The Role of Venture Businesses in Supporting the Commercialization of Nanotechnology

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In the United States where start-ups by venture businesses are being vigorously pursued, many venture firms have already started business in the field of nanotechnology (nanotech) as well. In Japan, although sluggish trends have been seen in overall venture business activities, nanotech is an exceptional area in which business creation is fairly active.

We have made a comparative analysis between Japan and the United State based on a list of nanotech ventures that have made their appearance in major conferences and the media in the United States and Japan. Although the number of the newly created business ventures is still larger in the United States, the difference between the two countries is small—actually coming down to fewer than 10 companies.

However, a comparison of the characteristics of newly inaugurated ventures reveals some major differences in the United States and Japan. These gaps essentially involve differences in terms of the innovative aspects of the core technologies underlying the business, the technological fields of their activities, and the format of business creation, i.e., whether spun off from a private corporate or established from university basis.

As the United States is some 15 to 20 years ahead of Japan with respect to the various policies targeted at encouraging venture start-ups, considerable progress has been made in accumulating know-how and fostering human resources related to the creation of venture firms. Moreover, a phenomenon in which venture businesses themselves lead to the creation of even newer ventures has also started to emerge.

As there are a number of differences in the environment surrounding business creation between Japan and the United States, cases developed along the US model should not necessarily be viewed as precedents to be followed. However, a further vitalization of venture creation (start-ups) is necessary in order for Japan to prevent nanotech developments from ending up as mere technology. Furthermore, the goal should be to commercialize and create businesses out of nanotechnology by overcoming the Valley of Death and the Darwinian Sea syndromes that typically must be crossed in the course of high-tech business creation.

I Towards the Commercialization of Nanotechnology

The so-called Valley of Death is often singled out as the major barrier to be overcome in the course of moving from basic research to applied research and product development with respect to the creation of high-tech businesses. The chief obstacles making up the Valley of Death essentially relate to the difficulties in fund raising and securing human resources. And even if the Valley of Death can be crossed successfully, what awaits those who reach the other side is an intensely severe competitive environment that threatens the survival of both new participants and incumbent companies as well. This competitive venue is called the Darwinian Sea, by likening it to the biological world where only those species that can withstand the environmental challenges can survive the process of natural selection.

Unless the twin obstacles of the Valley of Death and the Darwinian Sea can be overcome, it is not possible to grow the results of basic research into profitable high-tech businesses. This means that creating a new business in any high-tech field requires that the Valley of Death and the Darwinian Sea be explicitly recognized, and that a comprehensive vision from basic research to business development be developed.[1] And nanotechnology, which is a typical example of high-tech research and development, is no exception to this rule.

Nanotech is one of the common, fundamental technologies that will support the high-tech industries of the 21st century, such as materials, IT (information technology) and biotechnology. Moreover, the creation of new high-tech industries and high-tech businesses constitutes the core foundation that will support Japan's global industrial competitiveness in the future.[2] Because of this recognition, the government as well as private-sector companies are implementing many policies and measures designed to enhance nanotech research and to smooth the way for commercializing the research results. However, it cannot be said that all of these measures fully take into account the difficulties in creating nanotech industries—especially the challenges represented by the Valley of Death and the Darwinian Sea.

Among these recently introduced measures, for example, there are many that copy mechanisms adopted in the United States, the country that continues to hold the lead in high-tech business creation. These include a Japanese version of the Bayh-Dole Act regarding patent rights and a Japanese version for the SBIR (Small Business Innovation Research) program, which is a venture (business) support system in the US.

The Bayh-Dole Act has made it possible for universities or even individual researchers to acquire the patent for a new technology or process even when the R&D behind it is carried out on the basis of government funding. This has significantly increased the incentive for university researchers to acquire patents in the United States. This act went into effect in the US in 1980. The Japanese version wasn't adopted until 1998, meaning that Japan lagged some 18 years behind the United States in implementing this type of measure.

With respect to the SBIR, a venture business development program in which the government provides various aid centered on funding high-risk projects, the original concept was started in the United States in 1983. The Japanese version didn't come into being until 1998, a delay of 15 years behind its implementation in the US. Moreover, subtle changes have been incorporated into the program mechanisms introduced in the Japanese version in order to match the program to the actual situation in Japan.[3] Therefore, it is questionable whether the features inherent in these mechanisms can effectively work in Japan in the same way as in the United States. Moreover, it is doubtful whether these mechanisms will really contribute to the promotion of nanotech business creation. In sum, the introduction of new systems designed for the actual situation within the country, as well as a new awareness of what is really needed, are among the approaches that are required in Japan.

By drawing on the current situation as outlined above, this paper will focus on the creation of venture businesses, which constitute one of the major formats that connect the results of basic research in nanotechnology to new businesses. As these start-ups seem to lag behind those in the United States, this paper will also offer some comparisons on the current status of venture businesses in Japan and the United States. Furthermore, consideration will also be given to concepts as well as measures to promote the commercialization of nanotech and the creation of businesses in the future based on the results of these comparative analyses.

II Comparison of Nanotech Ventures in the United States and Japan

Fifty-one nanotech venture companies in the United States and 45 companies in Japan picked on the basis of media exposure and/or from among participants at major conferences such as the Nanotech Venture Fair held in California in 2002 have been listed in Attachments 1 and 2. A comparison between these companies in Japan and the United States was made from the following six perspectives: (1) the high-tech or innovative aspect of the core technology involved; (2) the year the firm was established; (3) the field of nanotech; (4) the annual change in the number of newly started businesses by field; (5) company scale (in terms of the number of employees); and (6) the format of business creation (whether the core technology was originated on a private corporate or university basis).

1 Japan Lags Behind the United States in Terms of the Innovative Aspects of Core Technology

Table 1 compares nanotech ventures in the United States and Japan with a focus on core technology. Core technologies are classified in this table in terms of their high-tech or innovative aspects and arranged in descending order. The companies owning each core technology are then listed in the relevant technology row.

If the existing technology categorization were applied to such classifications, it would be impossible to establish a ranking order because technologies such as electronic devices and biotechnology fall under different fields. Instead, the order among technologies in this list considered that these technologies all fall within the single sphere of nanotechnology.

Quantum dots and nanomolecular devices are device technologies that transcend the limits of existing technologies and are based on totally new principles. Accordingly, it is considered that the innovative aspects of these technologies are high. Take, for example, the memory devices that are one of the products in which nanomolecular technology is applied. Unlike existing memories using semiconductors, optical or magnetic materials, totally new devices that use organic molecules or proteins are being proposed. Accordingly, it is deemed that the innovative aspects in such cases are high.

Moreover, the application of nanoparticles in biotechnology, i.e., applications involving DNA (deoxyribonucleic acid) or protein markers, is a technology that remarkably expands quantification techniques and can be considered a new quantum dot application. Accordingly, the innovative aspects are obviously high. In addition, superhigh-density memories also have a high innovative aspect as they move well beyond the recording limits of existing magnetic materials.

On the other hand, while it appears certain that new technologies will be given birth in such areas as nanoparticle manufacturing, nanoprocessing, nanomeasuring and crystal growth, these new avenues can be considered as outgrowth applications that extend the scope of existing technologies. Accordingly, a low order was assigned to these technologies. This same concept was used for vacuum devices and hyper-compact sensors.

If the concept of innovative aspects as defined in this paper is applied, nanotech ventures in the United States are concentrated in technologies with high innovative aspects. Because Japan has many nanotech ventures related to core technologies that are considered to have a relatively low level in terms of their innovative aspects, the differences between the United States and Japan become more explicit. As represented by semiconductor technology, Japan's approach to nanotech is focused on a "top-down" methodology in which microscopic processing is applied to macroscopic objects to realize nanoscale science and technology. On the contrary, the United States stresses a "bottom-up" approach in which microscopic elements such as atoms and molecules are accumulated to achieve nanoscale objectives.[4] Clear distinctions can be readily confirmed in this aspect as well.

2 Expectations Focused on the Future with Respect to Business Creation in Japan

It is, of course, only natural that the United States would take the lead in terms of the year of establishment (Figure 1), as venture start-ups have been vigorously pursued in the United States for many years. In the US, for example, many start-ups were established prior to 2000, while such undertakings did not become active in Japan until after 2000.

Figure 1. Nanotech Venture Start-Ups by Year of Establishment

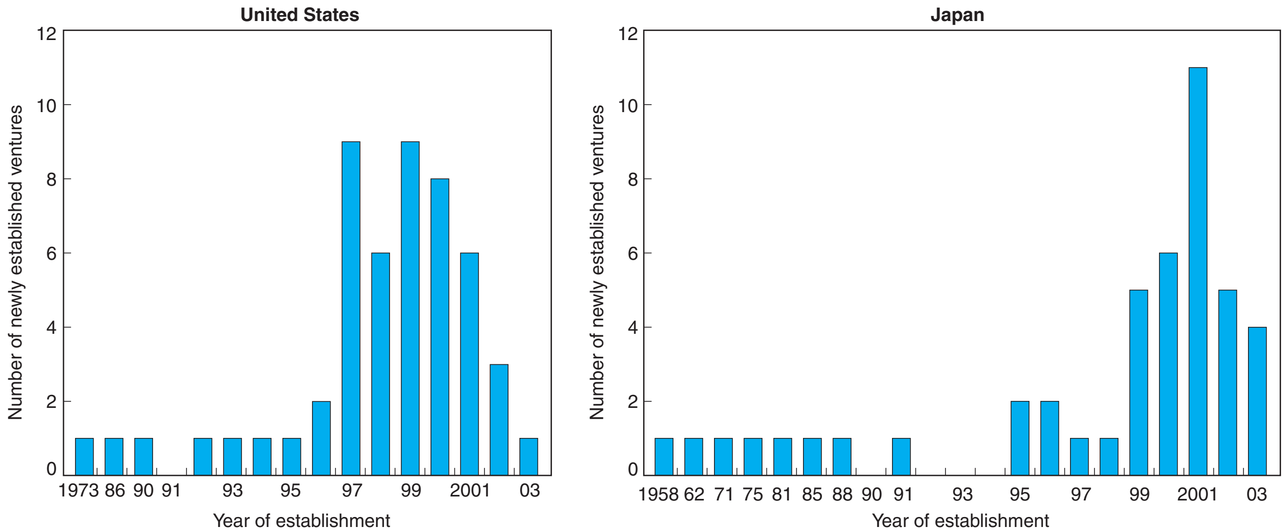


Table 1. Comparison of Pioneering Aspects of Core Technologies in Nanotech Ventures in the United States and Japan

