Spotlight on **Sendai**

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This is part of a continuing series profiling companies and institutes in specific regions.

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CITY OF SENDAI

Japan's other research hub

The city of Sendai has much to offer research and industry, but, says **David Cyranoski**, competition for funding and brains is stiff.

Particle physicists in Sendai (top) have led international work on the high-calibre KamLAND antineutrino detector.

LAWRENCE BERKELEY NATIONAL GALLERY

In Japan, Sendai is known for its lush greenery, its nearby hot springs and its beef tongue. Outside Japan, it is hardly known at all. Sendai has long lived in the shadow of the Tokyo/Yokohama hub in the Kanto plain and the Osaka/Kyoto/Kobe triangle that anchors the Kansai region. But it has been responsible for seminal advances in materials science, microelectronics and particle physics. Its researchers, particularly those at the city's core institution, Tohoku University, have a track record for turning basic science into practical, profitable applications. And the university's involvement with world-class facilities, such as the KamLAND antineutrino detector at Kamioka, attract international attention. Meanwhile, local initiatives are helping to attract companies and bring scientific understanding to the public.

All Japanese universities are facing increasing competition and expectations to find practical applications for their basic research. For Sendai to carve a niche, Tohoku University and its neighbouring research institutions will need to work closely with the local business community, launch new projects that bring global collaboration, and overcome the obstacles that make it harder for women (see 'Women's work') and Westerners to work in Japan.

Sendai already has a solid foundation on which to build, says Richard Dasher, director of the US–Asia Technology Management Center at Stanford University, California. The Sendai region boasts 13 universities, 5 junior colleges and 2 technical colleges. Overall, these have a total of 80,300 students. Tohoku University alone has more than 2,600 research and teaching staff, some 85% of whom work in the sciences. "If the research there was happening in Tokyo or Kyoto, it would be getting a lot more press," says Dasher.

Competition for the best brains is growing, as the number of students entering Japanese universities has dropped. A nationwide reorganization of the university system in 2004 (see *Nature* **429**, 210–214; 2004) has made it easier for faculty members to move from one institution to another, and for universities to compete for funds. The economic and industrial threat of China and other neighbours also looms, says the city's new mayor, Katsuhiko Umehara. "Global competition is becoming tougher and tougher, so Sendai will need to have a good strategy to compete with other cities, not only in Japan, but also in east Asia and the rest of the world."

However, Sendai has some advantages over its more prominent neighbours. A bounty of trees provides an alternative to the concrete and neon of other Japanese metropolises. It is only a two-hour bullet-train journey from Tokyo, but the buffer zone this distance creates provides the perfect setting for creative work, says mathematician Motoko Kotani. "Somehow, in Tohoku,

Sendai's mayor, Katsuhiko Umehara, is aware that the city faces tough competition from high-tech hubs within Japan and around the world.

I feel time goes slowly and quietly, and people can keep some distance from current trends. You can wait patiently for your idea to ripen," she says.

Tohoku University's greatest competitive advantage is its tradition of successful applied research. In the 1920s, two Tohoku University professors invented the Yagi-Uda antenna. This has many applications, one of the most recognizable of which is as a roof-top television antenna. And research dating back to the 1950s led to the development in the 1970s of perpendicular magnetic recording, a technology that is now poised to revolutionize hard disk drives with its tremendous memory capacity.

Ahead of the game

Many current research projects hold great, if underdeveloped, potential for future industrial application. Researchers at the university's best-known research organization, the Institute of Materials Research (IMR), are trying to turn expertise in collecting and analysing data on combinatorial materials into a new field called materials informatics.

Hideo Ohno, who heads the university's Laboratory for Nanoelectronics and Spintronics, says the key to these Tohoku achievements has been a tradition of going back to the fundamentals in parallel with working closely with industry. Ohno's own discovery — that electricity can be used to control the magnetic properties of semiconductors — led to the development of low-power-consumption semiconductor devices. "Researchers are aware of the needs of those outside academia even though they are working on basic research," he says. Likewise, Tadahiro Ohmi's Fluctuation-Free Facility for Information Industry lists a dozen core companies that are participating in his efforts to develop malfunction-free sub-100-nanometre semiconductors and other semiconductor technologies. "We try to stay 15 years ahead of industry, as we will be leading it into the future," says Yasuyuki Shirai, an assistant professor at the facility.

City-wide, regional and international collaborations are trying to make the most of this cutting-edge research. In 2002, the education ministry designated Sendai an 'Intelligence Knowledge Cluster' as part of an initiative that gives the city about ¥500 million (US$4.35 million) per year for five years to develop 'intelligent electronics'. The dozen joint-research projects between industry and Japanese corporations are aimed directly at society's welfare — for example, monitoring devices that accurately estimate energy consumption to help in the treatment of diabetic patients. Some of these projects are expected to boost the Sendai–Finland Wellbeing Center, a collaboration established in 2005 to promote the self-reliance of one of Japan's largest and fastest growing markets — the elderly. The 12 research projects are dominated by Tohoku University researchers, but two projects are being led by Sendai National College of Technology and one by Tohoku Institute of Technology.

Gathering steam

The trade ministry is also funding regional cluster programmes. Since 2001, it has given about ¥700 million per year to a project involving hundreds of academic organizations and small to medium-sized businesses that endeavours to turn successful academic work into commercial technologies aimed at helping Japan's ageing population. About ¥380 million per year has been allotted to a similar consortium of academic and industrial organizations looking for technologies to promote a sustainable society.

Some supporting mechanisms are already in place. The Intelligent Cosmos Research Institute has had some success in attracting research and development companies to the region since 1989. In 2004, the ¥3.2-billion Tohoku Incubation Fund started investing in university ventures. Sendai city is also converting an 81-hectare golf course into a science park in the hope that 50 companies, from inside and outside Japan, will set up business there.

WOMEN'S WORK

Mathematician Motoko Kotani (pictured) rose to fame in Japan without facing much discrimination. But a star female researcher is still a rare event in Japan, and Kotani and others at Tohoku University have set out to level the playing field.

At present, 11.9% of Japanese scientists are female, a figure well below that of most industrialized countries. The central government has struggled to take greater advantage of female brainpower with various policies, but so far results have been modest.

Kotani, who is involved in an initiative to help Japanese women scientists advance their careers, says the key is helping women over certain stumbling blocks. These include encouraging female students to consider a career in science, helping researchers balance the demands of childbirth and child rearing with their careers, and ensuring that women do not feel overwhelmed by their minority status.

Tohoku University has historically been a leader. In 1913, it became the first of Japan's imperial universities to allow female students. In 2002, it established the Sawayanagi Prize, which is awarded to a successful research collaboration between women and men.

But Tohoku University remains below the national average: only 7.7% of faculty members, and only 6.3% of science faculty members, are female. Starting this year, Tohoku established policies to change this. Nurseries have been set up to care for children, and provide medical treatment when children are sick, and part-time workloads and support staff are available to working mothers.

Most notably, Tohoku University has established the 'science angels', a group of 40 graduate students who visit schools and encourage students to become scientists, thereby providing much-needed role models. The science angels also work to bring women at the university together.

The goal is to have women make inroads at all levels. By 2020, for example, they hope to have 30% of all committee seats and senior positions filled by women.

Kotani, who last year won Japan's Saruhashi Prize, which recognizes the work of Japanese women in science, says the solitary, theoretical nature of her research might have helped her avoid the more egregious forms of discrimination that a woman on a large experimental team might experience. "In maths, you don't need any facilities — only talent — and you are judged by what you have done alone," she says. She hopes the Tohoku project will extend this freedom to all Japanese women scientists. **D.C.**

But it remains unclear how much the local economy or Tohoku University will benefit from even the highest-impact research. Venture-capital support for local businesses lags behind that of other research hubs such as Osaka. Many scientists are happy to stick to basic research questions or collaborate with researchers far and wide — neither of which contributes to building a foundation for local industry. The semiconductor fabrication research at Ohmi's laboratory has been tremendously influential since the 1980s, but has generated little profit for the university as the group has tended to share their protocols freely with others in the field. "We want the technology to be used anywhere that researchers can take advantage of it," says Shirai.

Liquid asset

Access to some unique facilities is another of Sendai's great draws. Tohoku particle physicists, for example, have led an international collaboration of scientists from 13 institutions on the KamLAND antineutrino detector. The detector has a 1,000-tonne tank holding a liquid whose molecules emit light when antineutrinos collide with them. KamLAND is 400 kilometres from Sendai and is buried in an old mine shaft to screen out other subatomic particles. Machines as extensive and well-protected as this are rare, with only a handful worldwide, and this team has taken advantage of its location to discover new aspects of antineutrinos emitted from Japan's various nuclear reactors. The team has developed the field of neutrino geophysics, which uses the detection of antineutrinos released by radioactive elements within Earth to answer questions about Earth's heat balance.

The microelectromechanical systems (MEMS) facilities headed by Masayoshi Esashi also draw international and domestic researchers. But many of the 350 researchers — including 20 foreigners — who have come to Sendai from 39 labs are hoping for profit beyond publication. Esashi says that 35 years of experience is being brought to bear on MEMS, which integrate sensors and other electrical equipment on a single chip. "The knowledge is managed to be accessible, which I think should be the mission of the university," he says.

These ties give good reason for Sendai to be optimistic about possible industrial applications.

The tranquil surroundings of Tohoku University offer a perfect setting for creative thought.

TOHOKU UNIVERSITY

Esashi has spun off a company called MEMS Core, and a 'MEMS Park Consortium', which was established in 2004 with Sendai's assistance, has gathered more than 110 members.

"In a university system increasingly being modelled on the US system, some natives still find the Japanese way a boon to research."

And in a university system increasingly being modelled on the US system, some natives still find the Japanese way a boon to research. "People do not move from company to company in Japan, so companies do not mind dispatching them to the university. They will come back," says Esashi. "We are taking advantage of Japanese work habits to get a good collaboration."

Researchers are also buoyed by positive support from the community. Being recognized and accepted as a scientist makes adapting to life in Japan easier, says Alexandre Kozlov, a Russian-born Australian neutrino researcher (see 'At home in Sendai').

The city of Sendai has worked with the university to cultivate this awareness. A monthly science café is held in the architecturally innovative Sendai Mediatheque, a seven-storey structure with irregular tubes running through it that house elevators and staircases. The monthly events introduce researchers' work to the hundred or so high-school students and other local residents that show up. Kotani's lecture was introduced by Sendai's mayor, who discussed the significance of mathematics using Fermat's theorem as an example.

