

研究 解説

Joint Research on Micromechatronics between the “Centre National de la Recherche Scientifique (CNRS)” and the “Institute of Industrial Science (IIS)”

フランス科学研究庁 (CNRS) と東京大学生産技術研究所 (IIS) の
マイクロメカトロニクスに関する共同研究

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The “Centre National de la Recherche Scientifique (CNRS)”, the main French research association having 27,000 staff members and the Institute of Industrial Science of The University of Tokyo have decided to settle a joint research project on Micromechatronics. Micro miniature machines and motion systems are investigated in a joint laboratory; the Laboratory for Integrated MicroMechatronic Systems (LIMMS) at IIS. Several researchers came from CNRS and stay in LIMMS for one to three years conducting scientific research with IIS faculty members and research staff.

1. Presentation of the joint laboratory : LIMMS.

The “Centre National de la Recherche Scientifique (CNRS)”, the main French research association, and the Institute of Industrial Sciences (IIS) of The University of Tokyo have decided to settle a joint research project, and have created a joint laboratory : the “Laboratory for Integrated MicroMechatronic Systems” (LIMMS).

Within the LIMMS, cooperative research work is carried out in the field of Micromechatronics by French researchers issued from CNRS laboratories and by professors and researchers form the “Research Group of Excellence (RGOE) on Micromechatronics” of IIS. At the Roppongi site, the LIMMS welcomes CNRS permanent researchers for stay durations of 2-3 years, and post-doctoral researchers within the frame of the fellowship from the Japanese Society for the Promotion of Sciences (JSPS), usually for

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one year long. In standard regime, up to six CNRS permanent researchers and an equivalent number of post-doctoral fellows, will be selected in France to join the LIMMS.

The technical topics of the joint research, as stated above, is related to Micromechatronics : integration of micro-machines and microelectronics into a complete integrated system. The research projects cover micromachining technology, extremely fine mechanical machining, new kinds of actuators / sensors development and atomic scale microscopy systems. Basically, the technical projects will combine the technological know-how of the IIS group of excellence in Micromechatronics and some expertise domains of CNRS laboratories such as optics, microwaves, acoustics. More details will be given in section 5.

2. Why LIMMS ? the CNRS view point.

2.1. General presentation of CNRS.

The “Centre National de la Recherche Scientifique (CNRS)” is the French government agency for basic research and is, by its size, the first European fundamental

research organization. CNRS gathers up to 27000 staff members including 11400 researchers and 15600 engineers, technicians and administrative assistants. CNRS is strongly associated with University and the research is organized within 1 300 laboratories distributed all over France. The CNRS was headed by Mr. François KOURILSKY from July 1988 to July 1994 ; Mr. Guy AUBERT is the present General Director.

The CNRS research activities are organized around 7 scientific departments, ranging from basic mathematics and physics to human sciences. The LIMMS belongs to the "Engineering Science" department whose scientific Director, Mr. Jean-Jacques GAGNEPAIN, played a major role in the creation of this joint research project. The research performed in the engineering department focuses on signal and information processing, process engineering, mechanics, fluids and health engineering. Among the research priorities, we find parallel architectures, intelligent structures and machines, but also ... microtechnologies in such a good place that it was a strong motivation to establish the LIMMS project.

2.2. CNRS interest.

The motivation of CNRS in LIMMS is strongly supported by two statements, a general and a scientific one.

Generally speaking, the equilibrium between scientific exchanges between Japan and France is not always reached, in particular, the number of French researchers in Japan is much lower than the number of Japanese researchers in France. Moreover, even if the willingness to have strong collaboration with Japan is very well established, the way the French researchers organize their stay in Japan does not give the corresponding impact. The French researchers are usually distributed into numerous Japanese laboratories and their technical activities are also widely spread. The return in France is usually organized individually so, unfortunately, the technical feedback is lowered and the basic collaboration willingness is not so well visible.

For the above mentioned reasons, the interest to have a clearly identified joint laboratory became obvious, therefore, CNRS felt the priority to organize the scientific exchanges and joint projects on an other base.

The covered scientific activities has to be included in a new, long range and potentially very attractive research field. Micromechatronics and microsystems were chosen mainly because they meet two requirements : first, these activities are clearly within the CNRS Engineering Sciences department research priorities ; second reason, Japan is

strongly engaged in microsystem research programs.

Among the possible partners, the IIS of the University of Tokyo presents the main advantage to have organized its micromechatronics activities within a coherent frame: the "Research Group of Excellence on Micromechatronics". This group, is gathering 6 laboratories, presents all the excellent technological means to fulfil the CNRS scientific interest and to produce long term research. Moreover, since the first contacts, the idea to create a joint laboratory, received a extremely favourable welcome from IIS Director, Mr. Fumio HARASHIMA.