Core Technology (In descending order based on pioneering aspects)	US	Japan
Quantum dots	Nanocrystals Technology NANOSYS, INC. ZIA LASER, INC.	
Nanomolecular devices	CALIFORNIA MOLECULAR ELECTRONICS CORPORATION NANOLAYERS	
New types of computers	NANOLOGIC, INC.	
Application of nanoparticles (biotech markers)	NANOPLEX TECHNOLOGIES, INC. NANOSPECTRA BIOSCIENCES, INC. NANOSPHERE, INC. QUANTUM DOT CORPORATION	
Superhigh-density memories	NANOCHIP, INC. NANOMAGNETICS LTD. ZETTACORE, INC.	OPTWARE Corporation
Carbon nanotube devices	Molecular Nanosystems NANOMIX	Proton C60 Power Corporation JCS Co., Ltd.
Micro total analytical systems	AVIVA BIOSCIENCES BIOMICRO SYSTEMS, INC. FLUIDIGM CORPORATION NANOSTREAM	Institute of Microchemical Technology Fluidware Technologies Inc.
Nanomembranes	iMEDD, INC.	Bio Nanotech Research Institute Inc. (BNRI)
Nanoimprintng	NANOINK, INC. NANONEX CORPORATION NANOOPTO CORPORATION	Device Nanotech Research Institute Inc. (DNRI) Nano Device and System Research Inc. MEMS CORE CO., LTD.
Laser manipulation	ARRYX, INC.	Cyber Laser Inc.
Immunoassays, probes	BIOFORCE NANOSCIENCES, INC. GENICON SCIENCES CORPORATION IMAGO SCIENTIFIC INSTRUMENTS CORPORATION	Research Institute of Biomolecule Metrology Co., Ltd.
Drug delivery systems	C SIXTY, INC. INSERT THERAPEUTICS, INC. NANOMED PHARMACEUTICALS, INC.	LTT Bio-Pharma Co., Ltd. Inter Cyto Nano Science. Co., Ltd. Nano Carrier Co., Ltd.
Artificial skin		Nidek Co., Ltd.
Optical ICs (Integrated Circuits)	NeoPhotonics OPTIVA, INC. SiWAVE, INC.	Photonic Lattice Inc. DEPT Corporation
Nanoparticle applications	NanoGram Devices NANOPOWDER ENTERPRISES, INC. Nano-Tex, LLC NTERA LTD.	Clean Venture 21 Corporation
Nanoactuators	NANOMUSCLE nPOINT, INC.	NANO CONTROL CO., LTD. EAMEX Corporation HEPHAIST SEIKO CO., LTD.
Carbon nanotube structures	CARBON NANOTECHNOLOGIES, INC.	Carbon Nanotech Research Institute Inc. (CNRI) NanoCarbon Research Institute Ltd. Frontier Carbon Corporation
Nanocoating	ADVANCED DIAMOND TECHNOLOGIES ATOMIC-SCALE DESIGN, INC. CHEMAT TECHNOLOGY, INC. INMAT LLC	Shiratori Nano Technology Co.
Nanoparticle structures	ALTAIR NANOTECHNOLOGIES INC. CIMA NANOTECH (NanoPowders Industries) MATERIALS MODIFICATIONS, INC. NanoGram NANOTECHNOLOGIES, INC. NANOVA, LLC. NANOVENTIONS, INC.	Millennium Gate Technology Co., Ltd.
Materials design		AdvanceSoft Corporation
Nanomeasuring devices		JASCO Corporation NanoPhoton Tokyo Instruments, Inc. Wyckoff Co., Ltd. Tsukuba Nanotechnology Co., Ltd.
Nanoprocessing		ELIONIX INC. CRESTEC CORPORATION Cluster Technology Co., Ltd. X-ray Precision, Inc.
Crystal growth		NITRIDE SEMICONDUCTORS Co., Ltd. NANOTECO CORPORATION SiXON Ltd. Oxide Corporation
Ultra-compact sensors		LEVEX CO., LTD. Photonic Science Technology, Inc.
Vacuum devices		R-DEC Co., Ltd. Adtec Plasma Technology Co., Ltd. Optorun Co., Ltd.

A phenomenon known as the nanotech boom arose following the announcement of the nanotech strategy by President Clinton in January 2000. As noted above, start-ups involving nanotech ventures in Japan became active after this boom.

However, nanotech R&D had been active in Japan even before this boom, and nanotechnology in Japan was at a world-leading level. If these facts are taken into account, it would seem obvious that venture business creation in the field of nanotech in Japan has the potential to become much more active. Particularly with respect to those areas related to the innovative core technologies in which major discrepancies were observed in the previous comparisons between the United States and Japan, increases in the number of nanotech ventures can be expected.

3 Fewer Ventures in Biotechnology and Healthcare in Japan but Many Ventures in Measuring Technology and Equipment

A difference between the United States and Japan is also noticeable in the areas of focus for nanotech ventures (Figure 2). Ventures specializing in materials account for 37 percent of the total in the United States, and those specializing in biotechnology and healthcare account for 27 percent. This means that more than 60 percent of all ventures can be classified into the two fields where nanotech is expected to bring about major innovations. In the case of Japan on the other hand, ventures specializing in measuring technology and equipment account for the largest share, or 36 percent, followed by materials at 24 percent and MEMS (microelectromechanical system) technologies at 13 percent. Compared to the United States, ventures specializing in biotechnology and healthcare are extremely few, coming in at only 9 percent.

One of the reasons for the high ratio of measuring technology and equipment in Japan is that nanotech ventures in Japan include those originated by trading firms engaged in the imports of equipment related to physics and chemistry. Moreover, it is relatively easy for university-originated ventures to start business activities in this field, as universities and research organizations are also users of measuring equipment and such researchers are well able to determine the market potential.

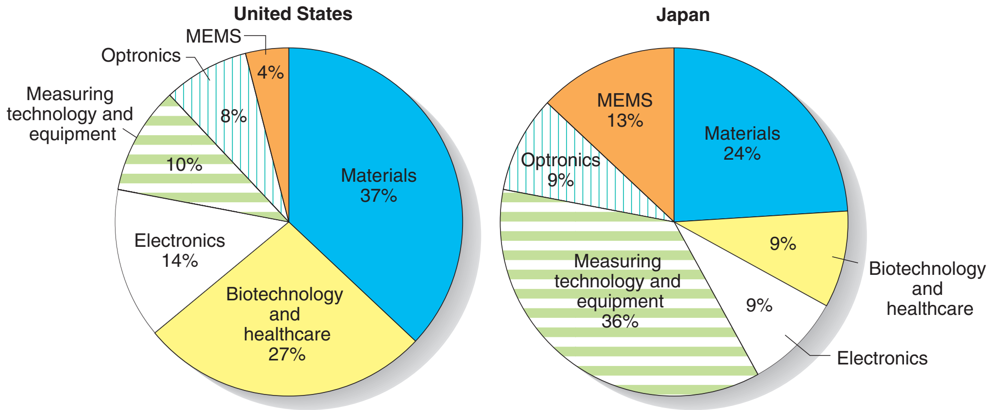
At the same time, it has been pointed out that one reason for fewer ventures specializing in biotechnology and healthcare in Japan reflects the fact that Japan lags behind the United States in various aspects of basic research of these fields. This suggests that the existence of good technical seeds is essential in the establishment of nanotech ventures.

4 Synergies Between Biotechnology and Nanotech Are Emerging in the United States

When we examine the year in which nanotech ventures were established by field of specialization, we see in the case of the United States that the number of ventures specializing in materials reached a peak in 1997, and those in biotechnology and healthcare peaked two years later (Figure 3). This suggests that nanotechnology originated in work focused on materials innovations, and then expanded to the field of biotechnology and healthcare thereafter. In Japan, measuring technology and equipment came first, and the number of ventures specializing in the materials field increased after the start of the nanotech boom.