Dasher is concerned that, despite support from the city and Sendai's various attractions, many students leave the Tohoku region for industry jobs in Tokyo or Osaka after a BS or MS degree. He thinks that changes in Japan's economy will enhance the value of PhD holders and university research in general — drawing more attention from students and industry alike to Tohoku University's fields of expertise.

If predictions prove right, Sendai and Tohoku University will shine. Dasher, who now works as a special adviser to the president of Tohoku University, says: "It reminds me of Silicon Valley before it became known as Silicon Valley." ■

David Cyranoski is *Nature*'s Asia-Pacific correspondent.

AT HOME IN SENDAI

Japan has a reputation for being a difficult place for non-Japanese scientists to work, in terms of language, culture and the different ways in which research is organized. But some outsiders have adapted to Sendai.

Richard Smith, a supercritical-fluids specialist at Tohoku University, has taught physics classes in English with some success. "The students study hard — if you give them the materials beforehand, they will come prepared," he says.

Daily life necessities, such as English-speaking doctors, are also accessible, says Alexandre Kozlov, a Russian-born Australian neutrino researcher whose second child was born in Japan. Kozlov says it was a joy to work in the orderly and efficient Japanese group on the KamLAND neutrino projects. "Each member could have done various parts of the experiment, but they each knew their role and did it well," he says.

Rather than being a barrier, some foreign researchers say the cultural aspects are a big draw. Smith says the *koza* or chair system, in which a strict hierarchy is maintained in the laboratory, is an essential foundation for mutual support and mentoring among his junior faculty and students. "They wouldn't know what to do without it," he says. **D.C.**

Chapter1: Sendai – City of Trees

A blend of natural beauty, urban convenience and pioneering science

The excellent quality of life and research environment attract highly motivated scientists and innovators to Sendai City in the 'four seasons region'

Approximately 100 minutes north of Tokyo by the Tohoku shinkansen bullet train, Sendai city in the heart of the Tohoku region of northeastern Japan, offers a balanced mixture of natural beauty and the sophistication of a modern, lively city.

The climate of the Sendai area is moderate; its average temperature is 12.1°C (Year), 21.5°C in summer (Jun.-Aug.), 2.5°C in winter (Dec.-Feb.) and annual precipitation is 1,242mm. Japan is well known for its beautiful four seasons. In Sendai and Tohoku region, trees in mountains and on roadsides display impressive colour changes signaling the transition of autumn to winter. Throughout the year, there is a wide choice for local excursions including hot springs, ski resorts and Matsushima bay with views of over 200 tiny pine-clad islets, recognized as one of the three most beautiful sights in Japan.

These advantages have made the city one of the most popular places to live in Japan. With a population of more than one million, Sendai is the 11th largest city in Japan with a vibrant economy reflecting the creativity of its residents.

For 400 years, Sendai has flourished as a city of entrepreneurship and culture after Lord Date Masamune, one of Japan's most famous feudal lords and also renowned for his excellent cultural background of poetry and tea ceremony, laid his foundation here in 1601. In the early 17th century, Date was also internationally active by sending a diplomatic mission to Europe to promote trade.

Sendai is a prosperous commercial and academic city. Looking to the future, the city is encouraging even more research-oriented companies to locate in the region and strengthen the local economy. As part of its efforts, the city promotes the growth of SMEs, technology transfer to the business sector and international collaboration.

"Life here is easy-going and living expenses are moderate. That's why I believe it is an environment suited for creative work," Nobel laureate Robert B. Laughlin told the SENDAI NEW newsletter. Laughlin, a professor at Stanford University and winner of the 1998 Nobel Prize in Physics, has been involved in joint work in Sendai with Tohoku University researchers.

The prestigious Tohoku University, one of the academic and research institutes in this region, has been the focal point of the city's technological creativity and innovation for the past 100 years. Symbols of Date can be found at the site of Sendai Castle in Aobayama, where the university's main campuses are also located. And the campuses house botanical gardens where rare plants can be found that have thrived through 400 years, since Date preserved the area.

To meet the increasing demands for new research facilities, Tohoku University will relocate some of its departments and research facilities to the new Aobayama campus (see page 14), which is just 20 minutes by car from Sendai Station in the city's downtown area.

The high quality of life and the internationally recognized scientific excellence attract many researchers from all over the world. Tohoku University quietly lets its researchers concentrate on long term projects without being influenced by short term trends. The university's stance has led to numerous innovative ideas and findings.

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Jozenji Street, Sendai City

City of Sendai *www.city.sendai.jp/index-e*
Tohoku University *www.tohoku.ac.jp/english*

Chapter2: Pioneering fundamental research to benefit the global scientific community

Tohoku University's priorities are research and education for the benefit of society. Situated away from the capital, it provides a favorable research and education environment. Extensive fundamental research has been conducted and the results returned into the public domain.
This section describes examples of fundamental research being conducted at Tohoku University to contribute to the world body of scientific knowledge.

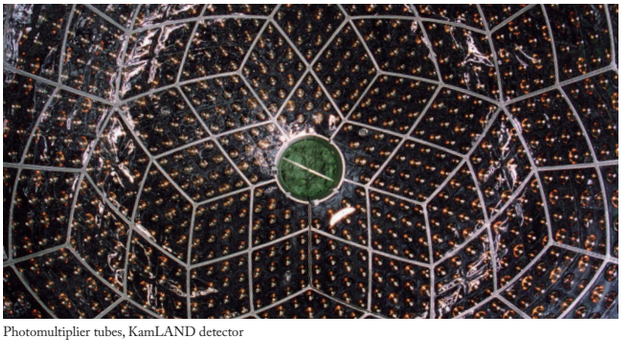
The device that keeps measuring and measuring ...

The KamLAND antineutrino detector was designed to study a central question in particle physics. But like the best of scientific devices, it is showing itself to be adaptable for a wider variety of uses. A team of Tohoku University scientists is leading it through a very beneficial scientific evolution.

In 2005, earth scientists got a boost from an unlikely source. The KamLAND detector, buried one kilometer beneath Kamioka, Japan, detected geoneutrinos, which result from radioactive decay within the earth. The discovery makes possible new ways to determine the structure of radioactive elements within the earth and thus provides a valuable tool to estimate the balance of heat there.

But KamLAND was designed for another purpose – particle physics – and it already had an impressive track record in this previous role. In January 2002, the detector started taking data on collisions of antineutrinos shooting out from seventeen Japanese sites with protons within KamLAND's 18 meter diameter tank.

The result was published in *Nature* and the paper was featured on the cover [*Nature* Vol.436, P.499-503, 2005].



Photomultiplier tubes, KamLAND detector

Staff of the KamLAND facilities

The paper was number one on the Thompson ISI impact factor listing in September and October 2003.

Since then, an international team led by Tohoku University researchers and including scientists from the United States, China and France, has put together a string of papers showing that antineutrinos can change from one variety to another. KamLAND has added further weight to the theory of and precision to the measurement of neutrino mass. Whether or not they have mass has been a longstanding controversy within particle physics.

"It was not, however, enough to just understand the anti-neutrinos," says Kunio Inoue, professor at Tohoku University's Research Centre for Neutrino Science. Inoue has led a team that witnessed for the first time antineutrinos from deep earth elements, such as thorium and uranium. The experiment is creating a map of the distribution of these radioactive elements. KamLAND will push forward our knowledge of fundamental processes helping scientists to understand how heat is transferred deep inside the earth, such as in mantle convection. "Geochemists have not been able to explain the heat distribution in the deep earth that causes basic earth processes, but this will help," says Inoue. "This is the first step towards neutrino geophysics."

Already work is underway to increase the sensitivity of KamLAND so that more precise deep earth measurements can be made. Inoue hopes that neutrinos will increasingly become a bridge between particle physics and other areas of science: "Now we can use neutrinos and antineutrinos as a tool," he says.

Already KamLAND researchers have their detector set on an even larger extraterrestrial target—the sun. Low energy solar neutrinos are known to exist but they have so far been elusive. "No one has ever seen them, and we want to be the first," says Alexander Kozlov, a Russian researcher at Tennessee University who has been working at Tohoku University for four years. With an improved KamLAND, this should be possible, and the resulting solar neutrino measurements will give new insight into the fusion reactions that are going on in the sun. Researchers should be able to measure the CNO cycle in the sun, an experiment first proposed by the late Raymond Davis, who won the Nobel Prize for the discovery of solar neutrinos in 2002.

KamLAND has proven itself, and continues to do so. "Many theoreticians thought KamLAND couldn't respond to the demands of these experiments, but we have proven them wrong," says Inoue.

Dr. Kunio Inoue

Director and Professor,
Research Centre for Neutrino Science,
Tohoku University

www.awa.tohoku.ac.jp/en

Sexual differences of the brain and in behaviour – analysis at the individual, gene, and cell level

Behavioural research is now one of the major areas of brain science, but about 30 years ago it was thought that behaviour is provoked as the result of accumulated, small, unexplainable factors. This stereotype was scientifically disproved in the 1970s following research using *Drosophila*, a fruit fly, which showed behavioural changes related to gene mutations. Daisuke Yamamoto, professor at the Graduate School of Life Sciences, followed these reports in his college days and decided to experimentally analyze the sexual behaviour of Drosophila at the gene level.

Discovery of males exhibiting abnormal sexual behaviour

Yamamoto used to be fascinated by insects, and decided to study animal behaviour at the Tokyo University of Agriculture and Technology. Later, he moved on to research in electrophysiology at the Institute of Physical and Chemical Research. In 1988, at the age of 34, he was appointed project leader at the Mitsubishi Kagaku Institute of Life Sciences and had a chance to conduct research freely. "I thought that I should begin research on behaviour and genes, which was something that I had always wanted to do. Therefore, I proposed a project to study sexual behaviour at the gene level using *Drosophila*, and it was adopted," remembers Yamamoto. He chose to study sexual aspects because he thought that such behaviour had to precede the diversification of organisms under natural selection.