So, as the planned collaboration with IIS fulfilled all the basic CNRS motivations, from the CNRS view point there is a strong will to create LIMMS.

2.3. The 3 founding CNRS laboratories: IEMN, IMFC and LAAS. Presentation and roles.

From the CNRS side, the LIMMS is affiliated to the three main French laboratories working in the field of microtechnics; namely:

- the Institute of Electronics and Microelectronics of Northern France (IEMN) in Lille,
- the Institute of Microtechniques of Franche Comté (IMFC) in Besançon, and,
- the Laboratory for the Analysis and the Architecture of Systems (LAAS) in Toulouse.

These 3 laboratories have two main roles. The first one is to select permanent CNRS researchers and French post-doctoral fellows that are welcomed within LIMMS. The second role is to propose scientific projects that meet both their needs and the IIS micromechatronics processing capabilities. These second role provides them with a scientific responsibility within the frame of the CNRS evaluation committee.

IEMN, located in Lille (North of France), and directed by Mr. Eugène CONSTANT, gathers 300 researchers and PhD Students. IEMN focuses mostly on material sciences, micro-structures, components and microelectronics circuits. A large part of activities is also devoted to optoelectronics and microwave circuits. A 900 m² clean room is implemented for III-V based process and microtechnology.

At IMFC in Besançon (East part of France), directed by Mr. Daniel HAUDEN, research activities are performed on materials, CAD and processes for micromechatronics, microactuators, microsensors and robotics. These activities are completed by measurement systems and near field microscopes developments. 420 researchers and PhD students work at IMFC with strong expertise on metrology,

mechanics and optics. A 350 m² clean room is also available at IMFC.

The LAAS laboratory, in southern France, Toulouse, is one of the largest CNRS laboratories : 400 researchers and PhD students. The research topics include silicon and III-V based microelectronics, optoelectronics and integrated optics, microsystems and sensors and finally, robotics and artificial intelligence. 900 m² of clean room and laboratories are available with various types of microscopy systems. The LAAS is directed by Mr. Alain COSTES.

3. IIS's interest in LIMMS.

3.1. General interest.

The concept of LIMMS is very much in coherence with IIS's general policy. The first policy is the fusion of different disciplines. In contrast to the Faculty of Engineering where both undergraduate education and research at the graduate school level are performed, the IIS focuses mainly on research in conjunction with industries as well as in the graduate school. Each faculty, no matter how young it is, has an independent laboratory in which state-of-the-art topics in various engineering fields are studied. Many of these topics are categorized as interdisciplinary or transdisciplinary research ; it means that the study cannot be completed within one conventional engineering discipline. IIS encourages faculty members to form research groups in order to tackle the problem. There are more than 15 research groups on specific subjects such as anti-earthquake engineering and intelligent mechatronics. Micro mechatronic systems which is the main research topic in LIMMS, also requires collaboration among electrical and electronic engineering, mechanical engineering, chemical engineering and material science. A research group, RGOE on Micromechatronic, was established in 1992 and has been active in the field of micro systems and micromachines. The LIMMS provides IIS with the opportunity to enhance the activity further.

The second policy is the international exchange and collaboration. The IIS has made international agreements on research cooperation with foreign universities and research institutions which, of course, include CNRS. Some of the faculty members were invited from foreign countries and about 150 foreigners stay in IIS as students and visiting scientists. Since research topics are becoming more and more global, the importance of international exchange keeps growing. The LIMMS is very unique among many international activities. A substantial number of senior and

post-doctoral researchers stay in IIS to investigate a well defined subject for several years. Close interaction between French and Japanese researchers is to be expected through experimental works and discussions. Both of us are willing to take the opportunity to learn each others culture and way of thinking. Collision and fusion of different cultures are expected to stimulate the birth of innovative breakthroughs.

