LTM - Laboratoire des technologies de la microélectronique

Rapport Hcéres

agence d'évaluation de la recherche
et de l'enseignement supérieur

Section des Unités de recherche

AERES report on the research unit

Laboratoire des Technologies de la Microélectronique (LTM)

From the

University Joseph Fourier of Grenoble (UJF)

Grenoble Institute of Technology (Grenoble INP)

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Le Président de l'AERES

Jean-François Dhainaut

Section des unités de recherche

Le Directeur

Pierre Glorieux

May 2010

Research Unit

Name of the research unit : Laboratoire des Technologies de la Microélectronique (LTM)

Requested label :

N° in the case of renewal :

Name of the director: M. Olivier JOUBERT

Members of the review committee

Committee chairman

M. Jean-Pierre COLINGE (Tyndall National Institute, Ireland)

Other committee members

Mrs Sophie BOUCHOULE (LPN, CNU representative)

Mrs Isabelle SAGNES (LPN, CoCNRS representative)

M. Adrian IONESCU (EPFL, Switzerland)

M. Alain CLAVERIE (CEMES, Toulouse)

M. Massimo GENTILI (Nicro and Nano Engineering, Italy)

M. Herbert STRUYF (IMEC, belgium)

Committee members suggested by CNU, CoNRS, CSS INSERM, CSS INRA, INRIA, IRD

Observers

AERES scientific advisor

M. Alain CAPPY

University, School and Research Organization representatives

M. Laurent DEAUDEVILLE and M. Jacques DEROUARD, Université Joseph Fourier, Grenoble 1

M. Didier GEORGES, Grenoble-INP

M. Claude AMRA and Mrs Nathalie MALBERT, CNRS :

Mrs Marie-Noelle SEMERIA and M. Laurent MALIER, CEA-LETI :

Report

1 • Introduction

- Date and execution of the visit

The visiting committee has been organized from Thursday January 28th to Friday 29th, 2010. The visit, combining talks and lab visits was very well organized. First, a general presentation was given by the LTM director of the lab and then the three group presented their activity and project. The comite also had meetings with LTM personnel and parent organization representatives.

- History and geographical localization of the research unit, and brief presentation of its field and scientific activities

LTM, the "Laboratoire des Technologies de la Microélectronique" was created in 1999 by the National Center for Scientific research (CNRS) and two universities: the University Joseph Fourier of Grenoble (UJF) and Grenoble Institute of Technology (Grenoble INP).

Since 1999, LTM and LETI have developed a strong partnership leading to a cooperation agreement which institutionalizes the LTM and LETI cooperation. Being located within LETI gives the laboratory the capability to conduct applied research in a rich technological environment allowing, among others, unique partnerships with key players of the Microelectronics industry. For LETI, having an academic research laboratory "embedded" is a strong advantage since new topics can be launched and jointly driven, bringing a significant advantage with respect to the international competition.

Four years ago, LTM was composed of about 60 permanent and non permanent members. With the reinforcement of LTM by young CNRS researchers, LTM working force is now about 90 people leading fundamental and applied research in the field of Nanotechnologies.

- Management team :

M. Olivier JOUBERT (CNRS) is the LTM director and Mrs Jumana BOUSSEY (CNRS) is deputy director.

- Staff members (on the basis of the application file submitted to the AERES)

	Past	Future
N1: Number of researchers with teaching duties (Form 2.1 of the application file)	9	10
N2: Number of full time researchers from research organizations (Form 2.3 of the application file)	13	17
N3: Number of other researchers (Forms 2.2 and 2.4 of the application file)	2	2
N4: Number engineers, technicians and administrative staff with a tenured position (Form 2.5 of the application file)	12	13
N5: Number engineers, technicians and administrative staff without a tenured position (Form 2.6 of the application file)	12	5 (known)
N6: Number of Ph.D. students (Form 2.7 of the application file)	27	9 (known)
N7: Number of staff members with a HDR or a similar grade	11	13

2 • Overall appreciation on the research unit

- Summary

LTM is a medium size laboratory with 35 permanent postions. Being located within LETI gives LTM the capability to conduct applied research in a professional environment allowing unique partnerships with key players of the Microelectronics industry. The main domains of research cover advanced lithography, nanomaterials and integratio, plasma processes for advanced devices. The quality of LTM personnel is high with skilled engineers and technicians and some very bright and active young researchers. The scientific production is largely above average and the scientific activity covers from basic physics to industrial applications. Several LTM works have an actual international impact. LTM has been able to establish strong interactions with industry through long-term agreements and with international private companies that are world leaders their field. LTM researchers have developed tight relationships with numerous of their counterparts in European countries in the framework of EU research programs and Networks of Excellence.