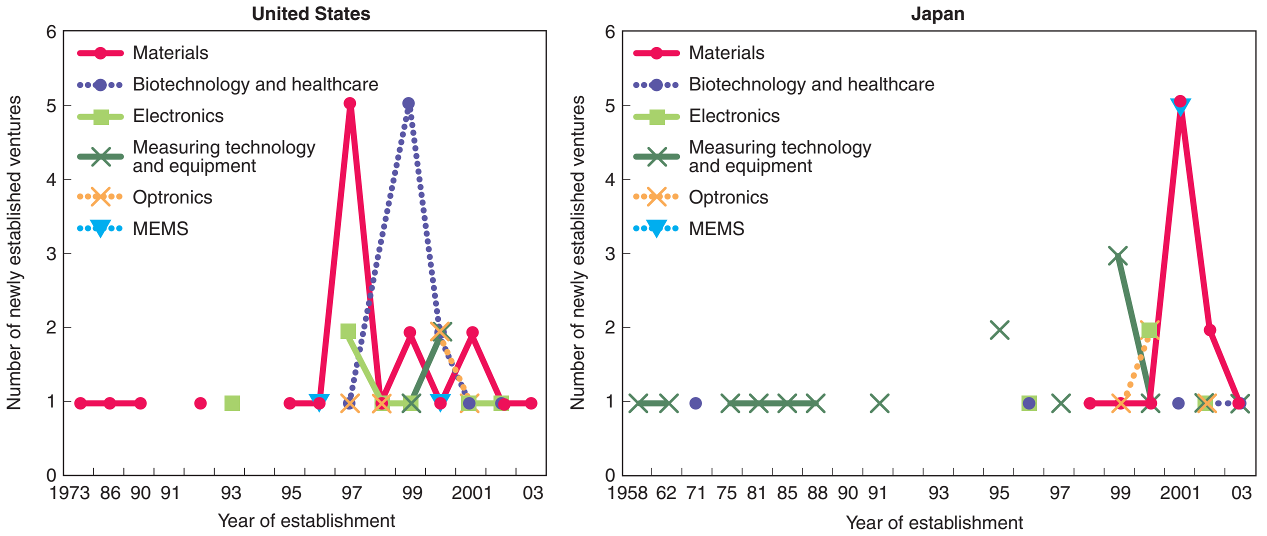
If we take into account the fact that venture business creation in the biotechnology field has long been active in the United States, the expansion in the fields to which nanotechnology is applied can be interpreted as the results of synergistic effects between biotechnology and nanotech towards business creation. If this premise is correct, the fact that fewer business start-ups in the biotechnology and health fields took place in Japan can be attributed to the lack of such synergistic effects. In order to derive the maximum benefit offered by the features of nanotechnology, R&D and the development of technologies must be able to transcend the barriers imposed by existing field categorization. These results

Figure 2. Nanotech Venture Start-Ups by Field



Note: MEMS = microelectromechanical systems.

Figure 3. Transition in the Number of Nanotech Venture Start-Ups by Field



suggest a shortage of interdisciplinary R&D and slowness in developing convergent technologies in Japan.

5 Small-Scale Starts Leading to Gradually Expanding Companies in Japan

A comparison between Japan and the United States in terms of the distribution of the number of employees in nanotech ventures is shown in Table 2. Unlike the situation in the United States, the number of companies that fall within the 10–19 and 20–49 categories is relatively low in Japan. Instead, many companies have a scale of nine or fewer employees. Although the United States also has companies with only a few employees, such cases typically involve close outsourcing connections to a university. As noted in Attachment 1, moreover, there is even an extreme case in which the only employee is engaged in sales, and all development activities are carried out at a university.

In Japan, where outsourcing to a university by venture firms is not as active as in the United States, Table 2 shows that there is a fear that the minimum critical mass essential for business growth is not available in many cases. This raises the concern that the critical mass needed to successfully cross the Valley of Death cannot be secured.

Figure 4 shows the relationship between the number of current employees at nanotech ventures and the year of its establishment. In the case of the United States, there appears to be no noticeable correlation between the year of establishment and the number of employees, and many companies are grouped within the range of 20 to 50 employees regardless of the year such firms were set up. In the case of Japan, however, the relationship between the year of establishment and the number of employees has shown a falling trend over time, suggesting a growing tendency in recent years in which venture companies are initially established on a small-scale basis, and then gradually expanded as business success is achieved over time.

6 Many Company-Originated Ventures in the United States vs. Large Number of University-Originated Ventures in Japan

Figure 5 compares the number of newly established ventures in terms of the format used in setting up nanotech ventures from the viewpoint of the sources of the core technology and human resources. From this perspective as well, a clear distinction between the United States and Japan is readily apparent.

In the case of the United States, spin-offs from existing companies account for the largest ratio at 35 percent, followed by spin-offs from universities at 29 percent. In Japan, spin-offs from universities represented a large ratio of 39 percent, followed by in-company technology (cases in which the original nanotechnology was developed after establishing a venture) at 31 percent, and spin-offs from national research institutes at 15 percent. Spin-offs from existing companies make up a low 15 percent.

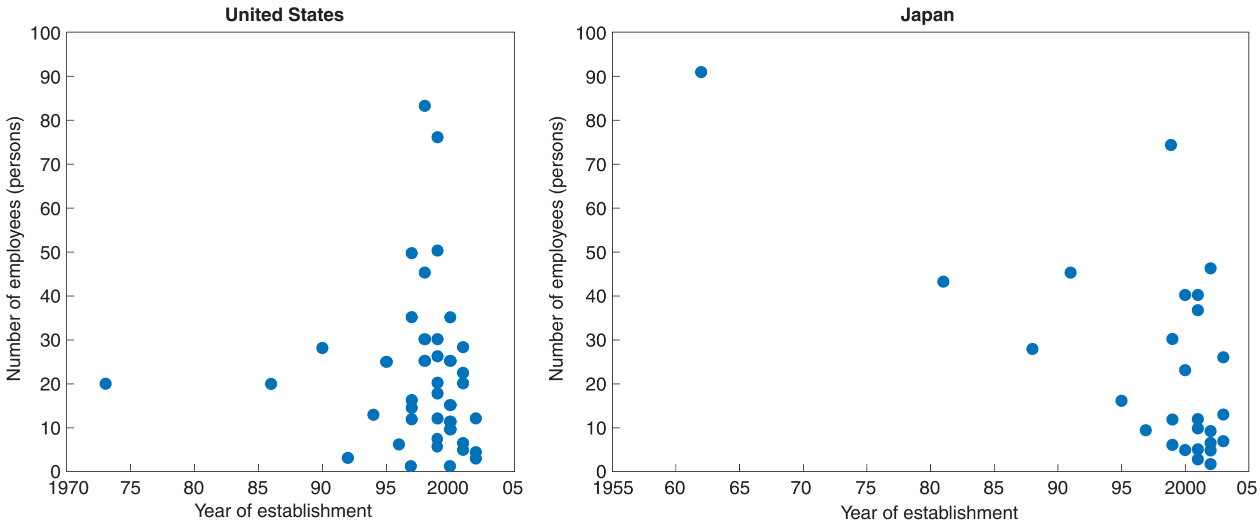
The government target of "establishing 1,000 or more university-originated ventures by 2004" is deemed to have had a major influence on a large ratio of spin-offs from universities in Japan. Sharp increases in the number of small-scale, university-originated ventures may have been the result of sticking too much to the goal of increasing the number of ventures. Furthermore, the reasons behind the limited number of ventures spun off from existing companies could be attributed to the fact that the spirit of pursuing challenges is weak within corporations, or that an environment that encourages the establishment of ventures is not well developed in Japan.

When a new development theme is suspended within a Japanese company, the R&D personnel engaged in the relevant work are usually transferred to another

Table 2. Comparison of Employee Distribution in Nanotech Ventures in the United States and Japan

Number of Employees	US	Japan
50 or more	GENICON SCIENCES CORPORATION FLUIDIGM CORPORATION NANOSTREAM	Nidek Co., Ltd. JASCO Corporation HEPHAIST SEIKO CO., LTD. Optorun Co., Ltd.
20 ~ 49	OPTIVA, INC. QUANTUM DOT CORPORATION NANOOPTO CORPORATION NTERA LTD. NANOSPHERE, INC. NANOTECHNOLOGIES, INC. CHEMAT TECHNOLOGY, INC. ZIA LASER, INC. C SIXTY, INC. CARBON NANOTECHNOLOGIES, INC. NANOMIX NANOMUSCLE SiWAVE, INC. NANOSYS, INC. ALTAIR NANOTECHNOLOGIES INC. IMAGO SCIENTIFIC INSTRUMENTS CORPORATION MATERIALS MODIFICATIONS, INC. NANOINK, INC.	AdvanceSoft Corporation Cluster Technology Co., Ltd. Tokyo Instruments, Inc. Bio Nanotech Research Institute Inc. Cyber Laser Inc. Carbon Nanotech Research Institute Inc. OPTWARE Corporation R-DEC Co., Ltd. LTT Bio-Pharma Co., Ltd. NITRIDE SEMICONDUCTORS Co., Ltd.
10 ~ 19	AVIVA BIOSCIENCES BIOMICRO SYSTEMS, INC. CIMA NANOTECH (NanoPowders Industries) NANOMAGNETICS LTD. NANOVENTIONS, INC. nPOINT, INC. BIOFORCE NANOSCIENCES, INC. CALIFORNIA MOLECULAR ELECTRONICS CORPORATION iMEDD, INC. NANOPLEX TECHNOLOGIES, INC. NANOPOWDER ENTERPRISES, INC. INSERT THERAPEUTICS, INC. ARRYX, INC. NANONEX CORPORATION	LEVEX CO., LTD. Device Nanotech Research Institute EAMEX Corporation Research Institute of Biomolecule Metrology Co., Ltd. Inter Cyto Nano Science. Co., Ltd. Fluidware Technologies Inc.
9 or under	INMAT LLC NANOCHIP, INC. NANOLAYERS ZETTACORE, INC. NANOSPECTRA BIOSCIENCES, INC. ADVANCED DIAMOND TECHNOLOGIES ATOMIC-SCALE DESIGN, INC. NANOVA, LLC. NANOLOGIC, INC. NANOMED PHARMACEUTICALS, INC.	NANO CONTROL CO., LTD. Wyckoff Co., Ltd. Proton C60 Power Corporation DEPT Corporation Tsukuba Nanotechnology Co., Ltd. Oxide Corporation NanoCarbon Research Institute Ltd. Photonic Lattice Inc. Institute of Microchemical Technology Shiratori Nano Technology Co.