3.2. Scientific interest.

The LIMMS project has many features in terms of scientific research. Making small machines such as an artificial ant is one of human dreams for a long time. One can see milliard of possibilities of micro miniature machines; medical micromachines going into veins to cure the affected parts from inside of our body, scientific micromachines manipulating molecules or atoms, and a bunch of environmental micromachines purifying a polluted area. As described earlier, a research group, RGOE on Micromechatronic, was established in 1992 and has been active in the field of micro systems and micromachines. The purpose of the micromechatronics research is to integrate micromachines and microelectronics into a complete mechatronics system which works in the micro world. The research projects cover from micromachining technologies using both semiconductor processes and extremely fine mechanical machining to micro motors and actuators based on novel principles. Ultra-precision control down to atomic dimensions and intelligent motion control using advanced sensing scheme are also investigated. The prospective application includes bio-medical engineering, micro robots, micro optics, micro fluidic systems and information storage and retrieval devices. However, the research activities have focused mainly on fabrication processes and control schemes for micromachines. On the contrary, research on microsystems in the three CNRS laboratories involving LIMMS is more application oriented. The reason is that they have strong background in application areas such as optics, precision metrology and microwave applications. Because directions of the research are complementary between both parties, it is natural and beneficial for us to form a joint project.

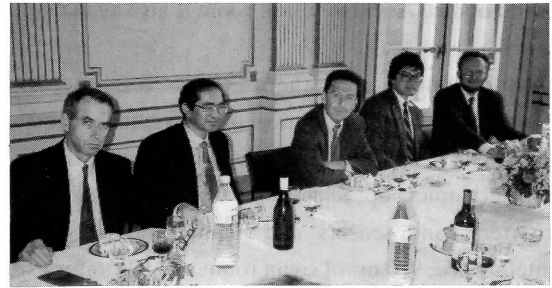
4. Key dates of the project and LIMMS organization.

4.1. The historical view point.

In 1992, The CNRS was trying to promote its own research in microtechnologies by launching an internal project which aimed to group several laboratories on a realization of micromechatronics objects. At the same time,



(a) At IEMN : up and down, from left to right : H. Fujita, H. Bleuler, E. Constant (IEMN Director), C. Bruneel, D. Collard, M. de Labachellerie, M. Lannoo (IEMN Deputy Director), F. Harashima (IIS Director), P. Godts, T. Masuzawa.



(b) At CNRS Headquarters : from front to back : J. J. Gagnepain (CNRS/SPI Director), F. Harashima (IIS Director), A. Costes (LAAS Director), H. Kawakatsu, G. Salmer.



(c) At CNRS Headquarters : from front to back : F. Kourilsky (CNRS General Director), T. Masuzawa, B. Dubuisson (CNRS/SPI Deputy Director), D. Hauden (IMFC Director).

Figure. 1 Some pictures from the French tour on February 1994.

the recently created CNRS office in Tokyo was promoting cooperation between CNRS and Japanese scientific institutions. In February 1993, a visit of French scientists to Japanese institutes working on microtechnologies was organized. At the same time the idea of creating a French-Japanese joint project on micromechatronics was proposed by M. Jean-Jacques GAGNEPAIN, Director of the engineering sciences department of CNRS. This idea was proposed in December 1993 to the Institute of Industrial Science of The University of Tokyo and received a great welcome.

In February 1994, a visit of the 3 founding CNRS laboratories and of the CNRS headquarters was organized for the IIS professors of the Research Group of Excellence on Micromechatronics. Some pictures of these events are given in figure 1.

On May 1994, the LIMMS office is officially inaugurated by the CNRS General Director, Mr. François KOURIL-



Figure. 2 Inauguration of the LIMMS office : front, from left to right : H. Yoshikawa (President of The University of Tokyo), J.B. Ouvrieux (French Ambassador) and F. Kourilsky (CNRS General Director).

SKY and the President of the University of Tokyo, Mr. Hiroyuki YOSHIKAWA (figure 2). At that date, a letter of intention for cooperative research plan was signed.

On June 1994, in Paris, the CNRS and The University of Tokyo have signed a general agreement on joint research in the frame of which the LIMMS enters. After several months of discussion, the final constitutive agreements and related organization rules were signed on February 1995.

4.2. LIMMS organization.

The established IIS/CNRS joint laboratory, LIMMS, will welcome up to 6 CNRS senior researchers for duration stays of 2-3 years. These CNRS researchers are dispatched in the laboratories of the IIS research group of Micromechatronics. Each French researcher manages a research project which is defined jointly with an IIS professor, the LIMMS manager and the founder CNRS laboratory from which the researcher is issued. To ensure a successful approach, each research project has to meet the mechatronics experiences and interesting process capabilities development from IIS, in one hand, and the expertise domain of the founding CNRS laboratory, in the other hand.

Half of the basic LIMMS research budget is provided by the CNRS and half is provided by Monbusho under a cooperative research agreement.

In addition, each senior CNRS scientist will be helped by a French post-doctoral fellow supported by the Japanese Association for the Promotion of Science (JSPS). The post-doctoral fellowship is usually for 1 year duration.