- Strenghts and opportunities

The stability of the LTM within CEA- LETI and the interests of this situation are very well perceived by the entire laboratory. LTM has the opportunity to work on research programs strongly connected to industry in partnership with LETI using world-class, state-of-the art technology and equipments. This gives the LTM the capability to address technological challenges better than most other CNRS laboratories. Research efforts are coordinated between LETI and LTM is such a way that LETI addresses more immediate problems (development of processes), while LTM works on higher-risk, longer-term research topics. Owing to the LETI clean room infrastructure, the LTM has been able to receive for free new state-of-the-art pieces of equipment from vendors for evaluation and for developing new processes on these machines.

Owing to the support of the BTR program, LTM has built the new advanced technological platform (PTA) on Minatec site. All LTM projects in the field of Nanosciences are using PTA which fulfils a real need of LTM researchers involved in these advanced topics which cannot be addressed in the LETI clean room. LTM has been able to set up strong interactions with industry through long term agreements and with international private companies leading their field (Applied Materials and EVG). LTM benefits from a very good support from parent organizations (CNRS, UJF) and from CEA- LETI. All the cost of LTM projects (clean room, wafers, installation of new tools) are charged to the CEA-LETI.

Strong relationship has been established with laboratories such as LMGP and IMEP owing to common participation to FMNT (Fédération des Micro-Nanotechnologies). FMNT is the union of 4 laboratories, set-up by CNRS in 2003 and assembling the research competences of 4 Grenoble-Minatec laboratories involved in the field of Micronanotechnologies. FMNT is composed of :

- LMGP, Laboratoire des Matériaux et Génie des Procédés, working on advanced materials elaboration and characterization
- Laboratoire des Technologies de la Microélectronique (LTM) working if the field of new technologies involved in the miniaturization of nanoelectronics devices.
- Spintronique et Technologie des composants (SPINTEC) working to optimise new paradigms / devices in the emerging field of spin electronics
- Institut de Microélectronique, Electromagnétisme et Photonique (IMEP) working in the field of CMOS devices (characterization and simulation of new CMOS architectures) and photonics (integrated optics on glass). Excellent team spirit.

Very good scientific production.

Exemplary partnership with international industry.

Very good vision for the future.

The handling of the complex environment surrounding the LTM by the management (director and deputy director) is highly appreciated by the LTM members and by the AERES review committee.

Fair and balanced sharing of the financial resources.

Many former LTM students have found jobs in high-profile companies.

- Weaknesses and threats

The LETI clean room being more adapted to pure industrial projects, it is sometimes a little bit difficult to do the type of “exploratory” research that LTM wants to do. This is impacting the cycle time of LTM lots even though these lots are in general requiring a limited number of technological steps. Similarly the maintenance of LTM tools is not the highest priority of the maintenance teams of LETI, leading in some cases to relatively long immobilization of the tools for maintenance.

Access to LETI grounds requires some level of security clearance. As a result, there is a long delay (3 months) for obtaining a badge for some students. This is a little bit in contradiction with the rules of academic freedom.

Very poor quality of the office space (crammed workspace and derelict “temporary” office building, no meeting rooms, no mechanical shop, no external lab facilities, etc.). This has a negative impact on work efficiency and on attracting new researchers.

- Recommendations to the head of the research unit

- Promote the visibility of LTM as an independent entity with its own skills and expertise.
- Increase the involvement of LTM members in leading national or international research projects or networks.
- LTM could improve its level of networking with other national (academic) institutions. This could improve the success rate of ANR proposals and the exposure of young researchers to the national scientific community.
- Due to the growth of the size of the LMT, the need arises to create a steering committee or some equivalent structure that includes the different group leaders and the deputy director.