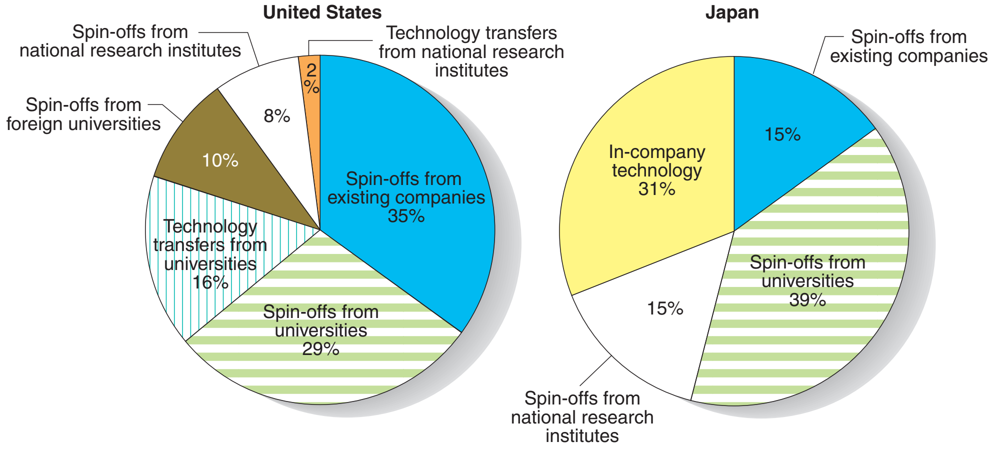
Figure 4. Employees of Nanotech Ventures by Year of Establishment



project within the same company. There are almost no cases in which work on the given theme is continued by those involved by setting up a venture firm through a spin-off from the existing company.

However, this situation has also been undergoing a major change in Japan over the past few years. Although the number of cases is still small, nanotech ventures spun off from existing corporations are starting to

Figure 5. Nanotech Venture Start-Ups by Business Creation Format (Source of Core Technology)



appear, such as the cases of Optware (spun off from SONY) and Cyber Laser (spun off from NEC).

III Selected Nanotech Ventures in the United States

As presented in the previous chapter, the comprehensive comparison of nanotech ventures in Japan and the United States confirmed that the United States is ahead of Japan many aspects. This chapter will look at specific cases of nanotech ventures in the United States whose core technologies have high innovative aspects, and examine the features involved.

1 QUANTUM DOT CORPORATION: Procuring Basic Patents From the Outside and Doing Business Under Applied Patents

The previous section noted the possible synergistic effects between nanotech and biotechnology in starting nanotech ventures in the United States. This venture represents exactly this type of case.

QUANTUM DOT has developed products designed for use in the field of biotechnology that use the quantum effects generated in microstructures whereby the colors of luminous semiconductor nanoparticles change in response to changing the particle size.

The company has adopted a business model in which exclusive licenses for basic patents are obtained from public institutions such as universities and national research institutes, and profits are earned from joint development and contracted development on the basis of such licensing and underlying patent rights. So far, QUANTUM DOT has received exclusive licenses for 22 patents from the University of California, the Lawrence Livermore National Laboratory, MIT (Massachusetts Institute of Technology), the University of Melbourne, Indiana University and the University of Arkansas, etc. Using these patents as the underlying foundation, QUANTUM DOT has applied for more than 90 applied and peripheral patents. In other words, QUANTUM DOT has been procuring basic patents from the outside, and developing the related applied or peripheral patents on its own.

Many of the inventors of these technologies have joined the company's Science Advisory Board. This board also includes professors and assistant professors from MIT, the University of Washington, the University of Melbourne, Stanford University, Kenbridge University, the California Institute of Technology, etc., including Professor Paul Alivisatos of the University of California at Berkeley.

The mechanism by which the company rolls out R&D businesses on the basis of negotiating exclusive licenses to utilize patents held by university researchers—rather than creating businesses around core technologies built on in-house patents—is an idea attributed to the two founders of this company. By drawing on the strength of these exclusive licenses for basic patents and related technological verification work, the company has succeeded in procuring ample funding through a capital infusion of $37.5 million.

It is obviously not easy to achieve the research results that support the granting of basic patents. Accordingly, this technique of first creating a business image and then negotiating exclusive licenses with researchers who own the patents that give substance to the business image has been remarkably effective.

From the standpoint of patent holders, moreover, commercialization is not possible with basic patents only. But by transferring exclusive licenses to venture businesses that are capable of implementing applied research, vast new vistas for potential commercialization opportunities are opened up. This provides researchers with a huge incentive to pursue activities that can link industry and academia. Beyond this, it is also possible to be involved in applied research as a technological adviser and to further participate in the commercialization process itself. The compensation for success in these endeavors also offers an attractive financial incentive.

As noted above, this method of negotiating exclusive licenses for the necessary basic patents and developing peripheral patents that correspond to the business image is a system that offers advantages to both venture capitalists and patent holders, and is highly effective to raising the probability of surviving the Darwinian Sea.

2 NANOSYS, INC: Focusing on the Latest in Quantum Dot Technology

NANOSYS is rolling out businesses related to the latest in quantum dots that are highly evaluated in terms of the innovative aspects of the core technologies involved. The company engages in the development of device manufacturing technology using quantum dots and a bottom-up approach in its applied devices. NANOSYS also adopts a mechanism of procuring basic patents from the outside and developing the related applied patents on its own.

The company negotiated exclusive licenses for basic patents relating to silicon nano-wire FET (field-effect transistors using superfine silicon wire with nanosize diameters), solar batteries, quantum dot lasers, etc., with Columbia University, Harvard University, MIT, the University of California at Los Angeles, the University of California at Berkeley, the Hebrew University of Jerusalem, etc. The company now holds 140 patents including those developed on its own, and has procured some $70 million in development capital on the basis of these patent rights.

While this paper will not deal with the details, all five founders including Mr. Larry Bock, CEO (chief executive officer), have a wealth of experience in creating and operating high-tech ventures. Furthermore, many of the university professors who provided major patents to the company participate in its Scientific Advisory Board. Among them is Professor Paul Alivisatos of the University of California at Berkeley, who is also a science adviser of QUANTUM DOT. Because of the fact that both companies share the quantum dot research results of Professor Alivisatos, NANOSYS has a close relationship with QUANTUM DOT.

3 CARBON NANOTECHNOLOGIES, INC: Representative Example of a University-Originated Venture

CARBON NANOTECHNOLOGIES is a classic example of business creation through university-wide support provided by Rice University and Professor Richard Smalley, winner of the Nobel Prize in chemistry for his discovery of the Buckminsterfullerene. Professor Smalley serves as chairman of the board of directors of this nanotech venture, which was started in 2000 by the current CEO, who has 36 years of experience with a major chemical company, and two co-researchers who resigned from Rice University.

The company's core technology involves the use of lasers in the highly efficient manufacture of hyperpure carbon nanotubes. The firm is now engaged in the mail-order sales and distribution of single-wall carbon nanotubes at $500 per gram and fullerene fluoride at $900 per gram.

A single-wall carbon nanotube is a carbon nanotube that consists of a single-layer carbon molecular film. While multi-wall carbon nanotubes that consist of multiple-layer carbon molecular films are more suitable for purposes such as those that utilize the mechanical functions of carbon nanotubes, single-wall carbon nanotubes are generally more suitable for usages relating to electronics. However, a single-wall carbon nanotubes are difficult to manufacture and quite expensive.

Fullerene fluoride, which is a compound of fullerenes and fluorine, has been the subject of considerable scientific interest, as isomers having structures particular to this substance can be created on a diversified basis if the number of fluorine molecules in the compound is changed. Applied research is under way in the field of nanobearings and nanoball solid lubricants that are based on fullerene fluoride.

Rice University has granted CARBON NANOTECHNOLOGIES an exclusive license for the patent on the consecutive manufacturing technology for single-wall carbon nanotubes by the vapor phase method. Unlike the nanotech ventures previously introduced, however, this company is not procuring basic patents from the outside. CARBON NANOTECHNOLOGIES is a representative case of a university-originated nanotech venture in which the creation of a venture business and the essential university-centered basic research and human resource education have both been achieved in full measure.

Another feature of this company is the extensive range of partnerships that have been established with other companies and universities through the core technology. The fact that the core technology of this company is focused on fundamental manufacturing processes has made it possible to establish multiple partnerships that are said to number more than 300 tie-ups.

With NANOINK, for example, a company that developed a nanolithography technology in which minute patterns are drawn on a surface by using an AFM (atomic force microscope) probe to carry and distribute the ink, joint efforts are under way to develop components that use single-wall carbon nanotubes. The joint development of next-generation polymer products through the realization of improved performance by adding carbon nanotubes to polymers has also been started with another company.

These activities of CARBON NANOTECHNOLOGIES represent cases in which moves to create businesses based on basic technologies invented at a university have led to joint development projects with universities and/or companies, which in turn have vitalized both industries and companies. Supplying high-performance prototypes means laying the groundwork for new product development, regardless of whether new or existing fields are involved, and enabling technological innovation to take place.

4 NANOSPHERE, INC: Including a Partnership with a Japanese Company in DNA Detection Applications

In closing this introduction of nanotech ventures in the United States, I would like to touch on one more university-originated case. Similar to the situation with QUANTUM DOT as previously outlined, this example also involves a business operation in which nanoparticles are being used in biotechnology-focused applications.

NANOSPHERE was founded in 1998 by the president of the Nanotechnology Research Institute of Northwestern University and a professor emeritus of the same university who now serves as a science adviser to the company.

The use of gold nanoparticles for DNA detection constitutes the core technology of this company. This technology was not acquired from the outside, but was invented by the two founders mentioned above. In this regard, the NANOSPHERE situation is similar to that of CARBON TECHNOLOGIES.

Specifically, gold nanoparticles with a diameter of slightly more than ten nanometers are combined with a DNA probe (single-chain DNA fragments marked by fluorescent colors in advance). The existence of the target DNA sequence in the sample can be detected with great sensitivity by using this gold DNA probe. This technology is considered to increase detection sensitivity by more than ten times through the use of the quantum effects generated by nanoscale gold, as compared to the existing methods of using DNA as a probe. Furthermore, more than 100 times greater detection sensitivity can be achieved by chemically sensitizing a gold DNA probe combined with the target DNA base sequence. The process means that detection sensitivity can ultimately be improved by a factor of 1,000 or more over standard methods.

