CHAPTER 7

BUSINESS, EDUCATION, THE ENVIRONMENT, AND OTHER ISSUES

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ABSTRACT

This chapter reviews elements of the study that are not central to the particular technologies studied, but that nonetheless affect both the development and the efficacy of micromanufacturing. Facets of the educational systems, business potentials and practices, governmental policies, and cultural characteristics in all of the countries visited drive and/or enable the technological development necessary for moving micromanufacturing forward. While this chapter makes some effort to compare the U.S. with other countries on these issues, readers can easily conduct similar comparisons from their own perspectives.

BUSINESS

The potential of micromanufacturing from a business perspective—and, collaterally, from the societal perspective as well—is significant. Medical applications, to consider one area, currently abound. With the movement toward minimally invasive surgery, very high-precision miniaturized devices are needed to perform procedures within the body without the collateral damage inherent in conventional surgery. There are also numerous military applications. The evolution of combat into a highly focused effort that inflicts damage on combatants and not civilians necessitates the increased use of miniaturized sensors and delivery devices. Allowing an increase in the extent that the U.S. is already dependent on foreign sources for micromanufacturing may not serve the country's security needs well. One of the important areas of application for both military and commercial use is miniaturized optics. A very visible recent application is electronic cameras in cell phones.

Many Asian companies are concerned about losing manufacturing "offshore" to China. The response of many companies is to increase their investment in research and development to maintain their competitive edge; for example, Samsung (South Korea) plans to more than double its rate of investment in research and development to about 8½% of the corporate budget, while FANUC personnel estimate that their firm currently invests up to 10%. There is a belief that this policy will work as long as there is a concentration on bringing high-tech, short-lifetime products to market, thereby keeping all others out of the loop. As soon as a product is on the market and others understand both the product technology and the manufacturing technology, then they will have the potential to jump into the market. In the short term, at least, this may be the most viable strategy.

Concern over the movement of manufacturing offshore did not seem to be as strong in Europe. That may be because, as in the U.S., this is a phenomenon that has been going on for a much longer time. Europe seems to have developed its own response. For example Kugler, GmbH, which is a small German manufacturer of very high quality ultraprecision machine tools, has a normal research and development budget of 15–20%.

Outsourcing is an issue that affects the Far East as well as the U.S. When questioned, the response at Samsung was well-structured in that outsourcing was focused on mature products that had reached or were reaching maturity—personal computers (PCs), computer mice and keyboards, small cooling fans, TV inverters, and conventional TVs—and had attained commodity status. Again, these firms appear to see their future as dependant on maintaining their lead in the technology race. However, by controlling the outsourcing, they continue to control their market segment, and maintain a share of the profit.

In Japan and South Korea there seemed to be a large number of young PhDs at several of the industrial laboratories that the panel visited, and there were clearly plans in place to hire more PhDs at several of the laboratories. However, at one university an increasing numbers of PhDs with industrial experience were looking for jobs at universities. Apparently, this is because some companies are downsizing their research organizations. One expects then that the response in Japan and Korea to manufacturing moving offshore is as varied as the response is in the U.S.

In Japan and Korea it appeared that in some cases, industry was willing to invest in enabling technology for micromanufacturing, even though the total market for a particular machine technology might be on the order of 10-12 units. RIKEN is commercializing machines that it develops and selling them to industry. Those machines are used to produce ultra high-precision tools that are used, in turn, for micromanufacturing operations, thus supporting a relatively wide range of micromanufacturing efforts with only a few specialized machines.

The president of The Metal Industries Research & Development Centre in Kaosiung, Taiwan, made some very interesting comments during discussions. First, the probability of success for micromanufacturing projects is quite high when compared with MEMS projects because they are industry-motivated and application-driven. Second, virtually all materials used in micromanufacturing are conventional materials. There has been little need to develop new materials for micromanufacturing. Innovations in materials must be performance-driven since material volumes are too low for either cost or economics to drive the development. However, since the actual volume for micromanufactured parts is so small, very expensive materials can be economically justified. A lesson to be learned here for U.S. funding agencies is that independent materials research that is not strongly connected to industrial needs may not be appropriate for funding.