First, he randomly destroyed gene functions using transposon and looked for mutants with abnormal sexual behaviour. Next, he used mutants of males displaying the act of courtship towards males and mutants that did not display any act of courtship at all. Yamamoto says: "Although they are male, they completely ignored the females even when they saw them. I thought this is exactly the transcendence of libido, and named the mutants, '*satori*'."*

* Buddhist term for achieving spiritual enlightenment free from desires

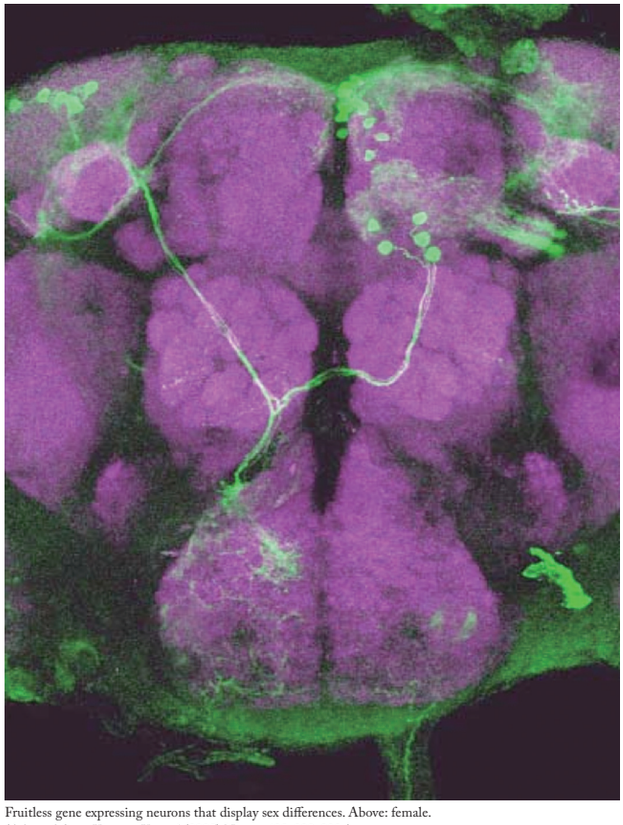
Sexual differences in gene usage and neurons

After these experiments a succession of studies was adopted in a large scale project supported by the Japan Science and Technology Agency (JST), and in 1996 he succeeded in identifying the *satori* gene. "I thought I had found the world's first gene, but in fact, the *satori* mutation was located on the same locus as the *fruitless* mutation, which was discovered in 1963," says Yamamoto. One after another, based on subsequent detailed gene analyses, Yamamoto clarified that (1) the mRNA of the fruitless gene is expressed in both males and females in certain neurons under development, but that the protein exists in only males; (2) the sex difference at the protein level is caused by the sex-specific splicing and the translational repression of the gene product; and, (3) there are differences in induced sexual behaviour of males depending on the degree of the mutation.

Yamamoto has been asked the same question every time his findings are reported in the media: "Is there a gene similar to the *fruitless* mutation that exists in humans, too?" He says that, "The amino acid sequence of the protein of the gene product differs considerably even in mosquitoes, which is of the same order as *Drosophila*, because the evolution speed of the *fruitless* gene is very fast. It would be impossible to discover the human counterpart even if human beings had a gene derived from the same origin as the *fruitless* gene." However, he also points out that the research results of *Drosophila* studies offer clues about sexual behaviour and sexual differences in human beings. For example, in the case of humans, it is known that there are sexual differences in the thickness of callosum, but analysis at the gene and neuron level remains a challenge.

In 1999, Yamamoto moved to Waseda University and then in 2005 he relocated his research base to Tohoku University. In the same year, he demonstrated sexual differences at the cell level labeling only the *fruitless* gene-expressing neuron; the results were used as the cover image of *Nature* (November 10, 2005). "There were two significant differences between the male and female. One of them was in the central part of the brain. There were 30 neurons expressing the *fruitless* gene per hemisphere in males but only 5 in females," says Yamamoto. Significant differences were found not only in the number of neurons, but also in the extension of neurite due to sex type. "In the future, I would like to find solid evidence to support the hypothesis that *fruitless* is a *bona fide* gene, which determines sexual behaviour by 'hyper'-activating and deactivating the *fruitless* gene in labeled neurons", concludes Yamamoto.

Yamamoto's unique research provides clues for studies on the sex differences of the human brain and it is also anticipated that this research could be used for the sterilization of pests in agriculture.



Fruitless gene expressing neurons that display sex differences. Above: female.
(Adapted from Kimura, K. et al.(2005) Nature 438, 229-233.)

Dr. Daisuke Yamamoto

Professor,
Graduate School of Life Sciences,
Tohoku University

Chapter3: Materials, information technology, communications and electronics for creating new civilizations

Tohoku University scientists are internationally acknowledged for inventions that have spawned new industries and paradigms. Some well known accomplishments are the Yagi-Uda antenna, proposed by Hidetsugu Yagi and realized by Shintaro Uda; and the divided anode type magnetron invented by Kinjiro Okabe. Fujio Masuoka, who invented the flash memory device, is also a Tohoku University graduate and is now continuing research as a professor at Tohoku University's Research Institute of Electrical Communication. More recently, Koichi Tanaka, who received the 2002 Nobel Prize in Chemistry for development of the soft laser desorption ionization method for mass spectrometric analysis of proteins (Fellow of Shimadzu Corporation, General Manager of Koichi Tanaka Mass Spectroscopy Research Laboratory) is a graduate of Tohoku University's School of Engineering, Department of Electrical Engineering. A closer look at these inventions shows that fundamental understanding of materials was vital for their development. Synthesis and exploitation of materials can prompt powerful changes in society leading to the creation of new civilizations. This section highlights how scientists at Tohoku University have contributed to a deeper insight into the properties of metals and related materials and their use for the development of innovative devices and concepts.

The Institute for Materials Research

Academic excellence with industrial relevance

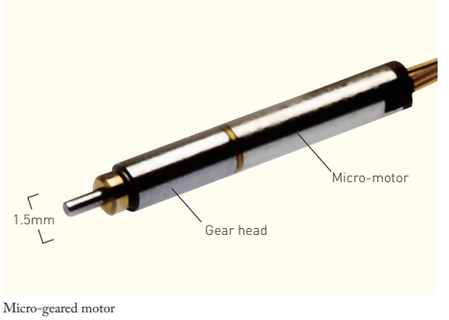
The Institute for Materials Research (IMR) is Tohoku University's centre of excellence in metals, alloys and electronic materials. It is located on the Katahira Campus, a short walk from Sendai Station. The IMR was established in 1916 with a mission to support and nurture Japan's iron and steel industry. Kotaro Honda, the first Director of the Institute and 6th President of the University, strongly encouraged interaction with industry. "The spirit of his leadership lives on today, 90 years later," says Akihisa Inoue, the current Director. "In 1932 Honda invented the 'KS magnet steel', the strongest permanent magnet at the time. It was used to improve the performance of electrical measuring equipment."

The IMR is consistently ranked top in ISI citations on materials research. "The citations reflect our policy of conducting highly original but industrially significant research," says Inoue, who in 1988 first reported the use of copper mold casting to synthesize magnesium and lanthanide based *bulk metallic glasses*. The high strength, ductility, anti-corrosion and unique electrical properties of *metallic glasses* are not found in conventional crystalline metallic structures (see *Jpn. Jnl Appl. Phys. Vol.27, L2248, 1988*). Inoue recalls that, "when we first published the results on *metallic glasses*, there was little response from the scientific community. I even wondered whether the research was significant. But now our papers are the most widely cited publications in this field."

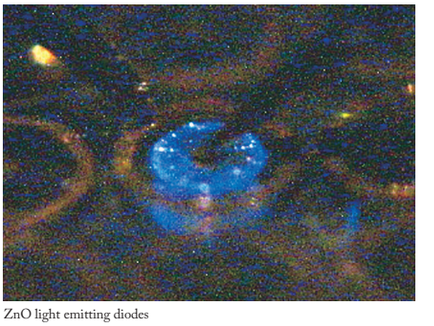
The industrial implications of Inoue's research are far-reaching. The most recent examples are high sensitivity pressure sensors and the world's smallest, high torque *micro-geared motors* with outer diameters of only 1.5 mm. Inoue was awarded the 2006 Prime Minister's Prize for this research. The micro-gears and sensors were developed by a highly motivated group of scientists and engineers as part of an industrial collaboration supported by New Energy and Industrial Technology Development Organization (NEDO), a government funding agency. "The City of Sendai has shown great interest in this project and local companies will manufacture these new technologies for the medical and automobile industry," says Inoue.

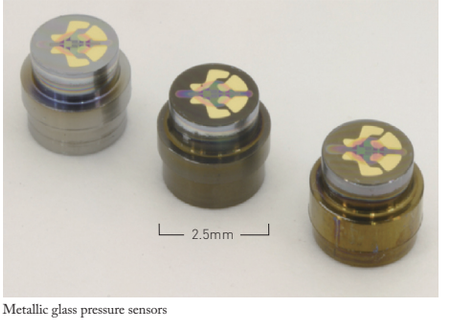
Research at the IMR is not limited to metals but also encompasses other novel materials including oxide semiconductors, which have potential applications in the electronics industry. Masashi Kawasaki is exploring 'oxide electronics'. In 2005, Kawasaki was awarded the 19th IBM Japan Prize for his work on oxide epitaxy and related devices.

"A central theme of my research is *correlated electron systems*. That is, materials such as titanium oxide, whose properties are determined by interactions between electrons. Another topic is zinc oxide based light emitting devices for producing white light illumination," says Kawasaki. Recently, Kawasaki fabricated the world's first zinc oxide (ZnO)blue LED using *'repeated temperature modulation'* to grow high quality, electrically conducting ZnO films (see *Nature Materials Vol.4, p.42-46, 2005*). "ZnO is an alternative to group III nitride semiconductors," explains Kawasaki. "Advantages include an abundant supply of minerals for

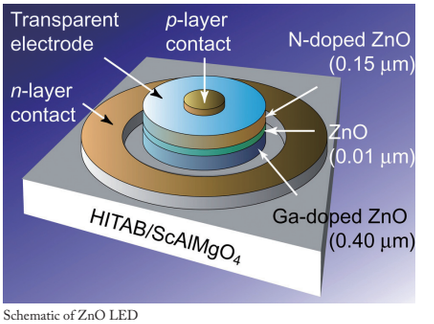


Micro-geared motor


ZnO light emitting diodes



Metallic glass pressure sensors



Schematic of ZnO LED

are applied parallel to the magnetic media plane at the Research Institute of Electrical Communication, Tohoku University, Iwasaki often thought about the next breakthrough in magnetic recording.

In the 1970s, Iwasaki thought that placing information perpendicular to the magnetic recording plane would enable increases in the recording density without having to make the media thin as in usual tapes.