- Production results

(cf. http://www.aeres-evaluation.fr/IMG/pdf/Criteres_Identification_Ensgts-Chercheurs.pdf)

A1: Number of lab members among permanent researchers with or without teaching duties who are active in research (recorded in N1 and N2)	27
A2: Number of lab members among permanent researchers with or without teaching duties who are active in research (recorded in N3, N4 and N5)	17
A3: Ratio of members who are active in research among staff members [A1/(N1+N2)]	1
A4: Number of HDR granted during the past 4 years	4
A5: Number of PhD granted during the past 4 years	27
A6: Other relevant item in the field	

Technical team shared by the different teams of the Laboratory:

	past	future
N4: Number engineers, technicians and administrative staff with a tenured position (Form 2.5 of the application file)	5	5
N5: Number engineers, technicians and administrative staff without a tenured position (Form 2.6 of the application file)	2	2

3 • Specific comments

- Appreciation on the results:

  – Relevance and originality of the research, quality and impact of the results:

The quality of LTM personnel is high with skilled engineers and technicians and some very bright and active young researchers. The scientific production is largely above average and the scientific activity covers from basic physics to industrial applications. The LTM works "in symbiosis with LETI": While LETI works on processes that are directly relevant to the industry; LTM works "upstream" and explores new ideas, novel high-risk techniques and activities. The scientific quality of the LTM research extremely high and its embedding within LETI insures that it is industrially relevant.

  – Number and quality of the publications, scientific communications, thesis and other outputs:

During the period 1/01/2005- 30 /06/2009, the members of LTM have published 268 articles in scientific magazine (ISI woK), 26 invited talks in international Conferences and 248 Communications in international conferences. They have also filed 12 patents. This is a production of approximately 3.7 publications (or conference papers) per CNRS person (or professor) per year. This is an impressive number.

LTM is hosting and educating PhD students. Currently, 26 PhD students are involved in different research topics under the supervision of LTM scientists and 27 theses were successfully defended since 2005. 100% of the LTM PhD graduates were hired for well qualified positions in high-tech companies or research isnstitutions during the weeks immediately following their thesis presentation.

  – Quality and stability of partnerships

LTM has been able to establish strong interactions with industry through long-term agreements and with international private companies that are world leaders their field (Applied Materials and EVG). LTM benefits from a very good support from parent organizations (CNRS, Univ. Joseph Fourier (UJF)) and from CEA-LETI. A strong relationship with laboratories such as LMGP and IMEP has been set up owing to the common participation of these laboratories to the FMNT (Fédération des Micro-Nanotechnologies).

- Appreciation on the impact, the attractiveness of the research unit and of the quality of its links with international, national and local partners:

  – Number and reputation of the awards obtained by staff members, including invitations to international conferences and symposia

26 invited talks in International Conferences. Publications are in high-quality international journals and conferences.

  – Ability to recruit high levels scientists, post-docs and students, and more particularly from abroad

During the period 1/01/2005- 30 /06/2009, 3 external CNRS scientists decided to join LTM, two others are partially working at LTM and three young new researchers were recruited through the CNRS recruitment procedure. This significant increase is certainly due to the high level of the candidates proposed by LTM to CNRS recruitment but also to the LTM attractiveness and its capacity to drain skilled and confirmed researchers.

- Ability to raise funds, to successfully apply for competitive funding, and to participate to scientific and industrial clusters

A large amount of LTM resource is coming from MEDEA + programs , NANO 2008 programs and private contracts with STMicroelectronics in the field of microelectronics. This underlies the importance of the research carried out at LTM to industry partners. The revenues of LTM during the period 2005-2008 amount to13M€, which represents an average of more than 3.2M€ per year. In addition, LTM receives "in-kind" funding from industrial companies such as EVG, which gave state-of-the-art equipment for LTM to evaluate and develop new processes. Very few research labs are able to secure such funding; this is clear evidence that the high-quality research at LTM is highly valued by industrial partners.