Such remarkably high sensitivity makes it possible to detect SNPs (single nucleotide polymorphisms: meaning a single-site discrepancy among DNA base sequencing) without using PCR (polymerase chain reaction) technology to increase the DNA when analyses are difficult due to the small DNA volume available. As understanding the relationship between such minute discrepancies and a disease makes gene therapy possible, great things are expected from the future development of this technology. The company has already succeeded in raising $24 million in capital funding.

NANOSPHERE, which has made investments in a number of other companies including Japan's TAKARA BIO, INC., has also formed a development and distribution alliance with TAKARA BIO. By means of this partnership, it is expected that TAKARA BIO will be able to develop compact, super-sensitive DNA detection devices by combining its DNA technology and gold nanoparticle DNA probe technology.

As has been previously pointed out, Japanese companies are paying much more in research consignment fees to overseas universities than to domestic universities, and such amounts have reflected a steady growth trend on a year-to-year basis. In essence, such investment by Japanese companies in university-originated nanotech ventures in the United States can be viewed as extending Japan's dependence on overseas research and development.

Indeed, QUANTUM DOT is affiliated with Matsushita Electric Industrial Co., Ltd. and Sumitomo Corporation, and NANOSYS has a development contract with Matsushita Electric Works, Ltd. This means that investments in nanotech ventures that are not university-affiliated are also being made. In terms of the growth of nanotech ventures in Japan, these cases raise concerns over their impact in the future.

IV Identifying Japan's Tasks in Reference to Nanotech Ventures in the United States

In light of the cases so far introduced including the above four companies, this chapter summarizes the features of nanotech ventures in the United States and the tasks facing Japan.

1 Active Challenge of Business Creation From Leading-Edge Technology and Strong Relationships with Universities

As noted in the comprehensive comparison of nanotech ventures in Japan and the United States, a major feature of such undertakings in the United States is that many ventures have technologies with high pioneering or innovative aspects as the core technologies.

Leading-edge technologies in the nanotech field are often created at universities. As a result, there is an increasing number of ventures with high innovative aspects that procure core technologies from universities. Accordingly, such ventures are naturally established under alliances between industry and academia, and a strong relationship is established between nanotech ventures and universities.

In order to successfully establish effective cooperation between industry and academia, an explicit contractual relationship between a venture and a university is required as a premise. And for such a contract to become effective, it is essential that the university hold basic patent rights. In the United States, university professors are keenly aware of patent acquisitions partly due to the effect of the Bayh-Dole Act. Moreover, the system concerning the acquisition and maintenance of patents is well established through the operations of various university-affiliated TLOs (technology licensing organizations). While Japan is also pursuing an increase in the number of university-originated ventures as a national policy, there is much to be learned from the extensive experience of the United States in establishing linkages between industry and academia.

For example, the United States has recently been seeing the emergence of a mechanism in which professors participate in the establishment of nanotech ventures in cooperation with management executives by bringing together multiple basic patents in the related fields—the precursor of which has been observed in some of the cases previously introduced. Such mechanisms also deserve attention, as they do not follow the pattern of rolling out businesses on the basis of specific basic patents, but rather adopt an approach that combines patents that relate to a business image. The involvement of multiple core technologies and various skilled researchers can unleash added strength to respond to changes in the business environment, as compared to relying only on ideas based on specific patents.

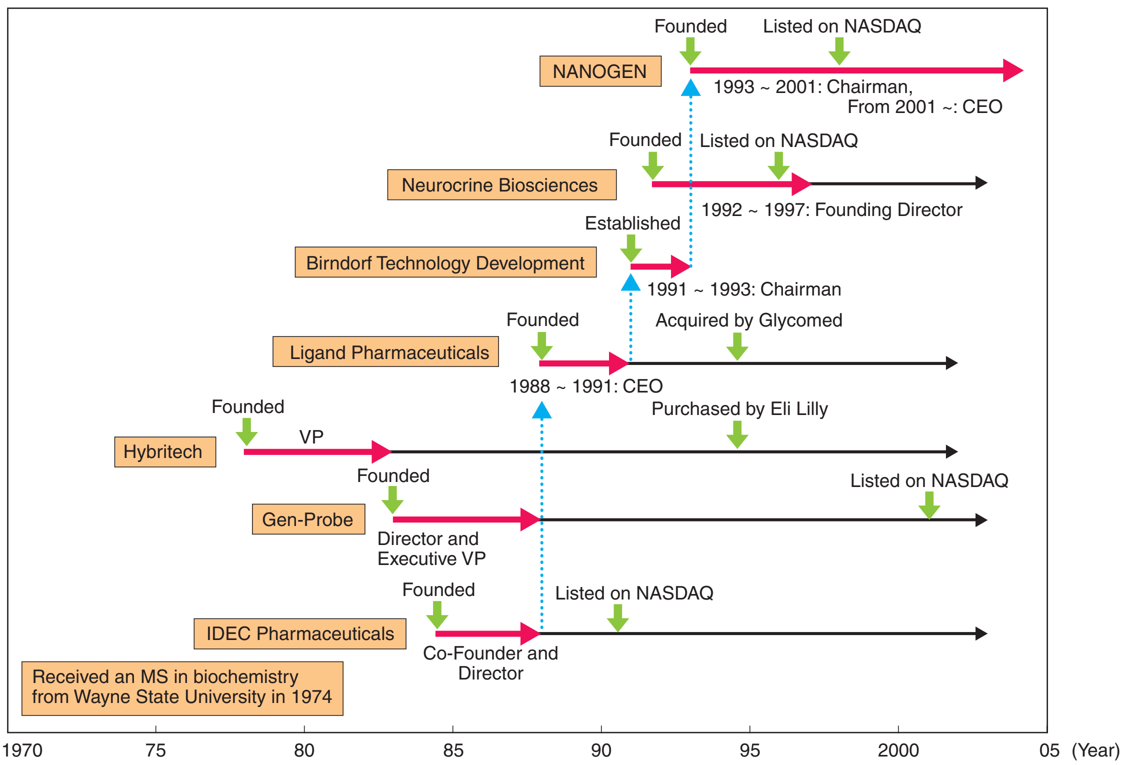
Through the reform of universities in Japan by a shift to independent administrative corporations that is scheduled to take place in April of this year, competition among universities is expected to intensify. In the face of the obvious needs mentioned above, however, greater collaboration by promoting efforts to transcend the borders between universities is needed now even more than in the past.

2 Existence of Superior Venture Management Based on Experience

An essential ingredient behind the establishment and ultimate success of a venture using core technology with high innovative aspects is top-flight management. And university professors with high achievements in basic research are not necessarily skilled in company management. What is needed to bring about effective cooperative relationships between universities and companies and between researchers and management that can lead to successful ventures is the existence of management executives who have accumulated abundant experience and superior management abilities.

The possibility of smoothly building a cooperative relationship with researchers is generally considered to be high in the case of a venture founder whose career also includes experience in working in research and development. In the United States, which has a long history of success in creating new industries by ventures, there are many examples of individuals who have started their careers as a researcher and who have become founders and managers of businesses. The cycle in which a researcher who has a strong will for business creation acquires many opportunities and further accumulates expertise as an entrepreneur has already been amply demonstrated in the United States.

Figure 6. Career of Howard C. Birndorf, Founder and CEO, NANOGEN



Notes: CEO = chief executive officer; VP = vice president.

A representative example can be seen in the case of Mr. Howard C. Birndorf, the founder of NANOGEN (see Figure 6; NANGOEN is not included in Attachment 1, as its stock is already listed and the firm is considered to have gone beyond the venture stage). After receiving an MS in biochemistry from Wayne State University in 1974, Birndorf participated in the establishment of more than seven nanotech ventures in the biotechnology field, four of which have been listed on NASDAQ and two that have been privately sold off.

Fostering such excellent nanotech venture entrepreneurs is also a major task of Japan in the future.

3 The Self-Proliferation Mechanism of Venture Companies

In the United States, many cases are seen in which multiple ventures are created from one core technology and in which new nanotech ventures are born from a nanotech venture. This business creation format differs from what might be called straight-line proliferation (such as when a child is born after the fetus is fully developed), but is closer to a cell-division proliferation in the course of growth. A typical case is shown in Figure 7.