At that time, recording losses due to demagnetization were a problem for high density longitudinal recording. When a high density head current was applied to magnetize the magnetic media, the read voltage was found to decrease. Iwasaki investigated this phenomenon and discovered the circular magnetization mode [1], where magnetization direction rotates in the cross section of medium and forms a closed loop. Using this effect he proved that magnetic flux does not leave the media, and head read voltage decreases. Furthermore, Iwasaki discovered that when a direct current magnetic field perpendicular to the media plane is applied, the rotating magnetization mode converts to alternating up and down perpendicular magnetization, and the read voltage recovers.

Then, in 1977, Iwasaki published experimental results on a CoCr-based perpendicular magnetic thin film medium and single pole read/write magnetic heads. Afterwards, he modified the magnetic recording part of the thin film medium into a two-layer structure, and thereby established the basic concept of the perpendicular magnetic recording method [2].

Iwasaki also found that the limits of longitudinal magnetic recording – when the recording density is increased, the repulsion (demagnetizing interaction) between the magnetization bits leads to decreases in magnetization – could be overcome by using perpendicular magnetic recording, where attraction strengthens the magnetization.

For Iwasaki, who had been working on longitudinal magnetic recording for 25 years, research on perpendicular magnetic recording meant that "I was destroying the foundation that I built. I needed courage." Every time he headed to his laboratory and saw the Yagi-Uda antenna that Hidetsugu Yagi and coworkers invented, he felt that revolutions in technology end up being simple in form. "I was always aware of the great research by my predecessors such as Kotaro Honda and Hidetsugu Yagi," Iwasaki remembers. He himself has also educated many researchers. He says, "I am happy that I built a leading area of research, and although it took 28 years after I published the paper, I can now see my research results as a commercialized product."

Dr. Shunichi Iwasaki

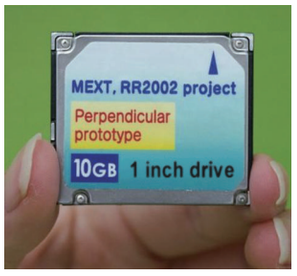
President,
Tohoku Institute of Technology
Professor emeritus of
Tohoku University

www.tohtech.ac.jp/eng/outline/message

Perpendicular magnetic recording for broadcasting and personal servers

Yoshihisa Nakamura (professor and previous Director of the Research Institute of Electrical Communication, Tohoku University) took over Iwasaki's research at the Institute.

Nakamura worked with Iwasaki on numerous experiments, and over a period of 10 years developed a magnetic recording simulator considering vector magnetization behavior of magnetic micro-particles in order to theoretically understand the rotating magnetization mode. He succeeded in proving and quantifying why the rotating magnetization mode reduces reproduced voltages [3].



△ Prototype of 1 inch size HDD (10GB)

▷ A prototype ubiquitous personal server, an application of very small large capacity HDDs

Although perpendicular magnetic recording amazed the world, initial practical application was attempted to realize perpendicular magnetic flexible disk systems, so reliability was poor, and in the late 80s development of perpendicular magnetic recording became less popular.

Nakamura thought that development of HDDs would be crucial to utilize the properties of perpendicular magnetic recording. After Iwasaki retired, Nakamura's primary work was to complete development of the perpendicular magnetic recording HDD with single pole heads and double-layered perpendicular media.

However, in the 90s, dramatic improvements in the characteristics of HDDs using longitudinal magnetic recording overshadowed his work, especially in the first half. In the latter half, Nakamura's perpendicular HDDs showed much better performances than conventional HDD. Companies started collaborating, and in 2000 demonstrations of HDDs were conducted with Hitachi. In 2005, the first prototype 1 inch perpendicular HDD was fabricated as a trial that could write 10GB of information (the amount of data recorded on two DVDs) on a disk approximately 25 mm in diameter.

For the multimedia era, features such as higher density, increased capacity, accurate and faster read/write capabilities were pursued even further. In early simulations and experiments [4], Nakamura predicted the possibilities of more than 1 Tbit/inch^2 in areal bit density through experiments and computer simulation.

HDDs were developed primarily to record data, and were not suited

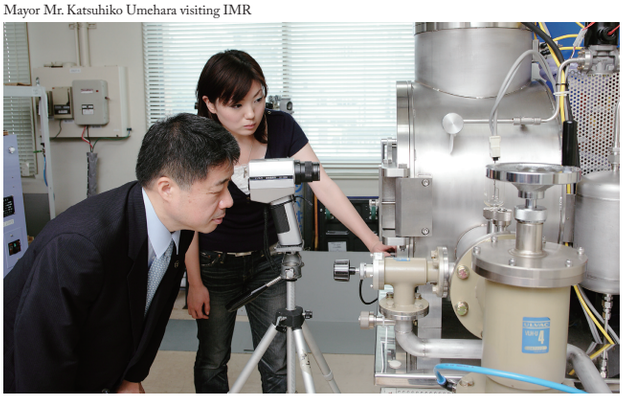
Commonly used inventions with links to Sendai

Yagi-Uda antenna

In 1925, Hidetsugu Yagi, a professor at Tohoku University, discovered the principles used in this antenna. He suggested to Shintaro Uda, a lecturer in his group, that research be conducted to make this antenna principle practical. At that time, the antenna was made up of a number of straight metal conductor wires placed in parallel as reflectors, driven elements, and directors. After disclosure, the antenna gained attention in Europe and in the US and led to the development of lasers. As of now, Yagi-Uda antennas are the most commonly used household television antennae.

The picture shows the UHF band receptor/transmitter used in a radio communication experiment between Sendai and Ohtakamori (about 20km apart) in 1929. This was displayed the next year at the Universal Exposition held in Brussels, Belgium.

Mayor Mr. Katsuhiko Umehara visiting IMR



producing zinc, availability of single crystal substrates and a large excitonic binding energy (60 meV); these features are very promising for producing high efficiency laser structures." The large bandgap of ZnO (3.37 eV) makes it transparent to visible light and the material will be used for fabricating thin film transistors for use in displays.

But what about the future? Kawasaki says, "We are producing *combinatorial materials* by laser ablation, a method based on *combinatorial chemistry*, first demonstrated by the 1984 Nobel laureate Bruce Merrifield. Synthesis of *combinatorial materials* involves handling huge volumes of information about the properties of complex structures. A major problem will be managing such information. We will require a new paradigm to effectively utilize our increasing materials database to create new materials. Analysis of such information will lead to the creation of a new field of research that I refer to as *materials informatics*."

Kawasaki envisages establishing a de-facto standard for predicting the physical properties of complex material structures using algorithms and intelligent platforms to visualize, overlay and integrate thousands of pieces of information.

The IMR has many assets to support such innovative ideas including international collaboration via its overseas liaison offices and the tradition of generating spin-off companies; the first was *Tohoku Kinzoku* (now *NEC-Tokin*) and the most recent is *BMG Ltd.*, set up to support projects on the applications of metallic glasses. The City of Sendai and the Mayor Mr. Katsuhiko Umehara takes a keen interest in developments at the IMR.

Inoue adds, "Our approach to research is based on Honda's saying 'industry is the *dojo** of learning'. Academic and industrial collaboration is at the heart of our activities."

* Training hall used by practitioners of the martial arts such as judo and kendo.

Dr. Akihisa Inoue

Director and Professor,
Institute for Materials Research,
Tohoku University

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Dr. Masashi Kawasaki

Professor,
Institute for Materials Research,
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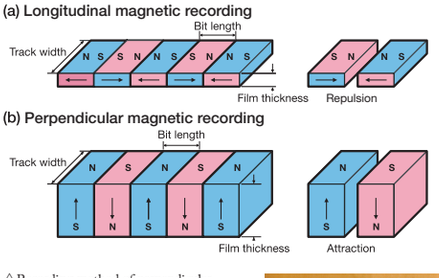
Invention of perpendicular magnetic recording

At last, increased memory capacity using perpendicular magnetic recording technology

In 2005, Toshiba Corporation announced the development and commercialization of the world's first computer incorporating a hard disk drive (HDD) using perpendicular magnetic recording technology. This April, Hitachi Global Storage Technologies announced a similar product. These announcements have ushered in a new era of mass-produced, high-capacity storage devices that use perpendicular magnetic recording. Estimates indicate that the market size for HDDs using perpendicular magnetic recording will be approximately 3.3-6 trillion yen ($ 28.7-31.3 billion) by 2010.

The principles of perpendicular magnetic recording were first proposed by Shunichi Iwasaki, President of Tohoku Institute of Technology and professor emeritus of Tohoku University. Iwasaki is also famous for inventing the metal particle tape in the 1950s. While conducting research on metallic tapes and longitudinal magnetic recording (in-plane magnetic recording) where magnetic fields



△Recording method of perpendicular magnetic recording

▷Hitachi Global Storage Technologies presented Prof. Iwasaki a trophy with the words "Father of Perpendicular Recording" on May 25, 2006 and the first commercialized HDD (2.5in, 160GB capacity)

for smooth and continuous replay of video pictures. Nakamura's group has also worked on audio and video magnetic tapes, so they are also conducting research on the use of HDDs to record video pictures.

The personal server with the 10GB HDD described above was born in this context. High-definition video pictures can be recorded and transmitted by wireless LAN to large screen TVs. Nakamura thinks the technology can also be applied to car navigation systems and to electronic medical records that could include high-definition images.

Research is being carried out to increase the data transfer speed by using a cylindrical storage medium with multiple heads. Theoretically, a data amount of more than 100GB could be stored within the cylindrical surface of an AAA battery.

Nakamura says that "the traditional philosophy of Tohoku University to do research for society has been unconsciously pushing me forward." From Iwasaki to Nakamura, and the next generation of technologists, the laboratory continues to use state of the art equipment such as disk and head evaluation equipment, ultrahigh vacuum film deposition systems and clean rooms, to research and develop technologies into new useful articles.