LTM is less successful in securing large amounts of funding from the National Research Agency, which would require increased participation in National research clusters.

- Participation to international or national scientific networks, existence of stable collaborations with foreign partners

LTM researchers have developed tight relationships with numerous of their counterparts in European countries in the framework of EU research programs and Networks of Excellence. Privileged partnerships do exist with ICN Barcelona, IMEC and Italy and constitute a valuable base for establishing further scientific collaborations and exchanges. Outside Europe, LTM is an active member within institutional international programs. LTM participates in the partnership between UJF and University of Texas in Austin. LTM is also involved in several international structures set up abroad by CNRS (with Georgia Tech). LTM is a member of the Associated International Laboratory in Nanotechnologies and Nanosystems (LIALN2) launched in July 2008 in partnership with Quebec-Canada. LTM has also a strong cooperation with University of Santa Barbara in California.

- Concrete results of the research activity and socio-economic partnerships

LTM has developed an novel technique for in-situ measurement of plasma etching and lithography pattern formation. This technique, called "scatterometry". Scatterometry is a non destructive metrology technique which allows analysis of the light diffracted by a periodic pattern in order to determine the shape of the pattern. The new real time scatterometry capability developed at LTM is very promising for nanoimprint real time studies but also for resist trimming and other critical etch steps development. LTM is currently considering spinning off scatterometry tools and software.

EVG has installed a prototype of its new-generation UV nano-imprint lithography tool in the LTM facilities. EVG has asked LTM to benchmark and evaluate the machine, and to assess its possibilities for advanced nanoscale lithography applications.

LTM has modified an Applied Materials multichamber plasma etcher to develop te pulsed-plasma etch technique, which is perceived to become the mainstream type of etching tool for future semiconductor processing.

- Appreciation on the strategy, management and life of the research unit:

  - Relevance of the research unit organization, quality of the management and of the communication policy

The organization of the LTM research unit is efficient; it yields high-quality results and has the support and approval of all the team members (Engineers, Technicians and Administration, Professors, CNRS researchers, post-docs and PhD students are all very happy with director and adjunct director; they can always talk about their problems.

- Relevance of the initiatives aiming at the scientific animation and at the emergence of cutting edge projects

There is no doubt in the AERES committee's mind that LTM is at the cutting edge of plasma etching technology and advance nano-imprinting technology. It is also placing itself at a level of the state-of-the art research in the field of nanoparticle self-assambly and controlled growth of semiconductor nanowires.

The fact that a large amount of LTM resource is coming from MEDEA + programs, NANO 2008 programs and private contracts with STMicroelectronics, EVG and Applied materials in the field of microelectronics underlines is aproof that the industry and the microelectronics community at large regards LTM as a cutting-edge research laboratory worth investing in in a substantial manner.

- Contribution of the research unit staff members to teaching and to the structuration of the research at the local level

LTM contribute to courses definition at Université Joseph Fourier and allows UJF to have high-quality publications in the area of microelectronics. In return, UJF gives PhD grants to LTM students.

Members of LTM teach many courses at Polytech Grenoble in the masters in microelectronics and in Nanosciences program.

- Appreciation on the project:

- Existence, relevance and feasability of a long term (4 years) scientific project

The LTM project is the juxtaposition of the the projects of the different research groups within LTM (Advanced lithography, Nanomaterials and integration, and Plasma etching processes for nanoelectronics and emerging devices.). Each of these will be discussed in the next sections. In each of these fields LTM takes care of the high-risk, high-payoff advanced research aspects while LETI focusses on the shorter-term development aspect. The AERES committee appreciates this form of collaboration which both benefits the scientific aspect of the research work and maximizes the chances of successful industrial transfer.

- Existence and relevance of a policy for the allocation of ressources

There is a clear policy within LTM for sharing the financial resources, such that more advanced research topics can benefit from funding secured by shorter-term industrial research contracts. This policy is efficient and perceived as fair by all the members of LTM.