EDUCATION

In Japanese universities, and to some extent in Korean, Taiwanese, and European universities as well, many of the individual academic departments had names that defined them uniquely (e.g., precision engineering, precision machinery engineering, microsystem engineering, mechanical engineering and intelligent systems, engineering synthesis, information storage engineering, mechanical systems engineering) in addition to a conventionally named department of mechanical engineering. In the U.S,, the functions represented by these dfferent departments would typically reside in a single mechanical, or perhaps a mechanical and aerospace engineering, department. Taken together, these departmental groups can be larger than any single mechanical engineering department in the U.S. These uniquely named departments typically represent multi-disciplinary educational efforts on a scale not seen in the U.S., where such efforts are usually found in much smaller cross-disciplinary centers. There is clearly a commitment to multi-disciplinary work, which is necessary for both manufacturing and manufacturing research, that well exceeds the commitment in the U.S. This, in part, may explain the excellence in micromanufacturing in these countries.

When questioned, both Asian and European industry personnel noted that, while initial training ranging from six months to two years was necessary, new engineering graduates typically had a good background for their technical careers. This indicates that they are making use of the traditional technologies taught in the universities. Like many U.S. companies, they find that their new engineering hires may not have all of the communication skills and team-building skills that they need to excel in industry.

The Japanese Government funded an interesting effort to bring technology to the younger generation. Professor Ikuta at Nagoya University designed, implemented, and now supports a microsystems interactive experience for children at the National Museum of Emerging Science & Innovation. It targets microsystems that are big enough for children to see under a standard microscope. The set-up at the museum is capable of downloading new designs from Professor Ikuta's laboratory so that new designs can be generated for the children to experience. The web site for the museum is http://www.miraikan.jst.go.jp. The museum hosts a microart contest for children to use the "art-to-part" process. This is one way that the Japanese government is insuring that the next generation of Japanese citizens is motivated to pursue careers in technology.

As noted in the previous section, a large number of young PhDs were found working at some of the Asian industrial research laboratories visited. Up to 30% or more of those PhDs were acknowledged to come from outside Japan or South Korea, including the U.S. The output of PhDs from the universities in Europe and the Far East individually now exceeds the U.S. In addition, in most U.S. engineering schools, the majority of PhD students are foreign born. While many of those students stay in the U.S. for their professional careers, many go back to their own countries since an increasing number of opportunities may be found there. The U.S. is now seventeenth in the world in the per capita output of engineering and natural science degrees. In 1975, the U.S. was third, behind Japan and Finland. China's output of engineers alone far exceeds the output of U.S. engineers. This does not bode well for the future competitiveness of the U.S. in terms of its ability to support the U.S. high-tech manufacturing effort. The reasons for this are many, and go well beyond the scope of this report.

A number of effective educational efforts are being employed throughout Asia and Europe to develop the skills necessary for micromanufacturing. An extremely creative educational effort was observed at Professor Hisayuki Aoyama's microrobotic laboratory at the University of Electro Communications in Tokyo. He deals primarily with graduate students. His students use off-the-shelf components (available in the "electronic city" Akihabara area in Tokyo). Professor Aoyama motivates his students by making their projects fun. Projects include building a desktop factory, "robot mating" using artificial insemination (a fish egg was actually fertilized by his students' robots), "microdrop mixturing" (mixing very small quantities of liquids, potentially for drug applications), and a micromanipulator driven by a Sony Play Station controller. The cost of each of the projects was less than $1 million, exclusive of the laboratory PCs that were used. It was clear that Professor Aoyama's students were ready and able to move into industry and to be productive very quickly.

ENVIRONMENT

During site visits, the WTEC panel saw no processes that would present a problem in terms of pollution. Some of the very fine-machining processes can involve the potential danger of particulate ingestion to manufacturing personnel. In each case a simple venting system and/or filters were sufficient to limit exposure. While the potential for hazardous materials is certainly present, most of the processes observed were scaled down in size from the conventional manufacturing counterpart. This results in, at least, lowering the volume of pollutants. In the case of the Korean Institute of Machinery and Metals (KIMM), one of the justifications for micromanufacturing was that it results in reduced industrial pollution. However, a number of the sites visited did actively consider environmental issues throughout product life.