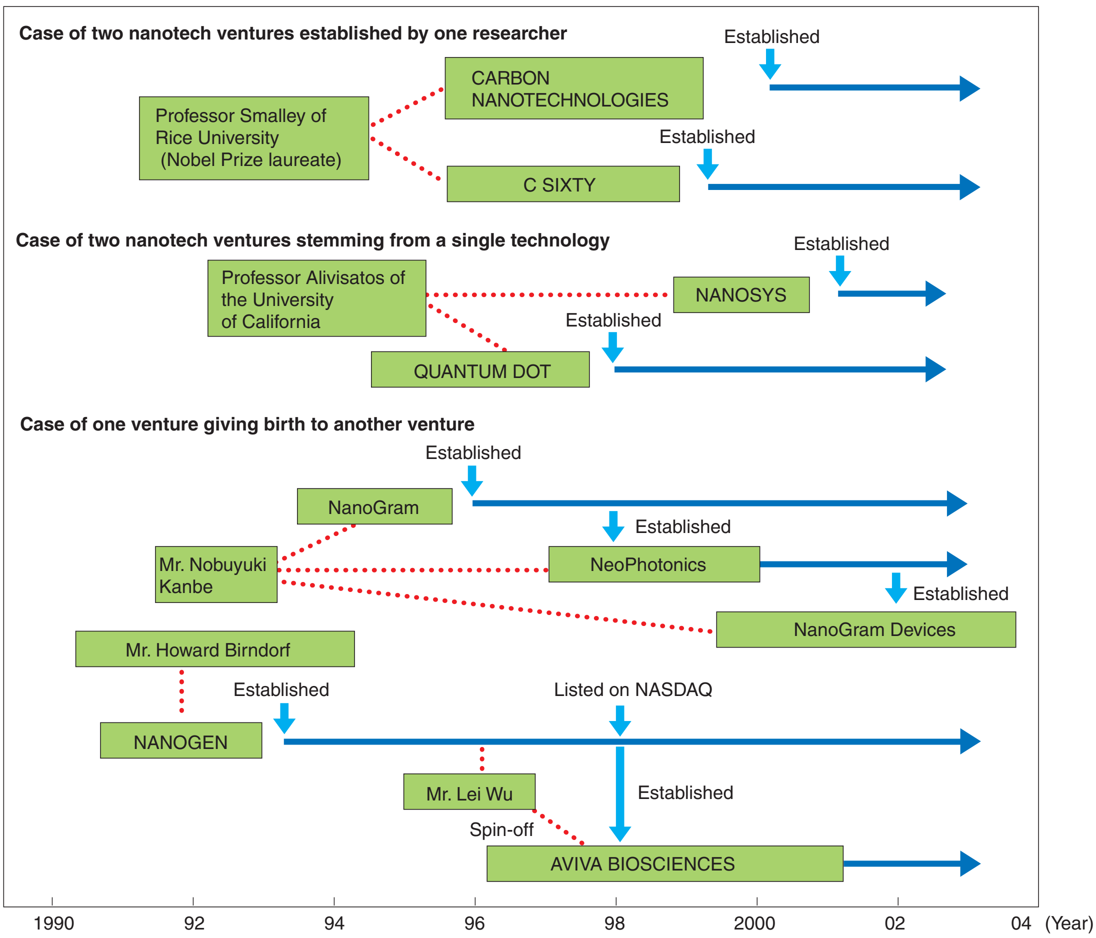
The first case involves one researcher who started two nanotech ventures. Before the establishment of CARBON NANOTECHNOLOGIES that was founded by Professor Richard Smalley and his associates, C SIXTY, INC. was set up in 1999 to work with fullerenes, the discovery of which earned Dr. Smalley the Nobel Prize. As the company name is derived from the fact that the first discovered fullerene is comprised of 60 carbon atoms, the firm engages in the development of fullerene applications—specifically the development of pharmaceuticals using fullerenes.

The next case relates to one core technology that led to the creation of two nanotech ventures. As described in the introduction of specific cases, QUANTUM DOT and NANOSYS were both founded on the basis of quantum dot manufacturing technology invented by Professor Paul Alivisatos and are the representative examples of this case. The former was established in 1998, and the latter was set up in 2001.

The third case concerns the creation of a venture by a venture. Figure 7 introduces two examples, including a firm established in Silicon Valley by a Japanese founder, Mr. Nobuyuki Kanbe.

Mr. Kanbe founded NanoGram in 1996 on the basis of a unique nanoparticle manufacturing technology that employs a laser-based methodology as the core technology. This company has patents on the nanomaterials used for the negative pole of lithium-ion secondary batteries and on solar battery materials. In

Figure 7. Self-Proliferation of Nanotech Ventures in the United States



Attachment 1. Nanotech Ventures in the United States (51 Companies)

Industrial/ Technological Field	Name of Company	Year of Establishment	Number of Employees	Features of Core Technology	Source of Core Technology	Features of Core Business and Products
Biotechnology and healthcare	NANOPLEX TECHNOLOGIES, INC.	2002	12	Nanoparticle bar codes (tags)	A spin-off from a venture engaged in the development of diagnostic and therapeutic technologies	Applied to biochips and tagged compounds for micro-diagnostics
	NANOSPECTRA BIOSCIENCES, INC.	2001	5	Non-invasive cancer therapies and diagnostics using nanoparticles	Technology transfer from Rice University	Applied to DDS, rapid immunoassays, imaging agents, etc.
	INSERT THERAPEUTICS, INC.	2000	11	DDS based on the development of new polymers	A spin-off from the California Institute of Technology	DDS, DDS for gene therapy
	NANOMED PHARMACEUTICALS, INC.	2000	1	Nanoparticle manufacturing technology, including drugs	A venture originated through the University of Kentucky	DDS, radiotherapy, biosensors, etc., using nanoparticles
	AVIVA BIOSCIENCES CORPORATION	1999	18	Biochips for ion channel measurement of cell membranes	A spin-off from Nanogen, Inc.	Disease diagnostics, licensing and sales of diagnostic kits
	C SIXTY, INC.	1999	26	Development of drugs using fullerenes	Established by a professor at New York University	Joint development with pharmaceutical companies
	FLUIDIGM CORPORATION	1999	75	Micro-fluid-chips based on soft lithography	Technology transfer from the California Institute of Technology	Product development for chips that can measure reagents and proteins on multiple and nanogram levels
	IMEDD INC.	1999	12	Nanomembranes for filters produced through silicon wafer processing	A spin-off from a DDS company	DDS and oral DDS using nanoparticles
	NANOSTREAM, INC	1999	50	Microfluidic chips for chemical reactions	In-company technology	Providing pharmaceutical development tools
	GENICON SCIENCES CORPORATION	1998	82	Ultra-sensitive genome assays by resonance light scattering (RLS)	A spin-off from the University of California	Genome assay technologies
	NANOSPHERE, INC.	1998	30	Molecular detection probes using nanoparticles	Technology transfer from Northwestern University	Applied to diagnostics and testing of drug compatibility
	QUANTUM DOT CORPORATION	1998	45	Labeling technology at the cell level using nanoparticles	Lawrence Livermore National Laboratory, MIT, the University of Melbourne, etc.	Applied to various assays using fluorescent labels
	BIOMICRO SYSTEMS, INC.	1997	16	Micro fluid analysis with multiple-level fluid control	Established by a research fellow at the University of Utah	Hybridization licensing, etc.
	BIOFORCE NANOSCIENCES, INC.	1994	13	AFM bioassays	Founded by a professor at Iowa State University	Applications such as gene diagnostics and licensing
Materials	ADVANCED DIAMOND TECHNOLOGIES, INC	2002	4	Diamond thin membrane manufacturing technology (CVD)	A spin-off from the Argonne National Laboratory	Joint development with companies engaged in the development of MEMS, electron sources, etc.
	NANOVA, LLC.	2002	3	Talc and calcium carbonate nanoparticles	A spin-off from Nanomat, Inc.	Mass production of NanoTalc and NanoCalc (product names)
	NANOLAYERS	2001	6	Molecular devices by molecular layer epitaxy	A spin-off from the Hebrew University of Jerusalem	Applied to electro-optical devices (FEDs, etc.)
	NANOSYS, INC.	2001	22	Quantum dot manufacturing technology and applied devices	Columbia University, Harvard University, MIT, etc.	Contracted development, licensing
	CARBON NANO-TECHNOLOGIES, INC.	2000	25	Highly efficient and high purity CNT (carbon nanotube) manufacturing by laser method	A venture originated through Rice University	Manufacturing and sales of SWNT
	INMAT LLC	1999	7	Nanocomposites with extremely low gas transmissivity	A spin-off from R&D Co., Ltd.; technology purchased from DuPont	Coatings using nanocomposites (for defense work)
	NANOTECHNO-LOGIES, INC.	1999	30	8nm to 80nm nanoparticle manufacturing technology (plasma)	In-company technology	Manufacturing nanoparticles of aluminum, gold, aluminum oxide, and titanium oxide
	Nano-Tex, LLC	1998	-	New textile materials using nanomolecules	A spin-off from a major textile manufacturer	Development and licensing of wrinkle resistant fabric, etc.
	CIMA NANOTECH, INC. (formerly Nano-Powders Industries)	1997	15	High productivity nanoparticle manufacturing technology by solid-phase method	Partial spin-off from Russian researcher	Manufacturing nanoparticles (metals, oxides, gel beads)
	NANOMAGNETICS LTD.	1997	15	Protein-based magnetic materials	A spin-off from the Lawrence Livermore National Laboratory	Superhigh-density memory devices (5 ~ 10 terabits per square inch)
	NANOPOWDER ENTERPRISES, INC.	1997	12	Nanopowders for lithium-based rechargeable battery electrodes and high-purity alumina	A spin-off from a company in the same line of business	Development, manufacturing and sales of nanoparticles such as high purity aluminum oxide, titanium oxide, tungsten-carbide, etc.
	NTERA LTD.	1997	35	Manufacture of porous titanium oxide and high-speed ECD technology	A venture originated through the University of Dublin	Such applications as shaded windows, paper quality display, dye-sensitized solar cells
	OPTIVA, INC.	1997	49	Self-assembling crystal optical films	Technology transfer from Russia	Licensing of plastic polarizer for LCDs
	NanoGram Corporation	1996	-	Nanoparticle manufacturing by laser pyrolysis	A spin-off from an existing company	Patents on lithium-ion secondary battery materials and solar cell materials
	NANOMIX, INC	1995	25	CNT manufacturing and new material creation	A spin-off from the University of California	Chemical sensors using CNT, hydrogen storage, FEDs, etc.
	ATOMIC-SCALE DESIGN, INC.	1992	3	Low inductivity materials (diamond-like carbon)	Technology transfer from NASA's Ames Research Center	Joint development

Attachment 1. (Continued)