Dr. Yoshihisa Nakamura

Professor,
Previous Director of the Research Institute of Electrical Communication, Tohoku University

www.riec.tohoku.ac.jp/lab/next-generation-inf/index-e.html

Spintronics research

Semiconductor spintronics opens the way for future spin devices

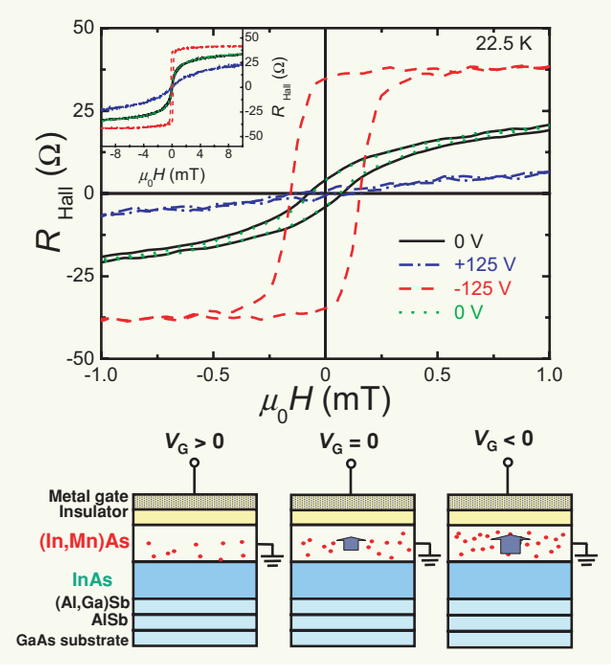
Spintronics shows tremendous potential as the foundation for next generation information technology, communications and electronics.

Electrons have two properties, 'charge' and 'spin', the source of magnetism. In modern electronics, the electron charge is used to process information in semiconductor integrated circuits and, for information storage, such as HDDs, magnetic materials taking advantage of electron spin are used.

The concept of spintronics is that if electrons are going to be used, then it is better to use both their charge and spin properties. Applications include ultra-high density storage and quantum computing.

Hideo Ohno, professor of the Research Institute of Electrical Communication, Tohoku University, is a leading player in the spintronics field. His research is focused on semiconductor spintronics, where the spin of electrons moving in semiconductor structures is used.

Ohno has succeeded in fabricating ferromagnetic semiconductors by doping non-magnetic III-V compound semiconductors such as InAs (1992) and GaAs (1996) with magnetic Mn ions. Furthermore, he showed that the electron spin direction can be aligned using heterostructures, made by inserting the non-magnetic III-V semiconductor GaAs or (Al,Ga)As between (Ga,Mn)As layers. Later Ohno found out that the ferromagnetism becomes stronger when the number of carriers increases in the conducting layer [5]. From these results, at low temperatures of approximately 25K, he succeeded in switching the ferromagnetism on and off at a constant temperature by switching a voltage of approximately 125V and changing the hole density in the (In,Mn)As ultra-thin films. This was the first ever report



In a ferromagnetic semiconductor (In,Mn)As ultrathin film, the ferromagnetism can be switched on and off at a constant temperature by adjusting the electron holes inside the material.

on the electrical control of the magnetic properties of a material.

In 2004, Ohno's group succeeded in reversing magnetization by moving the boundaries of the regions where magnetization is aligned (magnetic domain walls) with a very low current density of 10^5A/cm^2 through a (Ga,Mn)As ultrathin film. These results will enable the fabrication of low power consumption, semiconductor spin devices.

Based on these successes, Ohno received the 2005 Agilent Technologies Europhysics Prize from the European Physical Society.

Ohno is currently also working on magnetic random access memory (MRAM) devices. In April 2004, the Laboratory for Nanoelectronics and Spintronics was completed with state of the art equipment including molecular beam epitaxy equipment, femtosecond laser systems, and Fourier transform infrared spectrometers.

"In Tohoku University, you feel a pressure to do first class work. Since the research environment is among the best in the world, we need results. Currently, the synergy of fundamental and applied research is producing good results", says Ohno.

Dr. Hideo Ohno

Professor,
Research Institute of Electrical Communication, Tohoku University

www.ohno.riec.tohoku.ac.jp

*1) S. Iwasaki and K. Takemura, "Analysis of the Circular Magnetization Mode for Short Wave Length Recording", IEEE Transactions on Magnetics, vol.MAG-13, no.5, pp.1173-1175, Sep. 1975.
*2) S. Iwasaki, Y. Nakamura and K. Ouchi, "Perpendicular Magnetic Recording with a Composite Anisotropy Film", IEEE Transactions on Magnetics, vol.MAG-15, no.6, pp.1456-1458, Nov. 1979
*3) Y. Nakamura, IEICE Trans. Electron., vol. E78-C, no.11, pp.1477-1492, Nov. 1995.
*4) Y. Nakamura, J. Magn. Soc. Jpn., 18 (Suppl. S1), pp.161-170, 1994.
*5) T. Dietl, H. Ohno, F. Matsukura, J.Cibert and D. Ferrand, Science, Vol. 287, pp. 1019-1022, 2000.
*6) H. Ohno, D. Chiba, F. Matsukura, T. Omiya, E. Abe, T. Dietl, Y. Ohno and K. Ohtani, Nature, Vol. 408, No. 6815, p. 944, 21 December 2000.
*7) M. Yamanouchi, D. Chiba, F. Matsukura, H. Ohno, Nature Vol. 428, pp. 539-542, 1 Apr 2004

Chapter4: The Academic City of Sendai and Tohoku University

Abundance of opportunities for women, foreigners and young people

Sendai is an academic city with 10 universities, four junior colleges, about 49,000 students and 3,800 researchers. The oldest and largest university is Tohoku University, founded in 1907 as the third Imperial University. Its 'Open Door' philosophy is based on policies introduced by Seitaro Sawayanagi, the university's first president.

"Open-Door" policy since early times to support women and foreign nationals

First three female students

The University's open-door policy welcomes students as well as outstanding research faculty regardless of alma mater, gender or nationality. In its early days, Tohoku University admitted students who had not graduated from high school and foreign nationals. The famous Chinese novelist Lu Xun studied at the School of Medicine (see column). Currently, there are 2,263 foreign nationals from 92 countries including students and researchers.

Tohoku University is also known for being the first university to admit female students. In 1913, three women were admitted to the School of Science in spite of objections from the Ministry of Education.

Although there is a nursery school on campus, and efforts for gender equality and improvement of research and labor environments are continuing, only 7.7% of faculty is women. Therefore, the university decided that there is a need to offer more help to female researchers, and initiated the *'Mori-no-miyako female scientist hurdling support project'* this year. The project includes: (1) child care and health care support programs such as a part-time work system and hiring of research/education support workers; (2) environmental improvement programs enriching the work environment and sick child nurseries; (3) promotion of enrichment programs for the next generation, including the "Science Angel" project where students hold seminars at high schools; and (4) the establishment of female student networks and female researcher forums.

The "Science café" program offers monthly events at the Sendai Mediatheque, aimed at improving the public understanding of science. The lectures and discussion groups are especially aimed at encouraging teenagers to take an interest in science and technology. Such open-door policies promote the interaction of people in and out of the university and research.

Support for young researchers and scientists to conduct world class research

Based on its history of research prioritization, the open door policy, Tohoku University has become one of the largest universities in Japan with 10 undergraduate schools, 15 graduate schools, five research institutes and three specialized graduate schools.

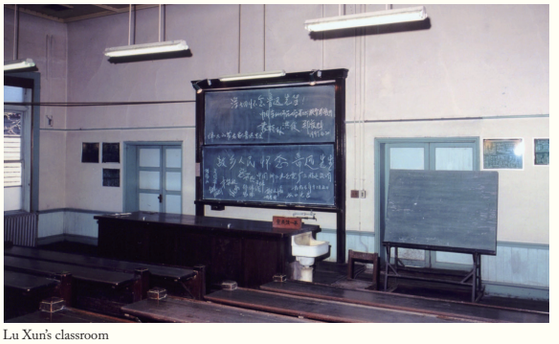
According to the ISI rankings of technical publications, which is a means of measuring research activity, Tohoku University as a whole ranks 69th in the world. In individual fields, material science ranks 2nd, physics 11th, chemistry 20th and engineering 38th.

There is also an emphasis on collaboration with overseas research and education organizations, and there is a Tohoku University U.S.

Column

Lu Xun, who remembered his advisor at Tohoku University

Lu Xun (1881–1936) was a leading writer and founder of modern Chinese literature in the early 20th century. In September 1904, he entered Sendai Medical School (current School of Medicine, Tohoku University). Dr. Genkuro Fujino, professor of Anatomy, personally mentored him with such care that he even proofread the notes that Lu Xun took during his lectures. Lu Xun later became captivated by the study of literature and withdrew from the medical school in March 1906. After a stay in Tokyo, he returned to China, and wrote many novels and essays including "The True Story of Ah Q". In his work "Professor Fujino", written about his advisor, he notes that he was encouraged by the word "Farewell" written on the back of Professor Fujino's photo that he received when he departed Sendai. The classroom that Lu Xun studied in still exists in Katahira Campus, Tohoku University.



Lu Xun's classroom

office and 11 liaison offices overseas. They support exchange of intellectual information, collaboration projects, visits of researchers and students and student participation in education programs. The University has exchange agreements with 92 major universities and 241 departments overseas.

To further enhance the competitiveness of young researchers, the Institute for International Advanced Research and Education was founded in April 2006. There are numerous support programs to support talented graduate students, and in the engineering, life science and medical fields the Program for Exploring Advanced Interdisciplinary Frontiers (tenure track program) was introduced to train researchers. This program is currently recruiting young and ambitious researchers.

Commonly used inventions with links to Sendai

Divided anode-type magnetron

Kinjiro Okabe, assistant professor at Tohoku University, in 1927 proposed the principles and later invented the divided anode-type magnetron. The research started from an incident where one of his students was doing experiments on a magnetron (a kind of vacuum tube that was invented by Robert Hall from the U.S. in 1921). The student reported the collection of strange data indicating that despite theoretical predictions that when the magnetic field reaches a certain threshold, the anode current should decrease rapidly, in reality the current started to increase. From such indications, Okabe predicted and proved the generation of electromagnetic waves with very short wavelength. In this research he had discovered that by dividing the cylindrical anode of the magnetron into two pieces in the axial direction and adding a vibration circuit in between, the oscillation becomes amplified, while making the wavelength even shorter allowed the vibration to become more stable. The discovery of divided anode-type magnetron that can efficiently generate strong waves has led to a device that is now the key item in microwave ovens.

*Prototype of The divided anode-type magnetron when invented

Science café program by Tohoku University to educate the public

Exchange students practicing Aikido

Column

Tohoku University is seeking candidates for a new pilot program of tenure-track systems (Program for Exploring Advanced Interdisciplinary Frontiers).