- Originality and existence of cutting edge projects

Each group within LTM is proposing cutting-edge, yet realistic research projects:

Advanced lithography: This group will focus on the dissemination of nanoimprint techniques during the next four years. They will mainly focus on thermal and UV-NIL imprinting processes. However, other patterning techniques such as soft lithography can be envisaged and developed for some dedicated applications. The main objective will be the fundamental studies of the polymeric material behaviour and template/resist interface in order to increase LTM's expertise of NIL processes. It will result in high maturity which will be used to provide NIL processes for specific applications. Advanced study of resists and scatterometry are also among the objectives of this group.

Nanomaterials and integration: This group will focus on the study of Emerging non volatile memoriy materials and structures (Resistive RAMs and Phase Change RAMs) and the electrical characterisation at nanoscale by scanning probe microscopy. Very promising is their activity on Group IV nanowires (Si, Ge, C) for nanoelectronics and photovoltaic applications. Finally, their activity on self-assembling of nanomaterials for nanoelectronics applications is addressing the "holy grail" of bottom-up integration.

Plasma etching processes for nanoelectronics and emerging devices: This group addresses the crucial problem of plasma etching of ultrathin (nanometer-scale, such as monolayer graphene sheets) layers with minimal defect generation. The activity "Plasma etching processes for advanced CMOS devices" (using pulsed plasmas) is very important for the future of the microelectronics industry. The other research pole of this group concerns plasma etching processes for spin electronic devices: this involves the etching of very complex material stacks with many different metal oxides.

4 • Appreciation team by team and/or project by project projet

Title of the team : Advanced lithography

Team leader: Mrs Cécile Gourgon

- Staff members (on the basis of the application file submitted to the AERES)

	Past	Future
N1: Number of researchers with teaching duties (Form 2.1 of the application file)	2	2
N2: Number of full time researchers from research organizations (Form 2.3 of the application file)	5	5
N3: Number of other researchers (Form 2.2 and 2.4 of the application file)	1	1
N4: Number engineers, technicians and administrative staff with a tenured position (Form 2.5 of the application file)	2	1
N5: Number engineers, technicians and administrative staff without a tenured position (Form 2.6 of the application file)	4	1 (known)
N6: Number of Ph.D. students (Form 2.7 of the application file)	6	2 (known)
N7: Number of staff members with a HDR or a similar grade	3	4

- Appreciation on the results:

  – Relevance and originality of the research, quality and impact of the results

The lithography activity in LTM which includes Nanoimprinting, Resist characterization, Metrology by Scatterometry and optical lithography modelling well reflect the intimacy with LETI and its successful history in collaboration with industry.

The more "fundamental" character of R&D carried out in LTM is also evident in the reported research lines. There is a evident effort in increasing the synergy and collaborative efforts among the four Reserch Groups. LTM carried out world-class research work in industrially-relevant areas of photolithography:

- The research on scatterometry is ground-breaking; it yields excellent results and has the potential for spinniing off equimnent and software tools.
- Ongoing research work on EUV lithography and resists.
- Development of fast computation methods for electromagnetic solvers.
- Development of in-situ scatterometry during plasma etching.
- Development of novel UV nano-imprint lithography techniques.

– Number and quality of the publications, scientific communications, thesis and other outputs

Journal Articles	Invited talks	Conference papers	Posters	Books	Book chapters	Patents	Theses
87	3	23	52	0	2	1	7

– Quality and stability of partnerships

Strong synergy with LETI, stable partnership with industrial partners such as EVG.

- Appreciation on the impact, the attractiveness of the team and of the quality of its links with international, national and local partners

– Number and reputation of the awards obtained by staff members, including invitations to international conferences and symposia

2 invitations to international conferences, 1 invitation to a national conference.

– Ability to recruit high levels scientists, post-docs and students, and more particularly from abroad

Due to the security constrains of being in the CEA/LETI and the confidentiality requirements of working closely with industry, LTM is not as flexible as it might want in the area of hiring foreign students. So the student supply ist mostly national. The Advanced lithography group has graduated 7 PhD. Students during the period of time under consideration.