Industrial/ Technological Field	Name of Company	Year of Establishment	Number of Employees	Features of Core Technology	Source of Core Technology	Features of Core Business and Products
Materials	CHEMAT TECHNOLOGY, INC.	1990	28	Anti-reflective coating via sol-gel technologies	A spin-off from the Swiss Federal Institute of Technology	Alliances, sales of spin-coater, contracted development
	MATERIALS MODIFICATION, INC.	1986	20	Nanopowder consolidation techniques and manufacturing technology (using plasma)	A spin-off from an existing company	Sales of high temperature wear resistant coatings and nanopowder manufacturing devices
	ALTAIR NANO-TECHNOLOGIES INC.	1973	20	Manufacture of titanium oxide and nanoparticle sprays	A spin-off from an existing company	Manufacture of nanoparticles, such as titanium oxide, zirconia, catalyst materials, etc.
Electronics	NanoGram Devices	2002	-	Development of batteries for pacemakers using nanoparticles	A spin-off from NeoPhotonics	Production and sales of built-in batteries for heart pacemakers
	Molecular Nanosystems	2001	-	CVD technology to grow CNT at a designated site	A spin-off from Stanford University	FEDs, gas sensors, chemical sensors, bio sensors, etc.
	ZETTACORE, INC.	1999	6	Superhigh-density, low-power molecular memories	University of California, North Carolina State University	Joint development of molecular memories
	NANOMUSCLE	1998	25	Actuator using shape memory alloy	In-company technology	Alliances with leading manufacturers of automobiles, toys, semiconductors, etc.
	CALIFORNIA MOLECULAR ELECTRONICS CORPORATION	1997	12	Molecular switches	License granted by New York University	Ongoing and joint development of 16-terabit 3-D memories
	NANOLOGIC, INC.	1997	1	New concept for logic circuits and data structures	A spin-off from the Lawrence Livermore National Laboratory	New computers based on nanologic systems
	Nanocrystals Technology Ltd.	1993	-	Discovered nonlinear optical phenomena of artificial atoms	A spin-off from an existing company	Applied to quantum dot lasers, FEDs, bio labels (markers)
Measuring technology and equipment	NANOINK, INC.	2001	20	Nanolithography using AFM	Technology transfers from Northwestern University	Development and sales of software packages
	ARRYX, INC.	2000	10	Laser trap technology	Technology transfers from the University of Chicago	Products developed on basis of laser trap systems
	NANONEX CORPORATION	2000	10	Nanoimprint lithography (NIL) technology	A spin-off from Princeton University	Manufacture and sales of NIL tools, resists, masks, etc.
	IMAGO SCIENTIFIC INSTRUMENTS CORPORATION	1999	20	3-D atom probes	A spin-off from the University of Wisconsin-Madison	Applied to semiconductors and memories, drug creation, creation of new materials
	nPOINT, INC.	1997	14	Nanopositioning and nanomotion	A spin-off from the University of Wisconsin	Design of nanostage, CNT-SPM probes
Optronics	ZIA LASER, INC.	2001	28	Quantum dot lasers	A spin-off from the University of New Mexico	Product development for 1310nm GaAs-based QD lasers that will run uncooled in devices designed for local and metropolitan area networks and 1550nm InP-based QD lasers
	NANOOPTO CORPORATION	2000	35	Subwave optic components by nanoimprinting	Licensing from Princeton University	Manufacture and licensing of polarizers, polarization beam splitters/combiners, etc.
	NANOVENTIONS, INC.	2000	15	Nanoparticles, polymer composites	In-company technology	Forgery-detection tags using nanoparticles with differing optical characteristics
	NeoPhotonics	1998	-	Development of optical integrated circuits by laser reaction	A spin-off from NanoGram	Development and sales of planar optical circuits
MEMS	SiWAVE, INC.	2000	25	Optical switch and fiber sensor integration technology	A spin-off from NASA's Jet Propulsion Laboratory	Optical switches, gyros, pressure sensors, distribution-type sensors
	NANOCHIP, INC.	1996	6	MEMS memories formed on silicon wafers	A spin-off from an existing company	200Gb/in^2 atom-probe ultrahigh-density memories

Notes: AFM = atomic force microscope; CNT = carbon nanotubes; CVD = chemical vapor deposition; DDS = drug delivery system; ECD = electrochromic display; FED = field emission display; LCD = liquid crystal display; MEMS = microelectromechanical system; MIT = Massachusetts Institute of Technology; NASA = National Aeronautics and Space Administration; nm = nanometer; SPM = scanning probe microscope; SWNT = single-wall carbon nanotube.

1998, he founded NeoPhotonics, which develops components for optical integrated circuits using nanoparticles, by recruiting a CEO who had served for 13 years as the sales manager and vice president of another high-tech company.

NanoGram Devices, which was spun off from NeoPhotonics in 2002, has succeeded in increasing the start-up voltage of lithium batteries by more than 1.8 times by using nanoparticles of silver vanadium oxide. Strong expectations are placed on this technology as a built-in battery for heart pacemakers.

The realization of the survival strength seen in these cases is a task that Japan must deal with over time, especially in light of the continuing advances being achieved in the United States in outpacing the progress being made by Japan.

V Suggestions for Nanotech Business Creation

A national consensus is being shaped that sees nanotech as the industrial technology for future development. In support of this trend, a national research and development budget has been allocated to this field on a priority basis, and Japanese versions of the Bayh-Dole Act and

Attachment 2. Nanotech Ventures in Japan (45 Companies)

Industrial/ Technological Field	Name of Company	Year of Establishment	Number of Employees	Features of Core Technology	Source of Core Technology	Features of Core Business and Products
Biotechnology and healthcare	LTT Bio-Pharma Co., Ltd.	2003	26	DDS, targeting therapy (manufacture of lipoic pharmaceuticals)	A spin-off from LTT Research, Co., Ltd.	Licensing of steroid drugs
	Inter Cyto Nano Science. Co., Ltd.	2001	10	Creation of cytokine-based drugs, gene therapy	A spin-off from Osaka University	Drug design based on structural information, 3-D structural analysis
	NanoCarrier Co., Ltd.	1996	-	Testing using DDS, drug creation, development of therapeutic methodologies	A spin-off from the University of Tokyo and theTokyo Medical and Dental University	Plans call for initiating clinical testing of two anti-cancer drugs
	Nidek Co., Ltd.	1971	1,095	Established J-TEC, a company engaged in the development of human cells and artificial skin	Technology transfer from Nagoya University (Professor Minoru Ueda) with respect to artificial skin	New businesses related to artificial skin, eye, and middle ear therapies
Materials	Proton C60 Power Corporation	2003	7	Fullerene modification technology	Exclusive license in Asia for patents on fullerene substances	R&D for fullerene proton-conducting membrane, electrode units
	Shiratori Nano Technology Co.	2002	2	Technologies relating to the manufacturing of organic ultra-thin membranes via layer-by-layer adsorption	A venture originated through Keio University	Manufacturing and sales of preservatives, contracted research on water-repellent processes for vehicle chassis
	DEPT Corporation	2002	6	Technologies relating to self-organization of inorganic materials, and HPC	Originated from the University of Tokyo (Professor Toshiya Watanabe)	Licensing for high performance copper alloys such as wiring materials
	Bio Nanotech Research Institute Inc. (BNRI)	2001	40	Technologies relating to nanoporous materials with nanocavities	In-company technology, technology transfer from the National Institute of Advanced Industrial Science and Technology (AIST)	Total membrane separation processes, membrane reactors
	Carbon Nanotech Research Institute Inc. (CNRI)	2001	37	Technologies relating to commercialization of fullerenes and CNT	Technology transfers from affiliated universities	Industrial commercialization technologies for fullerenes and CNT
	Clean Venture 21 Corporation	2001	-	Development of spherical micro silicon solar cells	A spin-off from the University of Tokyo and Ritsumeikan University	Business development for spherical micro silicon solar cells
	NanoCarbon Research Institute Ltd.	2001	5	Technologies relating to the manufacturing of low-price fullerenes	A spin-off from Toyohashi University of Technology	Development, manufacturing and sales of nanocarbon materials
	Frontier Carbon Corporation	2001	-	New fullerene manufacturing method (combustion method)	Manufacturing method of MIT in the US, etc., substance patent held by RCT in the US	Manufacturing and sales of carbon products such as fullerenes
	Oxide Corporation	2000	5	Stoichiometric optical crystal (lithium niobate) growth technology	A spin-off from the National Institute for Materials Science	Manufacturing and sales of opt-electronics single crystals
	Millenium Gate Technology CO., LTD.	1999	-	Powder particle (5 microns or more) metal surface processing	In-company technology	Manufacturing and sales of metal detergent and metal surface processing products
	SiXON Ltd.	1998	-	Established high-quality, low-cost mass-production technology for silicon carbide	A spin-off from Stanford University in the US	Manufacturing and sales of silicon carbide
Electronics	AdvanceSoft Corporation	2002	46	Development of analytic simulation software	Established with the University of Tokyo (a MEXT project) as the base	Marketing products produced for trial programs developed by the university
	NITRIDE SEMICONDUCTORS Co., Ltd.	2000	23	Technology relating to epitaxial growth using bulk GaN substrates	A venture originated through the University of Tokushima	Development, manufacture and sales of ultraviolet lasers
	NANOTECO CORPORATION	2000	-	Technologies relating to HBT epitaxial growth and device design	A venture originated through the Electro-Communications University	Contracted manufacture of various electronic devices and epitaxial substrates
	Japan Gain the Summit Co.,Ltd.	1996	-	Technologies relating to CNT solar cells and color identification	In-company technology	Planning, development and contracted development of various application software
Measuring technology and equipment	NanoPhoton	2003	-	SHG microscope	A venture originated through Osaka University	Development and sales of “SHG-11” microscope
	NANO CONTROL CO., LTD.	2002	9	Coarse and fine integrated actuators	A spin-off from the University of Tokyo (JST10 preliminary venture)	Manufacturing and sales of impact drive actuators, piezo and air impact drive positioner
	X-ray Precision, Inc.	2000	-	Compact X-ray sources with built-in power	In-company technology	Development, manufacture and sales of X-ray equipment
	Optorun Co., Ltd.	1999	74	Ion-assist deposition devices for optical thin film	In-company technology	Manufacture and sales of devices to create narrowband pass filters for WDM
	Research Institute of Biomolecule Metrology Co., Ltd.	1999	12	Technologies relating to visualization and measurement of biomolecules by AFM	A spin-off from the National Institute of Advanced Industrial Science and Technology (AIST) (Atom Technology Group)	Sales of protein visualization equipment and intermolecular force microscopes
	Tsukuba Nanotechnology Co., Ltd.	1999	6	Technologies relating to TOF/SIMS and nanoparticle creation	A venture originated through the University of Tsukuba (based on work of Professor Sang-Moo Lee)	Sales of cluster ion sources and nanoparticle manufacturing devices
	Wyckoff Co., Ltd.	1997	9	Measurement of particle diameter distribution for porous acid nanoparticles (DMA)	A RIKEN venture	Manufacture and sales of DMA
	CRESTEC CORPORATION	1995	-	Technologies relating to electron beam lithography with an address size (beam positioning resolution) of 0.0012nm	A spin-off from an electron beam lithographic device company	Sales of high-resolution electron beam lithographic systems and contracted lithography