Tohoku University is seeking candidates for assistant, associate and full professors in the tenure track. The term of the tenure-track positions is until March 2011. The program seeks researchers with outstanding accomplishments and future promise in the following scientific areas:

1) Mechanical Engineering (2 positions at the Graduate School of Engineering): aerospace engineering, advanced materials for fuel cell systems
2) Materials Science (1 position at the Graduate School of Engineering): functional materials for energy conversion devices
3) Electronic Engineering (1 position at the Graduate School of Engineering): magnetic material, magnetic nanoparticles
4) Life Science (2 positions at the Institute of Development, Aging and Cancer): oncology, immunology, neuroscience and related fields
5) Biomedical Engineering (4 positions at the related departments): key scientific areas will be announced soon

The appointed persons will run their own laboratories independently, supported by a starting allowance and an annual budget. Each appointee can employ a post-doctoral fellow and/or a technical assistant. The appointed person will be offered a tenure position if the academic achievements are judged to be at a level that can be expected of an associate or full professor.

Detailed job information is available at the following:
- 1)Home page of this project
http://www.ttsc.cress.tohoku.ac.jp
- 2) Japan Research Career Information Network (JREC-IN)
http://jrecin.jst.go.jp/index_e.html
(National university corporation/Tohoku University)
- 3) Graduate School of Engineering
http://www.eng.tohoku.ac.jp/php/eng/english/index-e.html
- 4) Institute of Development of Aging and Cancer (for Life Science)
http://www.idac.tohoku.ac.jp/information/tenure-t.2006.html

Program for Exploring Advanced Interdisciplinary Frontiers
Tenure Positions

Evalution

a new pilotprogram of tenure-track systems
Supporting systems for young researchers with program officers and senior mentors

Mechanical Engineering | Life Science | Materials Science | Electoronic Science | Biomedical Engineering

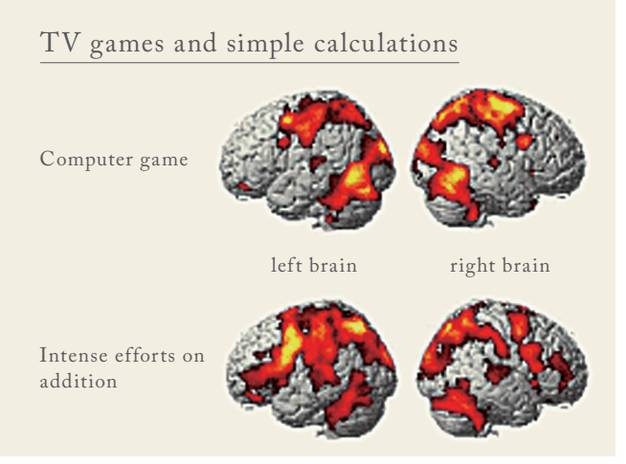
Foreign and domestic applicants

Chapter5: Bioscience research at Tohoku University

A unique, halcyon environment conducive to innovative research

Tohoku University has a long history of research in the life sciences and it is replete with research organizations including the Faculties of Medicine, Agriculture, Pharmaceutical Sciences; the Schools of Dentistry and Engineering and related graduate schools; the Institute of Development, Aging and Cancer; and the Biomedical Engineering Research Organization. The emphasis in this section is on three unique scientists.

Development of an effectual brain by functional analysis of prefrontal area



Ryuta Kawashima became well-known in Japan through his development of game software in a tie-up with Nintendo. He is an alumnus of Tohoku University and is currently a professor in the Department of Functional Brain Imaging at the Institute of Development, Aging and Cancer. His specialty is brain science, in particular functional analysis of the prefrontal area, using functional MRI, a non-invasive means of measuring brain activity. The prefrontal area plays a role in complex brain functions specific to humans such as thinking, communicating, learning, and creativity. Kawashima selected volunteers, mainly students from the university, and found that the activities of the prefrontal area increase as a result of training and exercises such as simple reading, writing, and math (Cognitive Brain Research, 18, 225-238, 2004/Neuroreport, 14, 1563-1566, 2003).

With confidence in his results, Kawashima set up a collaborative project with Sendai City to study further applications of his research. He has also trained dementia patients and healthy elderly people with simple reading, writing and math, as well as examining the progress of activities in their prefrontal area. "In many cases, the functioning of their prefrontal area has improved. Sometimes there were other effects, such as restoring communication with family members and care-giving staff, or eliminating the need for diapers," says Kawashima. In dementia patients, the number of neurons in the cerebrum decreases and their networks are destroyed. Kawashima explains: "What is important for the prefrontal area is whether or not the neuron networks are maintained rather than the actual number of the neurons. It seems that the network is strengthened by the plasticity induced by continuing simple training." (Journals of Gerontology, Series A, Biological Sciences and Medical Sciences, 60A: 380-384, 2005.)

Currently, he is investigating the relationships between activities in the prefrontal area, and the life habits and academic achievements of children, in cooperation with public junior high schools in Sendai City. He points out that the prefrontal area functions in integrating activities of the other areas of the brain, therefore it is also closely linked to brain development in children. He also has an interest in the association between functions of the prefrontal area and developmental problems in children, such as a tendency to lose their temper, having trouble concentrating and communicating. He says, "My goal in research is to clarify the relationship between the brain and the mind and to foster children's brains. I would like to put our research results on the prefrontal area to use."

Kawashima has published books that one can easily utilize for brain training (available from Kumon Publishing Co., Ltd.) and he is also working with Nintendo on the development of software for video game versions of these books. In addition, he has started to examine relationships between parents and children and life style habits for the brain development of babies before they start to read and write.

Dr. Ryuta Kawashima

Professor,
Department of Functional Brain Imaging,
Institute of Development, Aging and Cancer,
Tohoku University

www.idac.tohoku.ac.jp/dep/fbi/

Commonly used inventions with links to Sendai

Flash memory device

This is a semiconductor memory device developed by Fujio Masuoka, current professor at Tohoku University, while he was working for Toshiba in the 1980s. The flash memory can read and write information at high speed, while the recorded information does not disappear even when the power supply is cut off, but it is also possible to delete all the information instantly, in a flash. This development overcame the weak points of two conventional semiconductor memory devices: random access memory (RAM) that cannot retain its information when the power is shut down; and, read only memory (ROM) that cannot delete or rewrite its information. Flash memory devices are used widely as USB memory chips, memory cards and programmed BIOS (Basic Input/Output System) to control peripheral hardware of computers. Masuoka has received many international accolades for his research including the Economist Innovation Award in 2005.

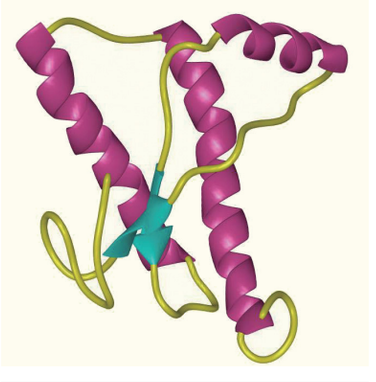
Warning for non-BSE infection route for prion disease

There are many researchers who have settled in Tohoku University due to the favorable research environment offered by the university. Tetsuyuki Kitamoto of the Graduate School of Medicine, the foremost authority on prion diseases in Japan, is one example. He says that, "I can concentrate on my research in my own way without being affected by information overload because it is isolated from the Tokyo area, though Tokyo is only one and a half hours away." He assumed his duties as professor in 1995 and has been working on the development of a mouse model of human prion diseases with high sensitivity to human prions.

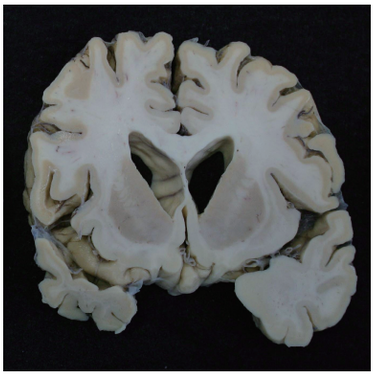
Though prions are a type of ubiquitous protein that is located in various parts of the body, once its conformation undergoes an abnormal change, it acquires the pathogenicity and idiosyncratic character that changes other, normal prions to the abnormal form. Prions are known as the causal components of BSE. Diseased cattle show neurologic symptoms, such as the inability to stand up and uncontrollable quivering and muscle spasms. Since then, examples of BSE-like neurologic symptoms and mental disorders (vCJD: variant Creutzfeldt-Jakob disease) have occurred among young people and it is suspected that the disease is transmitted from cattle to humans through consumption of high-risk regions of meat.

Kitamoto warns about the dangers of vCJD being transmitted from one person to another through medical practices, such as blood transfusion, blood products, surgery and dental treatment based on his finding that, besides the well-known accumulation of abnormal prions in the tissues of the central nervous system, these pathogens can also accumulate in follicular dendritic cells, which are peripheral lymphatic tissues (see Am J Pathol. 2003 Dec; 163(6), 2585-93). Meanwhile, he also points out that there are familial CJDs that develop the disease due to congenitally mutated prion genes and therefore there is also the danger of the infection being transmitted from patients. There are single nucleotide polymorphisms (SNPs) in prion genes, and it is considered that the sensitivity to vCJD depends on which type of SNPs one has. It is also known that susceptible types of SNP abound among Japanese people.

"Currently, a new prion disease is spreading among domestic animals and wild deer in North America and the situation is becoming serious," Kitamoto says. Developments of treatment methods and vaccines are being speeded up, but Kitamoto emphasizes that first, measures are needed to eliminate abnormal prions from daily life.



Tertiary structure of normal prion proteins



Autopsied brain of a CJD patient showing moderate atrophy

Dr. Tetsuyuki Kitamoto

Professor,
Department of Prion Protein Research,
Graduate School of Medicine,
Tohoku University

Measures to tackle avian influenza – making Sendai a model city

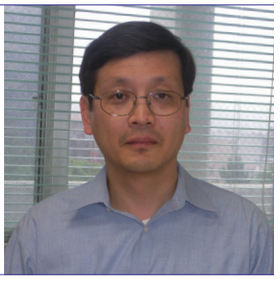
One scientist, who graduated from Tohoku University and then played an active role in the global fight against infectious diseases, has returned again to his alma mater. He is Hitoshi Oshitani, a professor at the Department of Microbiology, Graduate School of Medicine. At the World Health Organization (WHO), Oshitani, a Regional Advisor on Communicable Diseases, organized the collection of information on emerging infectious diseases, such as when SARS and avian influenza broke out, to understand the situation and take concrete measures. He was at the WHO's Western Pacific Regional Office for six years from 1999 to 2005.

