured numerous uniform micromachine parts, assembled reducers, and worked to achieve a low loss in drive trains.

Mechanical interfacing is a technology for improving performance through studying reduction methods and improving the contact surfaces of components in order to develop a reducer suitable for use in micro-spaces. We succeeded in developing a reducer with a reduction ratio of 1/200 and a size of 5 x 3.5 x 1.5 mm based on the planetary gear system (Fig. 2) constructed of a micro-gear in a 0.03 module. We attempted to improve the drive train efficiency by studying the bearing construction and improving the surface quality to decrease the friction coefficient and wear of the gear.

High-precision micromachining, measuring, and assembly are technologies for efficiently processing and assembling numerous microparts and with great precision and uniformity. By developing a more sophisticated form of electric discharge micromachining, we can reliably supply many microparts for constructing travelling devices. In our attempts to further improve precision in machining, we demonstrated the value of a method for on-machine measuring of micro-textures using a microvibration probe (minimum diameter of 20 mm and length of 1 mm). In order to produce many micromachines from machined parts more efficiently, we developed and demonstrated the effects of a self-aligning/self-assembly technology using excimer laser beam machining to etch a sacrificial layer.

We integrated these basic technologies to mount a travelling device in the tube inspecting micromachine system, demonstrating that the rotational drive of the drive device can be converted to horizontal and vertical locomotion of the inspection system.

3. Future Endeavors

Matsushita Electric Industrial Co., Ltd. hopes to add to its achievements in the ISTF Program by combining those results with other micromachine technologies and applying these technologies to such products as information-processing equipment.

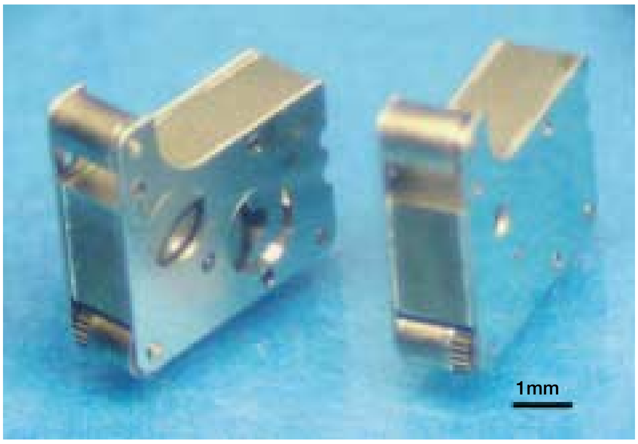

Fig.1 Traveling device

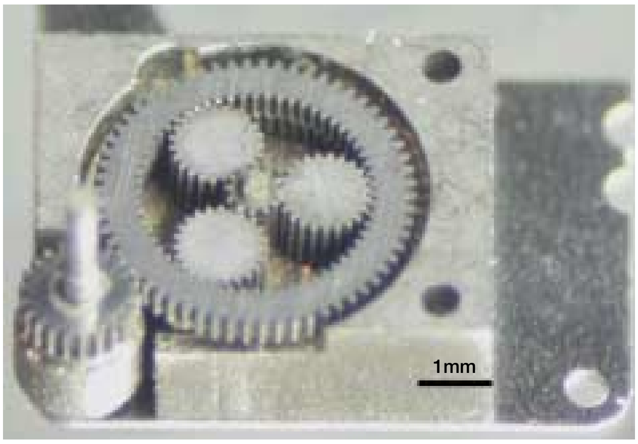

Fig.2 Planetary gear system

Introductory Course

Medical Applications for Micromachines, Part 4

Iwao Fujimasa,
Professor,
National Graduate Institute for Policy Studies

Micro-Electrodes: Data Interface with Living Organisms

Mechanical industries tend to view electronic systems as borrowed systems. With the human body, however, we must consider contact points between an electronic system and nerves in the human information system as a complex system from the beginning. The development of an interface between neural circuits and external instruments is essential as a base technology for micromachines. Recently Japan has been presented with a golden opportunity to make up lost ground in pacemaker development.

Forty years have passed since development began on pacemakers, now the most widely used artificial organ. The pacemaker is also a good example of the increased use of micromachines, achieving complex control and high compatibility with the human body. Pacemakers that have until recently been developed to treat bradycardia are starting to be incorporated as implanted defibrillators for treating tachycardia.

We are just now developing other methods of applying micromachines to the nervous system. In addition, diseases brought about by the nervous system of the heart and diseases brought about by nerves in the cerebral/peripheral nervous system have many common points in the form of electric signals. A great number of regions controlling human body functions can be manipulated electrically, and engineers have shown an interest in this field. However, we have tried to provide interface with macro-instruments located external to the body to provide a less invasive operating method. As a result experiments in Japan using the approach of installing a micro-electrode into the body have unfortunately been limited to animal experiments in our engineering departments. Although many approaches in a clinical setting have been proposed, there has been little research aimed at making this practical. Nowadays, researchers of neural systems have begun to assert that the 21st century is not only the age of gene research, but also of brain research.

Studies on micro-electrodes implanted in the human body have increasingly been conducted in the areas of visual and auditory systems, wherein multichannel needle electrodes are implanted to directly stimulate sensory areas in the brain. Some clinical achievements have been observed in the auditory field. A strong potential has also been seen in approaches to stimulate afferent nerves between sensory organs and the brain and in direct stimulation of sensory cells. In the auditory field, cochlear implants have found practical uses, while in the visual field there have been repeated experiments conducted to stimulate optic nerves using electrode, with inclined needle array. Japan has also been recognized for its advanced medical technology on implanting multichannel microsensors in the cranium to sample signals from the brain and determine functional regions. Many clinical examples that have been conducted are now common in health insurance coverage.