Cooperation with other partners are welcome and the common goal is to create an active international research center in this very fascinating field.

5. The French researchers : background, motivation and projects.

On beginning of March 1995, 3 CNRS researchers, Mr. Michel de LABACHELERIE, Mr. Moussa HOUMMADY and Mr. Dominique COLLARD are already joint the LIMMS. 3 post-doctoral fellows have also arrived, Miss Dominique CHAUVEL, Mr. Christian BERGAUD and Mr. Franck CHOLLET. Since December 1995, Mrs. Mari UMEHARA has been engaged by CNRS as LIMMS assistant. The next two following CNRS researchers will be welcome in LIMMS in October 1995, and also at that time two other post-doctoral fellows are expected to join us.

Michel de LABACHELERIE is a CNRS senior researcher whose main interest is related to Optics, Lasers and Optoelectronics. He was the leader of a research group named "Coherence improvement of Laser diodes" in the "Laboratoire de l'Horloge Atomique" belonging to CNRS, at the Orsay University in France. At that time, he developed a new class of lasers called "extended-cavity lasers" which uses laser diodes to obtain lasers with a high degree of tunability, frequency control and spectral purity, for various scientific applications. An example of this new class of laser is given in figure 3.

He came in Japan in September 1992 for a 3 years stay and conducted in the laboratory of professor OHTSU at Tokyo Institute of Technology, a successful research project which resulted in the demonstration of a large number of ultra-precise laser frequency references at $1.5 \mu\text{m}$, which improves the stability of $1.5 \mu\text{m}$ frequency stabilized laser diodes by two orders of magnitude. Five papers were published on that subject. He also worked as scientific advisor at the CNRS office in Tokyo where he was in charge

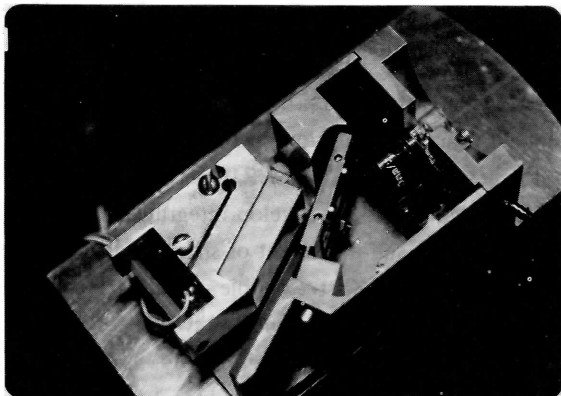


Figure. 3 An example of extended-cavity semiconductor laser which provides a very accurate frequency control.

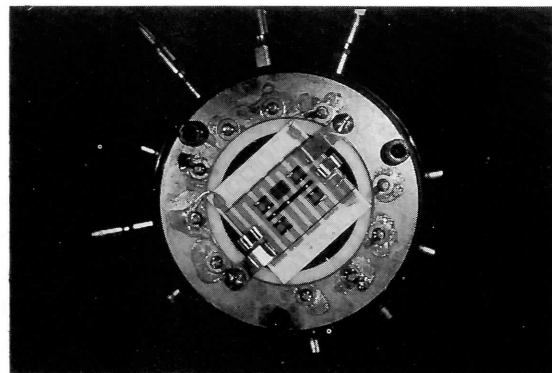


Figure. 4 Surface Acoustic Wave Gas sensor made at LPMO/IMFC/IXL/DRET.

of the topics related to MICROTECHNOLOGIES in Japan, and promotion of the French-Japanese joint laboratory project of Micromechatronics. In collaboration with professor FUJITA, of IIS, he defined the collaboration framework which led to the present LIMMS laboratory and manages the project from the French side up to his departure to France on July 1995.

His research project at LIMMS aims to study micro-optical components using micromechanical parts. Currently, he is interested in making an optical coupler with a movable optical waveguide which could be approached to a fixed main waveguide using an electrostatic actuator, in order to pick up a fraction of the main waveguide optical power which can be transferred to the movable waveguide.

Moussa HOUMMADY was born in 1962 in Morocco, senior scientist at the Centre National de la Recherche Scientifique (CNRS) since 1992. He did research at the IMFC since 1986. He received, in 1991, his PhD from the University of Franche Comté (Besançon) on elastic waves properties in thin piezoelectric substrates and their applications to physical or chemical sensors. He was promoting acoustic wave sensors and developed new sensors such as humidity, liquid viscosity, gas concentration, polymer phase transition sensors, in collaboration with several CNRS laboratories in Paris, Lyon, Bordeaux and Toulouse. To illustrate this activity, a gas sensor photograph is displayed in figure 4.