Oshitani says, "When I was at WHO, I was asked for responses by the minute. It was similar to being locked in the cage of a batting centre where I had to continue hitting the balls back and forth." He wanted to start research work once again and this was why he accepted the offer of a position at his alma mater. He is planning to examine the various strategies that can be used to mitigate the impact of an influenza pandemic in collaboration with Sendai City, using virological and epidemiological approaches.

Oshitani points out that, "the outbreak of infectious diseases could be caused by a set of unexpected coincidences." Though basic research, such as virology is advancing, he is concerned about the disparity between the research results and the information that is needed in the field, such as at public health centres. "I would first like to start by building a network to connect researchers, research institutes and public health workers." Oshitani's new challenges in Japan have begun.

Dr. Hitoshi Oshitani

Professor,
Department of Microbiology,
Graduate School of Medicine,
Tohoku University



Chapter6: Making the most of academic excellence to support SMEs

Sendai pioneered the attempt to strengthen collaboration between academics and the business sector in Japan. How does Sendai compete with rival cities? Here, we see how nano-MEMs specialist Masayoshi Esashi, is using his unique technologies to support small and medium companies in their quest to develop novel nanomechanical devices.

More open, more gain

A veteran micro-mechanical researcher shows the ideal style of collaborations

At Tohoku University's graduate school of engineering, Masayoshi Esashi is frequently seen showing guests around his labs. The guests are engineers from various companies who often travel from many parts of Japan and from abroad to seek his advice on improving the performance of their products. If needed, Esashi will let the visitors use his experimental facilities to carry out work that would be difficult or impossible at their own company, due to low cost performance.

Esashi, is a professor of nanomechanics, and his work exemplifies one of the most effective and well-managed collaborations between academics and the business sector in Japan. He's one of the world's experts in a technology called MEMS (Micro Electro Mechanical Systems), a micromachine that integrates sensors, processing circuits, actuators and other microelectronics on a tiny silicon chip. Currently, MEMS technology is mainly used for gyroscopic motion sensors in digital cameras, fabrication of ink-jet printer heads and acceleration sensors to trigger automobile air-bag safety systems. The potential demand for other applications is huge.

Small and medium sized companies are eager to develop high quality MEMS-based devices, but it is not easy because fabrication of MEMS requires highly sophisticated equipment as well as information about the latest technologies. Many engineers are facing difficulties conducting trial experiments on MEMS before bringing ideas to market due to a combination of limited technological resources and inflexible corporate laboratories.

Esashi thinks academic research should lead to practical applications for the benefit of the general public. "We are always trying to satisfy the needs of society," Esashi says.

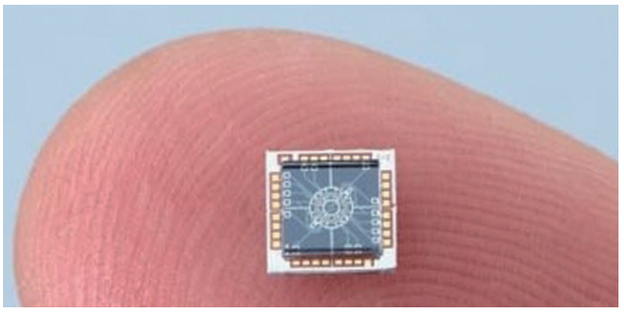
Esashi has an open-door policy, encouraging exchange of information and ideas between researchers. A large percentage of the equipment in Esahi's laboratory is unique and not commercially available having been designed and made by Esashi and his group. If required, users can further customize the equipment for experiments on, for example, etching MEMS devices. Both students and visitors are asked to take care of machines, share the use of them and give instruction to newcomers.

The university's engineering school has a larger MEMS lab that houses high-end equipment for more complicated experiments. It is operated under Esashi's supervision.

Esashi's efforts have proved to be a success, as seen by the 400-500 people who have registered to use the labs. Engineers from rival companies work together to solve problems. Meanwhile, Esashi occasionally holds seminars free of charge to share information. "I want people to know open collaboration is possible and useful," Esashi says.

Esashi's lab activities have been stretching to bigger projects involving companies and regional governments, with the aim of creating a MEMS knowledge base in Sendai. In 2001, a start-up company called MEMS Core was created, to produce prototypes on a contract basis. In 2004, the Sendai City, Miyagi Prefecture and other bodies tied up to establish the MEMS Park Consortium, a group consisting of major and local manufacturers, supporting organizations for industry and local governments to share information and seek the seeds for new business. The membership stands at more than 110 companies and organizations. Last year, a MEMS Design Center was added within the MEMS Core factory facility. And Sendai City also joined hands with Germany's Fraunhofer-Gesellschaft, Europe's leading organization for applied research, to work on the further development of MEMS technology. The networks and functions for the prospective 'Sendai MEMS Industrial Cluster' are now expanding.

• *MEMS Park Consortium URL*
www.memspc.jp/english



Electrostatically levitated rotational gyroscope

Dr. Masayoshi Esashi

Professor,
Department of Nanomechanics,
Graduate School of Engineering,
Tohoku University

www.mems.mech.tohoku.ac.jp/index_e

Line up everything from funding to leadership

Sendai is gearing up to foster budding business opportunities

Sendai is stepping up efforts to support universities and businesses looking to strengthen links.

Such efforts are important for Sendai to maintain its economic strength. The challenge is nurturing competitive businesses while maintaining the city's academic and culturally rich environment. In addition to MEMS, Sendai has set an initial goal of making the city stand out in the areas of ICT, the environment, health and welfare.

progressed to its second phase, 'Tohoku monozukuri corridor'.

Sendai City's main purpose in creating an industrial cluster is to build more active networks among researchers and companies, and to make them more internationally competitive.

Meanwhile, in 2002, the MEXT initiated a five-year project 'Knowledge Cluster' to develop a system under which universities are motivated to provide business seeds for companies, or vice versa, under a region's initiative. Its ultimate goal is to make universities and companies stimulate each other through collaborations and to spark technological innovations.

Sendai is one of the 16 regions selected for this scheme, and the ICR has been leading the way. Its research focus is 'intelligent electronics' based upon Tohoku University's technologies and nine research projects – ranging from next-generation wireless systems to technology to monitor a user's behavior – are underway. The support from the MEXT has provided 500 million yen ($4.36 million) per year in these 5 years.

Sendai Intelligent Knowledge Cluster's HQ in ICR recruited a general manager and several coordinators who have science and business expertise enough to create a bridge between universities and companies. The number of participating companies in these nine projects has risen to 30 from less than 10 at the beginning, and a few projects have already taken off in terms of commercialization.

• *Sendai Intelligent Knowledge Cluster*
http://sendai-cyber.icr-eq.co.jp/english

A new style of international academia-industry collaboration: Sendai – Finland Project

Sendai provides an encouraging international academia-industry collaboration model by the Sendai-Finland Wellbeing Centre (FWBC) project, which has been developed by key players involved in wellbeing research and development both in Sendai and Finland.

This project has been elaborating a new wellbeing concept by integrating Japanese and Finnish elderly care ideas. Under the new concept, the project has been facilitating academia and industry to develop new technology to enable the elderly to live independently at their homes as long as they would like to.

By combining mobile and security technologies we are realizing both social interaction and privacy for the elderly.

This project also shows a new style of international academia-industry collaboration providing a platform for universities, research institutes and companies. On the platform, they can develop R&D projects and/or businesses in various ways, independently, collaboratively or by forming a consortium, and support is available from Japanese and Finnish related organizations. This unique project is creating new integrated technologies based on different cultures.

SENDAI

- Private Companies • Tohoku Welfare University
- Tohoku Welfare Corporation
- Tohoku University
- Development Bank of Japan • City of Sendai
- Sendai City Industrial Promotion Organization

FINLAND

- Private Companies
- National Research & Development Centre for Welfare & Health (STAKES)
- Finpro (a Finnish foreign trade association)
- Oulu Region Centre of Expertise
- The Finnish Institute in Japan

Sendai-Finland Wellbeing Centre (FWBC)
New technologies developed through interaction between researchers and users promote independent life for the elderly.

Column

A next-generation science park is coming to Sendai

Tohoku University has had a long-term ambition of creating a Japanese version of Silicon Valley, by taking advantage of its scientific research prowess. The idea will soon be realized in the form of a next-generation science park.

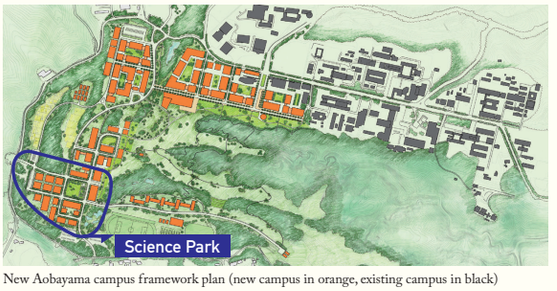
Behind the move is Tohoku University's renewed effort to further evolve as the world's top-level comprehensive university, as it celebrates its centenary in 2007. To this end, it is going to concentrate most of its departments and research institutes, which are currently scattered around Sendai, onto the hilly campus at Aobayama and, further, it will build the science park there as the flagship of the new campus.

The Aobayama campus will be extended by some 81 hectares and part of the new site will be available for the science park. The university plans to complete the construction of the park by 2010 creating a research environment harmonized with the rich natural surroundings, with the opening taking place the following year.

The science park will carry missions to strengthen cooperation between the university and private companies, to create more university spin-offs, to provide a better research environment and to generate new employment. A number of cutting-edge technologies, from DNA-sequencing equipment to a special-purpose clean-room, will likely be available.

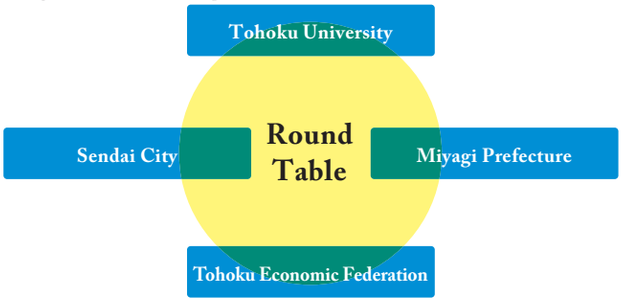
As a start, Tohoku University hopes to entice about 50 companies to the park. It will provide various support infrastructures for the park's tenant companies, including access to existing research facilities at the university, and an opportunity to apply for public grants. Foreign companies are welcome.

Contact: Tohoku University Science Park Promotion Office
p-science@bureau.tohoku.ac.jp



New Aobayama campus framework plan (new campus in orange, existing campus in black)

Developments of Round Table meetings



Developments

MEMS Park Consortium (over 110 Organizations)	Tohoku Incubation Fund ($27.7 million)
Regional Collaboration Fellows (Personnel Exchange)	Tohoku Univ. Science Park Plan Promotion

And more…

The aim is to use research to add value to these industries.