– Ability to raise funds, to successfully apply for competitive funding, and to participate to scientific and industrial clusters

Competitive funding won from industry. A long term relationship,formalized by a joint development program (JDP) since 2002, has been established with EVG in the field of nano-imprint. The cooperation started with the installation of a thermal nano-imprint system from which a strong background was generated in the field. Following this first successful phase of the JDP, a second one was launched in the field of UV nano-imprint leading to the evaluation of a step and repeat UV NIL stepper. This cooperation has allowed LTM and LETI to become undoubtedly European leaders in the field.

– Participation to international or national scientific networks, existence of stable collaborations with foreign partners

The Advanced lithography group has received "in-kind" funding from industrial companies such as EVG, which gave state-of-the-art equipment for LTM to evaluate and develop new processes. Very few research labs are able to secure such funding; this is clear evidence that the high-quality research at the Advanced lithography group is highly valued by industrial partners.

As all the lithographic technologies, Nanoimprinting is tool-dependent, and the AERES review committee fully approves the group's strategy of carrying out its research activity acting as a beta-site for the EVG tool vendor. This will allow the group to investigate the technique as a whole and determine, with the aid of tool vendor, what would be the extent of the tool influence on the final lithography result. This will permit the investigator to concentrate on fundamental aspects of the techniques rather then debugging experimental results.

– Concrete results of the research activity and socio-economic partnerships

- Appreciation on the strategy, management and life of the team:

– Relevance of the team organization, quality of the management and of the communication policy

This research unit is well organized and its research efforts are coordinated with those of LETI in order to avoid duplication of efforts. There is a evident effort in optimizingsing the synergy and collaborative efforts among the four Reserch Groups in the lithography area; the Nanoimprinting, Resist Characterization and Metrology are clearly working in close collaboaration, and the optical characteriszation research efforts are a clear bonus for the overall lithography research activity.

– Relevance of the initiatives aiming at the scientific animation and at the emergence of cutting edge projects

The real-time scatterometry capability developed at LTM is very promising for nanoimprint real time studies but also for resist trimming and other critical etch steps development. LTM is currently considering spinning off scatterometry tools and software. Research in nano-imprint lithography has allowed the development of new techniques that can lead to now commercial products (e.g. Diffraction grating SWIFTS).

– Contribution of the team members to teaching and to the structuration of the research at the local level

- Close collaboration and coordination of research with LETI.
- LTM contribute to courses definition at Université Joseph Fourier and allows UJF to have high-quality publications in the area of microelectronics. In return, UJF gives PhD grants to LTM students.
- Members of LTM teach many courses at Polytech Grenoble in the masters in microelectronics and in Nanosciences program.

- Appreciation on the project:

– Existence, relevance and feasability of a long term (4 years) scientific project

The project addresses the topics of errors, precision and reliability of the scatterometry technique. This plan would be perfectly synergic with the strategy of getting in touch with a commercial software house (possibolity of spinoff/commercialization).

Reported plan indicates that the resist group would focus its activity in what they have discovered to be the resolution deterioration when thickness is decreased. This clearly is very important topic to be investigated and the committee believe the competence and available equipment and metrology infrastructure will allow this group to carry out this task in the best way possible.

Nano-imprint lithography: the program outlined in the document sounds consistent with past activity and reflects well the scientific trend of this technology. In particular it is very interesting for practical future exploitation of NIL in large area patterning the research addressing the topic of NIL-induced self assembled patterns

– Existence and relevance of a policy for the allocation of ressources

There is a clear policy within LTM for sharing the financial resources, such that more advanced research topics can benefit from funding secured by shorter-term industrial research contracts. This policy is efficient and perceived as fair by all the members of LTM.

– Originality and existence of cutting edge projects

The research in scatterometry and solving inverse electromagnetic problems is really cutting edge.

• Conclusion :

– Summary

The lithography activity in LTM which includes Nanoimprinting, Resist characterization, Metrology by Scatterometry and optical lithography modelling well reflect the intimacy with LETI and its successful history in collaboration with industry. The more “fundamental” character of R&D carried out in LTM is also evident in the reported research activity.

– Strengths and opportunities

Acccess to LETI infrastructure and strong industrial contacts. Excellent research in both applied and fundamental fields.

– Weaknesses and threats

Research is very (too close?) close to the equipment providers. What is the role of the group in the new LETI-IBM alliance?