Some companies, such as Mitsubishi, have ongoing environmental management systems that monitor the effects of manufacturing activities and products on the environment, and attempt to prevent pollution before it occurs. Japan has national environmental laws, local ordinances, and agreements. Mitsubishi has set voluntary standards that promote energy conservation, clean energy, CO_2 emission reduction, waste reduction, restricted use of dangerous chemical substances, and environmentally friendly designs that support product life cycles. Mitsubishi's environmental policies are well-documented and open to the public. All employees are familiarized with it. The approach seen here is not necessarily directed at micromanufacturing. However, the environmental characteristics of micromanufacturing noted above certainly make it a viable alternative to more conventional technologies.

The Institute of Reliability and Micro-Integration, at the Fraunhofer Institute Berlin (IZM), takes an integrated environmental approach in the early stages of product design and process engineering. They work with industry partners to analyze electronic devices from an environmental point of view to foster eco-efficiency. IZM, in collaboration with the University of Tokyo, has developed a joint eco-design program.

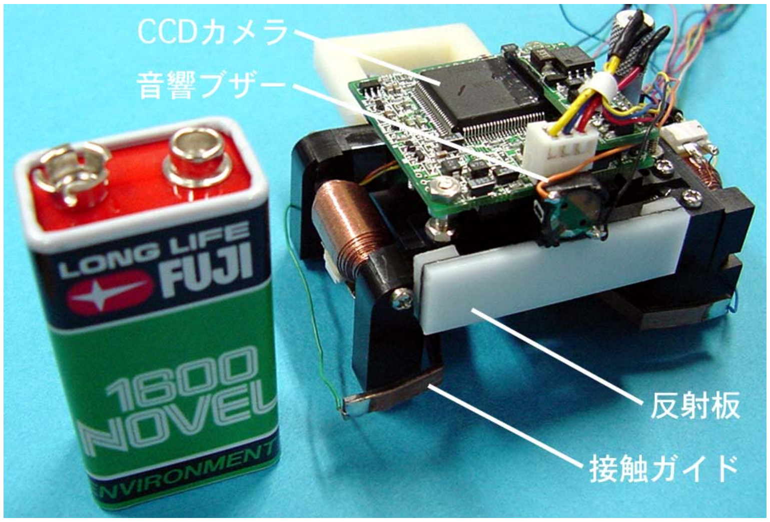

Figure 7.1. Female robot used for robot artificial insemination project.

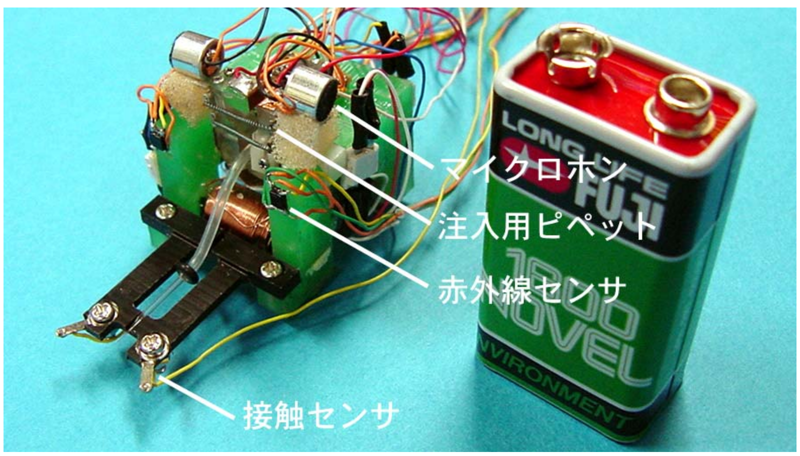

Figure 7.2. Male robot used for robot artificial insemination project.