Attachment 2. (Continued)

Industrial/ Technological Field	Name of Company	Year of Establishment	Number of Employees	Features of Core Technology	Source of Core Technology	Features of Core Business and Products
Measuring technology and equipment	LEVEX CO., LTD.	1995	16	Compact positioning sensor with the size of a propelling pencil core	A spin-off from a major company	Applied to robot arms (magic hands)
	Cluster Technology Co., Ltd.	1991	45	Nanoprocessing using ion-beam convergence	In-company technology	Ink-jet method DNA chip manufacturing system
	R-DEC Co., Ltd.	1988	28	Vacuum components, low-price R-HEED systems	In-company technology	Development, manufacture and sales of hyper-vacuum devices and chemical analytical devices
	Adtec Plasma Technology Co., Ltd.	1985	-	Total solutions for plasma devices	In-company technology	Design, manufacture and sales of equipment related to semiconductor plasma devices
	Tokyo Instruments, Inc.	1981	43	Microspectroscopy system for 3D nanometer scale imaging, FS laser processing	In-company technology	Development, manufacture, imports and sales of optoelectronics products
	ELIONIX INC.	1975	-	Electron, ion and x-ray application devices	In-company technology	Products include electron beam lithography systems, plasma units, etc.
	HEPHAIST SEIKO CO., LTD.	1962	90	Special linear and spherical bush bearings	In-company technology	Development of linear ball bearings, maximum-flexibility positioning devices
	JASCO Corporation	1958	268	Optical measuring instruments, SNOM, etc.	SNOM technology transfer from the Tokyo Institute of Technology (Professor Motoichi Ohtsu)	Near-field nanocarbon evaluation, supercritical crystallization systems
Optronics	Photonic Lattice Inc.	2002	5	Photonic crystal manufacturing using autocloning technology	A venture originated through Tohoku University (JST preliminary venture)	R&D and technology transfer for polarization splitters, polarizers, waveplates, etc.
	Cyber Laser Inc.	2000	40	FS lasers, LD pumped compact ultraviolet lasers, etc.	A spin-off from NEC	Manufacture, sales system development and contracted development of lasers
	Photonic Science Technology, Inc.	2000	-	Vibration Sensor using super fine optical fibers	A venture originated through the Chitose Institute of Science and Technology	Optical circuit components (rounded-end optical fibers, vibration sensors)
	OPTWARE Corporation	1999	30	Polarization collinear hologram optical memory devices	A spin-off from a major company	Licensing for media evaluation devices, etc.
MEMS	Device Nanotech Research Institute, Inc (DNRI)	2003	13	Nanoimprinting, RF-MEMS, etc	Technology transfer from the National Institute of Advanced Industrial Science and Technology (AIST)	Development of world's first nanoimprinting device for mass production
	EAMEX Corporation	2001	12	Ion conductive actuator, conducting polymer actuator	A spin-off from AIST (Researcher Keisuke Oguro)	Development of artificial muscles, artificial fish, robot hands, and active catheters
	Nano Device and System Research Inc.	2001	-	Micromachining technology such as X-ray lithography	A venture originated through Ritsumeikan University (Professor Susumu Sugiyama)	Contracted development, creating trial service environments, data analyses
	Fluidware Technologies Inc.	2001	10	Imprinting and microfluidic devices	A venture originated through the University of Tokyo	Development and licensing for microfluidic devices
	Institute of Microchemical Technology	2001	3	Design and development of microchemical chips	A spin-off from the University of Tokyo (KAST project)	Development and sales of integrated glass chips and photothermal microscopes
	MEMS CORE CO., LTD.	2001	-	Three-inch wafer process	A spin-off from Tohoku University (Professor Masayoshi Esashi, Professor Kazuhiro Hane)	MEMS trial foundry (acceleration sensors, optical encoders)

Notes: DMA = differential mobility analyzer; DNA = deoxyribonucleic acid; ECD = electro chromic display; FS = femtosecond; GaN = gallium nitride; HBT = heterojunction bipolar transistor; HPC = high-performance copper (i.e., low resistance, non-corrosive, non-oxidizing up to 750℃); JST = Japan Science and Technology Agency; KAST = Kanagawa Academy of Science and Technology; LCD = liquid crystal display; LD = laser diode; RF-MEMS = radio frequency microelectromechanical system; R-HEED = reflection high-energy electron diffraction; SHG = second harmonic generation; SNOM = scanning near-field optical microscope; TOF-SIMS = time-of-flight secondary ion mass spectrometry; WDM = wavelength division multiplexing; MEXT = Ministry of Education, Culture, Sports, Science and Technology.

the SBIR program have been introduced. Moreover, nanotech venture capital has started to come into its own. Through these overtures, Japan's nanotech research and development as well as the environment for the creation of businesses based on these results have been significantly improved of late. For scientists who have embarked on research in nanotech-related fields, it is relatively easy to secure research budgets, making it much easier than before to safely cross the Valley of Death, which has long been considered a major obstacle to business creation.

As illustrated up to now, however, there are a number of tasks that must be properly dealt with to pursue these developments. The following section classifies the various issues that are considered necessary for the further development of nanotech-related businesses into three major tasks.

1 Comprehensive Vision and Concentrated Input of Resources

Although the overall environment has been improved, it is not easy to inaugurate new businesses that can compete in the nanotech field. In creating a business related to nanotech, a comprehensive vision ranging from the technological seeds to the business as well as the specific plans to realize the given objectives must be developed under a clear recognition of the difficulties involved.

Of course, it is not necessary to implement all processes up to the creation of the business by one company alone. Indeed, this is most often impossible. Rather, even matters that could be handled internally should be actively outsourced if there is a major entity on the outside that is more suited to pursue a given matter than the company itself. In short, outsourcing should be utilized as much as possible for those things that can be handled on the outside, and internal resources should be concentrated on the company's core competence.

Accordingly, issues and themes that are not handled by the company itself should also be included in the plans. And naturally, the contents and extent of outsourcing should also be included in the plans. Outside procurement should be a carefully considered and well-planned activity, rather than relying simply on good fortune to obtain a core technology.

2 Creation and Cultivation of Competitive Seeds

Without the seeds that can adequately compete in the face of existing technologies, success in business creation will never be possible. Japan's many in-company research institutes have started to withdraw from the basic research that gives birth to these new seeds, and this trend is likely to accelerate even further in the future. Moreover, the links now being forged between industry and academia are apt to further push university-based R&D activities towards applied research. Yet it must be fully recognized that the essential role of university and public research organizations is the promotion of basic research, and the mission of such organizations in creating competitive seeds must be adequately fulfilled.

Private-sector companies should make efforts to discover and cultivate the seeds that are accumulated in universities, etc. The seeds of innovation often emerge from fields other than existing technologies. In other words, the research results that are not a straight-line extension of existing proprietary technologies may become necessary for the future of the company's existing business. In light of this possibility, systems that permit the implementation of joint industry-university research covering a wide range of fields without any specific or specified focus should be encouraged. Such systems are being implemented on a trial basis between some companies and universities. This will likely prove to be the path to uncovering promising development seeds within university research programs.

3 Providing Ample Venues to Match Seeds with Needs

It is the true matching of seeds with needs that is the key to success in business creation. With respect to new seeds, applied research will start and/or high-tech or nanotech ventures will be established when needs that correspond to such seeds are discovered. In short, venture firms serve as the venues to ascertain whether seeds are truly compatible with needs.

As pointed out in this paper, the ratio of nanotech ventures originated in the private sector is low in Japan. If the QUANTUM DOT and NANOSYS cases are taken into account, the fact that the number of corporate spin-offs is limited also means that the opportunities for utilizing licenses to basic patents are also limited—a fact that would suggest that the basic patents and equivalent intellectual properties owned by universities are being hoarded.

One telling observation comes from an analysis of results uncovered by the OECD (Organization for Economic Cooperation and Development): it appears that while innovations are continuously taking place in Japan, value creation from such innovations and contributions to economic growth are not moving forward.[5] One of the reasons for this shortfall apparently stems from delays in creating value from intellectual properties owned by universities, etc. In order to avoid the loss of opportunities in the course of creating value, it is therefore necessary to provide ample venues to promote the matching of seeds and needs. The private-sector companies that stand at the side of needs should play major roles in this regard. Moreover, with respect to the seeds accumulated within a company itself, venues to match such seeds with needs should also be actively developed.

A major responsibility of the private sector should be to pursue such activities in fostering and providing management resources with abundant experience in business creation for high-tech challenges, including those in the nanotech area. This also means the development of human resources that are capable of understating both the technologies and the market, and which can marshal the judgment needed to pursue the creation of high-tech business ventures.

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