In fact, Sendai heralded Japan's academic-business sector collaborations by establishing, in 1989, the ICR (Intelligent Cosmos Research Institute), which is designed to create and foster research-oriented companies in the Tohoku region. 14 such projects were created under the scheme, and some of them were successfully turned into commercial ventures, such as Sunrock, which is developing advanced sea-farming technology and now makes food products made of sturgeon and rare flatfish.

Currently, ICR plays a role as a business incubation centre, where the offices are almost full, housing 10 start-ups. Another important role for the industrial and academic collaboration activities of ICR is to attract more investment by acquiring central government projects, such as the Knowledge Cluster Project of the MEXT (Ministry of Education, Culture, Sports, Science and Technology), the Industrial Cluster Project of the METI (Ministry of Economy, Trade and Industry) and others.

Sendai officials along with local players know their efforts are unlikely to see the light of day without powerful political leadership. So in 2003, a top-level alliance was formed under the consensus of the President of Tohoku University, the Chairperson of Tohoku Economic Federation, the Miyagi Prefectural Governor and the Sendai City Mayor. They meet regularly to discuss how to utilize the region's intellectual property portfolio of universities and to promote the region's science and technology activities. These Round Table meetings have contributed not only to formal networking of the four members which results in swift decision-making on important projects such as MEMS Park Consortium, but also to informal networking with active discussions and exchange of information on an individual basis. At their first meeting, the leaders appointed several engineering professors, including Esashi, as fellows. They are assigned to work for the local governments a few days a month to accelerate projects while giving technical advice to small and midsized enterprises.

To solve the major headache for start-up companies – that is, finance – the Tohoku Incubation Fund was set up in 2004. The 10-year investment fund collected 3.18 billion yen ($27.7 million) from banks, public institutions and local governments. This is largest such local fund in Japan with the aim being to invest early in university based start-ups. The fund is managed by Tohoku Innovation Capital Corp., which has invested in more than 20 start-ups based on the technological seeds from universities . Its most promising investment targets are Ideal Star, Digital Powder Systems and also MEMS Core. These are Sendai's leading micro/nano materials/devices start-up companies (see the boxes below). Following such successful results, a second investment fund, Tohoku Growth Fund is being organized.

"We think we can leverage our abilities better by joining forces with various institutions and players," says Hiroshi Takahashi, Senior Director of the Industrial Policy Deparment at the City of Sendai.

• *Tohoku Innovation Capital Corporation*
www.tohoku-innocapital.co.jp/ticc/index_02.html

Connecting key players

In Sendai, a network among local companies is proliferating and energetic science experts are scrambling to facilitate collaboration between academics and SMEs

In general, industrialists are inclined to point out that efforts to apply a university's research results for practical use have rarely turned into successful businesses on the market, due to the lack of human resources and business expertise. In answer to these criticisms two of Japan's ministries, the METI and the MEXT, have selected the city of Sendai as a base for large-scale projects to try to bridge the gap.

In 2001, the METI decided to create new industrial clusters nationwide, and approved 19 ideas from various cities and regions. Following the initiative, the Sendai-led Tohoku region came up with two themes: one to develop products and services using ICT and welfare engineering technology to cope with an aging population, and the other to realize a sustainable society. This project has now

Chapter7: Welcome to Sendai

In and around Sendai, there are many places and events to enjoy in each season. Here is practical information on how to get around Sendai and Tohoku region.

In Tohoku region, there are many places and events for visitors to enjoy in each season: cherry blossom viewing in spring, sea bathing in summer, colorful leaves in autumn, ski resorts in winter.

Excursions from Sendai to natural settings, such as beautiful Matsushima Bay, the grand Akiu-Ohtaki water-falls, colourful autumn leaves at Naruko Gorge and silvery snow monsters at Mt. Zao will refresh those who visit. And near Sendai, spring flowers at Hanamiyama Park in Fukushima and a famous sacred place, Yamadera Temple in Yamagata attract visitors. Picking of seasonal fruit in Yamagata and Fukushima is also very popular .

As a gateway of the Tohoku region, major cities and tourist sites are easily accessed by rail and/or express bus from Sendai. Examples of well known places are Shirakami Mountains and Hiraizumi. The Shirakami Mountains, a large part of unspoiled virgin forest in north Tohoku, was one of the first sites registered on the World Heritage List in Japan. Hiraizumi, well known in Japan for its famous Buddhist temple Chuson-ji, was decided to be recommended by the Japanese Agency for Cultural Affairs as a World Heritage site in July 2006. In various parts of the region the rich natural environment is preserved.

In the downtown area of Sendai, long shopping arcades and various shops attract many people. Near the arcades, along Jozenji Street and Aoba Street, Zellkova trees form green tunnels and provide a refreshing atmosphere for urban residents and visitors. Sendai is affectionately called 'Mori-no-Miyako' (City of Trees).

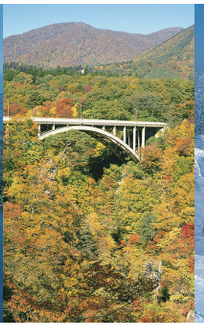
1. Information

- **Sendai Travel Information:** ***www.sentabi.jp/1000***
  * information for tourists: about Sendai City in general, access , crafts and restaurants in Sendai
- **Sendai Tourism & Convention Bureau:** ***www.stcb.or.jp/eng***
  * convention facilities and information on convention support
- **Sendai International Relations Association:** ***www.sira.or.jp***
  * information for foreign residents in Sendai, and Sendai International Center, Japanese language courses and international events
- **Multilingual guide to living in Japan:** ***www.clair.or.jp/tagengo***
  * Living Guide (in 13 Languages)
- **An Attractive City for Business:** ***www.city.sendai.jp/keizai/sangyou/yuchi-miryoku-e/***
  * industrial projects and support in Sendai

- **English Hotline:**
  +81-22-224-1919 (022-224-1919 from within Japan)
  * information of daily life, leisure activities, etc.
- **Sendai City Tourist Information Office: 2F, JR Sendai Station**
  * general information on sightseeing in Sendai, access, local organizations and local products. English available.


Cherry Blossom in site of the Sendai Castle


Matsushima Bay


Naruko Gorge


Snow Monsters in Mt. Zao Ski Area


Shopping Arcade


Aoba Street

With the harmony of beautiful nature and urban life, people in Sendai have nurtured and enjoyed various festivals, arts and culture.

'Sendai Tanabata Festival' (6-8 August) imbues the elegance of Japan's traditional star festival in midsummer and attracts more than 2 million visitors every year;

In 'Johzenji Streetjazz Festival' in September over 600 bands play jazz, which makes the festival the largest jazz festival in Japan;

'Sendai Pageant of Starlight' (12-31 December) impresses people with a million miniature light bulbs on Zellkova trees along the downtown streets.

'Sendai International Music Competition' aims to boost the careers of talented young musicians is held every three years. It is now a member of the World Federation of International Music Competitions.

There are about 20 concert and music halls and 20 museums in Sendai.

A lot of tourists visit Sendai with expectations for its exquisite cuisine. You will be satisfied with excellent sushi and seafood from places close to a fishery harbor, sake from high quality rice and fresh fruit. And in and around Sendai, there are 36 hot spring resorts offering relaxation to visitors.

Seeing is believing.
Sendai welcomes you.

2. Access

(1) Flight

From Sendai Airport (SDJ), planes leave for major East Asian cities and also for many domestic cities. It has convenient access from/to all over the world via major Japanese airports such as Tokyo-Narita and Nagoya-Chubu.

From Tokyo-Narita Int'l Airport (NRT): *55 mins.*
From Nagoya-Chubu Int'l Airport (NGO): *65 mins.*

- **Sendai Airport:** ***www.sdj-airport.com/english/***

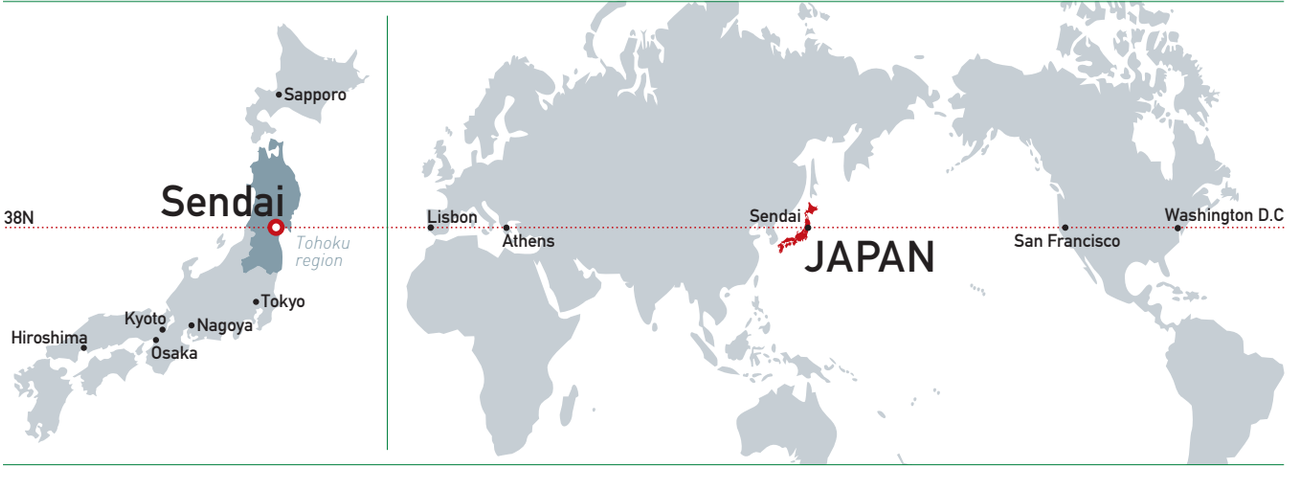
(2) 'Tohoku Shinkansen' Bullet Train

From Tokyo to Sendai: *Just 96 mins.*

(3) New Airport Railway

In March 2007, a new railway will connect Sendai Airport and JR Sendai Station in *17 mins.*

English signs have been placed all over the city to make sure foreign residents and visitors can get around the city easily.



Sendai Tanabata Festival

Johzenji Streetjazz Festival

Sendai Pageant of Starlight

Sushi

Oyster

Sakunami Hot Springs