GOVERNMENT POLICIES

At KIMM, the panel saw an excellent example of government policy directed at the mainenance of industrial competitiveness. The emphasis there was not on fundamental issues, but rather on developing the ability to produce next-generation systems such as white light interferometers (WLIs), and precision motion and machining capabilities. They also have an excellent history of working with industry to transfer technology. They appear to be poised to provide enabling technologies to Korean industry as their various micromanufacturing projects develop and mature.

Some Japanese government research laboratories may be feeling the effects of the global economy in that there appeared to be a change of mission in progress that did not seem to be well understood, even by the personnel in the laboratories.

The DTF project of the Fine Manufacturing Systems Group at AIST is shown below. There is a government-sponsored effort to make small machines to make small things, and this is one example of that effort. Figure 7.3 (left) is an overall view of the factory. Figure 7.3 (right) is a picture of the small press.

The Taiwanese National Science Council (NSC), part of the executive branch of the government, was established in 1959. The Department of Engineering & Science (DES) within the NSC funds academic research and places equal emphasis on fundamental and applied research. They support multi-year integrated and individual PI projects. In 2003, they received about 9,000 proposals, and were able to fund approximately 5,000 projects (about ~55%—compared to the ~15% funding rate in the Design, Manufacture, and Industrial Innovation Division at the National Science Foundation in the U.S.). The average level of funding for projects is $175,000 - $350,000 per year. Overhead on projects is limited to 8% (maximum), as compared to the roughly 50% that most U.S. universities charge. There is no specific program in place at the NSC to support micromanufacturing.

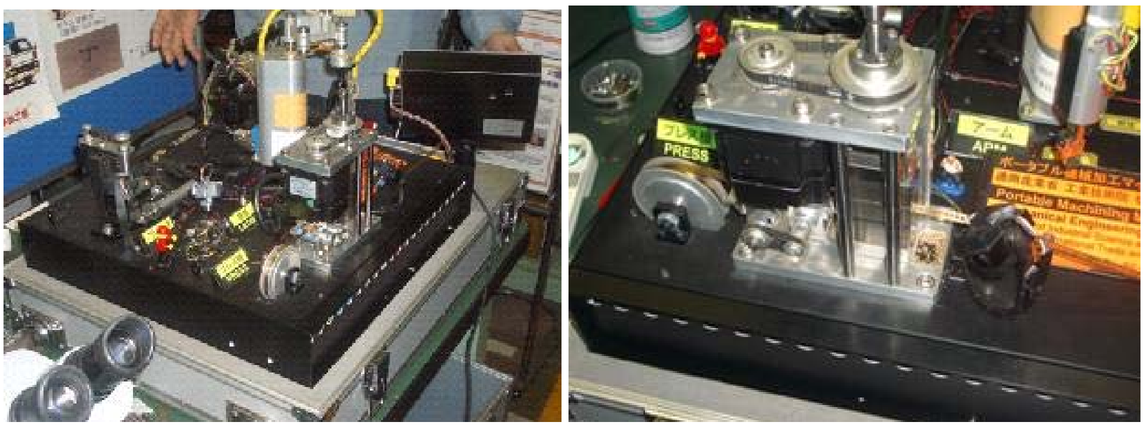

Figure 7.3. AIST desktop factory project.

The German Fraunhofer Institutes enjoy an extremely good relationship with German industry. Many times during conversations with German industry representatives, the subject of the Institutes came up. In every case, it was clear that the industries depended on the Fraunhofers for technologies, and that the relationship between the two was very solid. From the other side, it was clear that the Fraunhofers take their relationship with industry seriously and are dedicated to being a critical resource for industry. The result is that it is relatively easy for even a small German company to stay abreast of technological advances in their field. This is a tremendous advantage in a rapidly changing technological environment.

Besides providing research and laboratory training faculties to university students, the Fraunhofer Institutes offer industry-oriented training programs for the technologies in which they have developed expertise. They organize workshops and conferences as well as one-day technology forums for technology transfer to industry. The institutes also organize company-specific workshops.