He joined the LIMMS at the Institute of Industrial Sciences, University of Tokyo, on December 1994 where he manages a project related to the development of a new kind of scanning force microscope using nanostructures as cantilevers and surface acoustic waves for their excitation in the 100 MHz-1GHz range. The aim of this project is to improve the resolution of dynamic mode control of scanning force microscopy. His main interest in joining LIMMS include the development of micro- and nano- technologies as well as the fusion of different cultures and all forms for promoting Sciences in direction of young people and developing links.

Dominique COLLARD received his Engineer degree from ISEN in 1980 and his PhD degree from the University of Lille in 1984. His dissertation focused of silicon process simulation using the finite element method. In 1985-1986, he joined the TOSHIBA ULSI research Center in Kawasaki as visiting scientist for 1 year where he worked on the modelling and simulation of impurity diffusion mechanism in advanced CMOS processes. Back in France, he entered

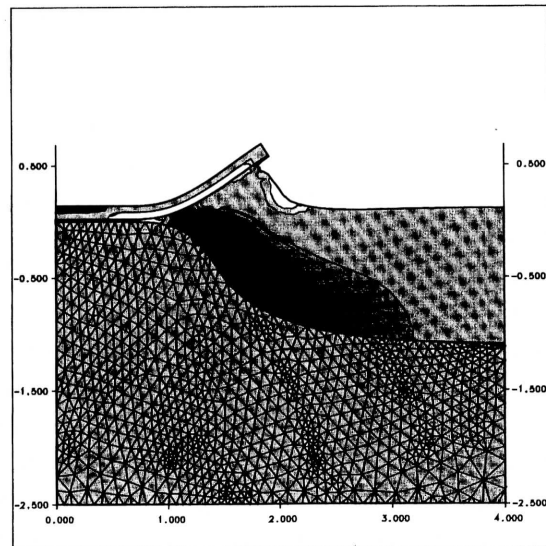


Figure. 5 Simulated shape of a local oxidation of silicon. The shearing stress profile is displayed in the oxide.

CNRS as senior researcher and settled a research group on silicon process and device simulation, he also became responsible of the electronics department of ISEN. All the research work of the simulation group is gathered in the 2D process simulator, IMPACT that is used in several leading semiconductors companies, in Europe and Japan. IMPACT main features are to accurately simulate impurity doping process under non-equilibrium conditions and mechanical stresses generated by the silicon processes. Figure 5 displays the stress profiles and 2D oxide shapes after a local oxidation. In 1992, he became responsible of the simulation activities of IEMN.

His main motivations in joining LIMMS are to renew the excellent experience he already had in Japan 9 years ago and to participate as much as possible to the excellent initiative of the IIS/CNRS joint research project. He also take advantage of the LIMMS creation to investigate in a closer way the real silicon processing after many years of simulation activities. He arrived in January 1995 for a planned 2 years stay duration, in July 1995, he will succeed Mr. Michel de LABACHELERIE as LIMMS Director.

His research plan is to develop integrated micro-motion system to permit self-alignment of small devices on silicon wafer surface. As a first example, using the concept of scratch drive actuator, an alignment system for laser diode on integrated microguide is under study. The actuation is induced by incremental steps created by electrostatic forces. Using this basic actuation the laser diode location is planned to be accurately determined by XY motion.

6. Conclusion.

It is far to be a conclusion, and all the authors of this paper really hope that the LIMMS will provide joint research results as excellent as was the initiative to create it.

Acknowledgments.

The LIMMS project has received numerous supports from many individuals and organizations. Without their support LIMMS would never have existed. We would like to acknowledge the participation of Mr. François KOURILSKY, the former Director of CNRS, and Mr. Hiroyuki YOSHIKAWA, the President of The University of Tokyo, for their initiative in concluding an Agreement on

Academic Exchange between the CNRS and The University of Tokyo; Science and International Affairs Bureau in The Ministry of Education Science and Culture, for providing financial support through the systems of Joint Research ; JSPS for providing support for travelling expenses for researchers and offering scholarship for post-doctoral fellows ; Mr. Jean-Jacques GAGNEPAIN and Mr. Fumio HARASHIMA for their continuous encouragement and support ; Mr. Eugène CONSTANT, Daniel HAUDEN and Alain COSTE who, as directors of the CNRS founder laboratories, have actively contributed to the project ; those who worked and helped to complete procedures to establish LIMMS. We sincerely thank all of them.

(Manuscript received, March 6, 1995)