Many approaches have been developed for treating peripheral nerves, such as microsleeve electrodes and nerve growth electrodes that incorporate the fiber-growing region of the nerve stump in an electrode. Studies are being conducted to create an interface between nerves and artificial devices, both internal and external to the body. Studies on both of these micro-electrodes and electronic devices must cover such medical engineering issues as the compatibility of micromachining methods and materials with the body tissue, and the intervention of nerve growth factors, such as endocrine substances. We must create new areas of research.

Micro Fluid Devices: an Essential Micromachine Technology for Medical Measurements

It is well known that the object of medicine, the human body, comprises 70% water. Many medical instruments operate using an aqueous solution or a solution containing cells or micro-particles. It is a well-known historical fact that the first idea for creating an automated biochemical analyzer, called an auto analyzer, came during the development of tabletop chemical plants. With these devices, methods of pumping, cleaning devices, separating samples, and detecting reactions were studied at dimensions near the micro-level to enable a drastic size-reduction in the plants.

Although there have been various proposals for developing micro-fluid devices since the beginning of micromachine development, even today these devices only function as a single component. We must reinvestigate and reconstruct all system components with the aim of versatility. To do this, we must begin by acquiring base technologies for designing micro-fluid systems, including theories for analyzing fluid behavior at high viscosity and approaching particle transport and the need for rheological analysis, which knowledge can help us zero in on the essence of living matter. It would not be an exaggeration to say that developing technical elements as systems will influence tomorrow's sample testing apparatus. However, we must still develop numerous components and study them as microsystems in order for micro-instruments used in sample measurement, such as micro-TAS (total analysis system) and on-chip labs, to become the next-generation of auto analyzers useful in medical treatment.

New Medical Industries Created from an On-site Demand for Micro-Instruments

In order to popularize medical products and their use in the home, we must develop technologies for manufacturing cheaper and smaller products. By taking up each instrument one by one, perhaps we will see the need to explore the feasibility and significance of manufacturing them at a micro-size. Most conventional medical equipment is manufactured manually one product at a time, resulting in high prices that have stifled the market. Manufacturing this equipment at micro-sizes would give rise to industrialization and lower costs, which could generate a large demand. Blood sugar testing apparatus that are already used in the home have generated a new direction for diabetes control and have generated an enormous market. Micro-syringes for use in the home, which have helped reform conventional methods of administering medicine, and the much smaller catheter, have the potential to radically change medical treatment in the future. Obviously in either case it will be necessary to develop impartial ideas with much consideration for the clinical sites. It is clear from experience that the more widespread the micromachine system can be used, the more likely the system may become Japan's original industry. The objective of our efforts is most likely to develop common equipment of widespread use aimed primarily at treating lifestyle-related diseases.

Since the components of micromachine systems are small, we have a tendency to think it difficult to mount circuits for information systems therein. However, the smaller the devices become and the more widely they are used, the more indispensable it is to automate data processing in devices and elements. If our research does not include the study of somewhat fixed distributed data processing systems in micromachines and their integration as systems, there will probably be less possibility of micromachines becoming an essential technology in the medical industry.

MMC Activities

The 12th Micromachine Exhibition "Micromachine 2001"

The 12th Micromachine Exhibition "Micromachine 2001" was held in conjunction with The 7th International Micromachine Symposium at the Science Museum in Kitanomaru Park, Tokyo, for 3 days from October 31 to November 2, 2001. The exhibition was received enthusiastically.

Exhibitors included the Micromachine Center and 10 of the center's supporting member companies. Altogether, a record number of 111 companies, organizations, universities, and research institutes from Japan and overseas joined the exhibition program. With a total of 164 booths, this year's event occupied 5 exhibition halls - one hall more than last year. The exhibition covered such topics as state-of-the-art micromachine technology and the latest research results. Because of its size and contents, this exhibition is highly regarded year after year as an exhibition specializing in micromachine technology.

The 10-year "Micromachine Technology" project - part of the Industrial Science and Technology Frontier Program promoted by the Ministry of International Trade and Industry (now the Ministry of Economy, Trade and Industry) - was completed last year and achieved tremendous results. Because of the growing interest in micromachines, a particular feature of this exhibition was the large number of newly exhibiting companies (nearly half) representing micromachine-related industries, such as production equipment manufacturers, measuring instrument manufacturers, and semiconductor production equipment manufacturers.

The exhibition welcomed a record number of approximately 7,460 visitors (including 359 elementary school children). Exhibition floors were crowded with the enthusiastic visitors, who spent a long time looking at the exhibited items and asking questions to booth attendants.

The schedule for the next exhibition, "Micromachine 2002," is shown below.
Period: November 13 (Wed.) to November 15 (Fri.), 2002
Place: The Science Museum, Kitanomaru Park, Tokyo
Inquiries: Mesago Messe Frankfurt Corporation
Tel.: +81(0)3-3262-8441
E-mail: micro@mesago-messefrankfurt.com
URL: http://www.mesago-messefrankfurt.com/micro

Preliminary Announcement

The 8th International Micromachine Symposium

November 14, 2002
at Science Hall, Science Museum, Tokyo, JAPAN

Exhibition

MICROMACHINE 2002

Novemver 13-15, 2002
at Science Museum, Tokyo, JAPAN

The Detail will be announced later.

Pictures on the cover : *Winning artworks in the Micromachine Drawing Contests : Micro-Volcanic-Eruption-Predictor, Walking Flowers, Shizu: The Rainbow-Making Machine, Repair/Rescue Robot Centipede*

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