Other Issues

One of the more impressive characteristics that ran across almost all of the industrial R&D laboratories that were visited was that there was a focus on making sure that a product and its associated enabling manufacturing technologies were brought to the factory floor very quickly. Laboratory personnel appeared to be well-connected to their counterparts in manufacturing engineering.

Perspectives on FANUC

FANUC indicates that it will not move its production overseas for several reasons. They do not feel that they are producing systems in quantities that are significant enough to warrant a transition overseas. They feel that it is important for R&D to be close to manufacturing. It may be that their high level of automation necessitates this, although this was not stated.

They are working hard to have a minimal impact on the environment, but major concerns appear to be not cutting trees down when they build new facilities and minimizing packing materials. They do not appear to consider environmental issues from a total product life perspective. For example, they appear to have not considered how to recycle their used robots.

The staff of FANUC indicated that they hired all engineers, with about 70% being mechanical engineers and 30% being electrical engineers. It was indicated that some training was necessary for new engineers, but they nominally had a good background for their technical careers at FANUC. As in the U.S., there was some concern regarding communication and team skills for new engineers. Among their engineering staff, three were women. This is an improvement from the past when no female engineers were included in their ranks.

FANUC has participated in a few government-funded projects, for example, the Intelligent Manufacturing System project that was recently finished.

Intellectual Property and Commercialization

The issues of commercialization and intellectual property were discussed with personnel at many of the university and government laboratories that were visited. As a general observation, the South Korean university educational community appears to be more closely tied to the U.S. university educational community than is the case for the Japanese. The South Koreans more typically have been educated in the U.S. An entrepreneurial spirit connects them with their industry. It appeared that Japanese educators were not particularly pressing the patent process, whereas Korea and Taiwan were. In fact, it seemed that in many instances in Japan, getting a patent might have been a fairly painful experience for academic personnel as they could be forced to commercialize material that was developed using government funding, and that they would not necessarily reap any economic benefit from the commercialization.

The Europeans seemed to be comfortable with the intellectual property and commercialization process. The relationships between universities, government laboratories, and industry appeared to be strong, with all players in this three-sided relationship appreciative of the contributions of the others. One could observe that the intellectual property and commercialization process appears to be considerably more mature in Europe than in the U.S.

The Importance of Human Resources in Micromanufacturing

With all of the focus on the technology of micromanufacturing, one tends to forget that there are real people that run the high-precision and highly automated manufacturing processes. This was brought home in the following way. Til Kugler, the son of the founder of Kugler, GmbH (Germany) commented that it took a special kind of worker to succeed in a high-precision environment, and hiring the right workers was critical. They had to be very neat and well organized. He said that he could tell in 15–20 minutes of conversation whether or not a potential worker would be able to succeed at Kugler.

An anecdote will serve to demonstrate the extent that individual human requirements in a high-performance micromanufacturing environment are challenging and that certain personality traits are highly correlated with the ability to perform well in the micromanufacturing environment. The panel next visited Zumtobel Staff (Austria). Here similar comments were heard. In this case, it was pointed out that there was one worker whose performance exceeded any of the other workers. Although the thesis of the comments was that it took a special person to succeed in micromanufacturing, there was no characterization given of the traits necessary for success.

Panel members were later given an opportunity visit a work area where three workers were actively involved in their trade, including the high-performance individual in question. As the panelists approached the individual's work area, it was clear that they were invading his space in that he immediately stopped tending his turning center and came over to us. The panelists stopped by a worktable that held the recent output from his work center. There was absolutely nothing out of place on the table. Recently manufactured high-precision parts were lined up perfectly on the table, as were tools. A quick inspection of the work spaces of the other two individuals working in the area revealed that their individual work areas were likewise neat and well organized. However, they paled in comparison to the work area of the high-performance individual. His was at a completely different level in this respect. Knowledgeable management, in some cases, is able to identify these personnel, and do so in comparison to other highly trained technicians. Clearly, the selection of workers is a very important element of maintaining a successful micromanufacturing enterprise.