– Recommendations

- Recommendation to explore applications of Nano-imprint lithography technology to non-microelectronics applications (e.g. optical gratings, integrated optics, microwave, etc.).
- Recommendation to evaluate a proper way of transferring the scatterometry technique outside the lab. Consider the possibility of converting this technique into a commercial tool. Scatterometry is attracting much attention from the industry since it is theoretically capable to determine at the same time feature size and shape of high resolution printed lithographic images without contacting. Now is a good time to capitalize on the results obtained by this group.
- Group should try to increase their visibility (improve publicity).

Title of the team : Nanomaterials & Integration

The team leader : M. Thierry BARON

- Staff members (on the basis of the application file submitted to the AERES)

	Past	Future
N1: Number of researchers with teaching duties (Form 2.1 of the application file)	6	7
N2: Number of full time researchers from research organizations (Form 2.3 of the application file)	3	3
N3: Number of other researchers (Form 2.2 and 2.4 of the application file)	0	0
N4: Number engineers, technicians and administrative staff with a tenured position (Form 2.5 of the application file)	4	3
N5: Number engineers, technicians and administrative staff without a tenured position (Form 2.6 of the application file)	3	0 (known)
N6: Number of Ph.D. students (Form 2.7 of the application file)	12	3 (known)
N7: Number of staff members with a HDR or a similar grade	3	4

- Appreciation on the results:

  – Relevance and originality of the research, quality and impact of the results

The research activities of the Nanomaterials & Integration group range from the materials to the devices, at the nanometer scale and are considered as part of the effort in the emerging fields called “beyond CMOS” and “More than Moore’ technologies. To reach these objectives, both top-down and bottom-up approaches are combined. the Nanomaterials & Integration group studies the elaboration of dielectric, metallic and semiconducting nanomaterials (0D, 1D, 2D), nanostructures self-assembling mechanisms (capillary forces, dielectrophoresis, block copolymers), physical properties of nanomaterials and their integration in devices. Equilibrium between advanced and applied research topics is maintained through collaborations with industrial partners, namely STMicroelectronics, ATMEL and an equipment supplier (ALTATECH). On the other hand, the Nanomaterials & Integration group has developed a strong collaboration with academic French partners via national project (ANR PREAANS and DUOSIL), european partners via the SiNano and NanoSil Excellence European Networks and international partners like Santa Barbara University and Sherbrooke University.

  – Number and quality of the publications, scientific communications, thesis and other outputs

Journal Articles	Invited talks	Conference papers	Posters	Books	Book chapters	Patents	Theses
102	6	72	28	0	0	7	8

– Quality and stability of partnerships

Strong synergy with LETI. Equilibrium between advanced and applied research topics is maintained through collaborations with industrial partners, namely STMicroelectronics, ATMEL and an equipment supplier (ALTATECH). On the other hand, the Nanomaterials & Integration group has developed a strong collaboration with academic French partners via national project (ANR PREAANS and DUOSIL), european partners via the SiNano and NanoSil Excellence European Networks and international partners like Santa Barbara University and Sherbrooke University.

– Appreciation on the impact, the attractiveness of the team and of the quality of its links with international, national and local partners

– Number and reputation of the awards obtained by staff members, including invitations to international conferences and symposia

3 invitations to international conferences, 3 invitations to a national conference.

– Ability to recruit high levels scientists, post-docs and students, and more particularly from abroad

Due to the security constrains of being in the CEA/LETI and the confidentiality requirements of working closely with industry, LTM is not as flexible as it might want in the area of hiring foreign students. So the student supply ist mostly national. The Nanomaterials & Integration group has graduated 8 PhD. Students during the period of time under consideration.

– Ability to raise funds, to successfully apply for competitive funding, and to participate to scientific and industrial clusters

Competitive funding won from industry in the field of nanoparticles for non-volatile memory applications (process transferred to ATMEL). More “upstream” research funded by European programs.

– Participation to international or national scientific networks, existence of stable collaborations with foreign partners

Participation to the national project (ANR PREAANS and DUOSIL) and the SiNano and NanoSil European Networks of Excellence. Collaboration with University of California, Santa Barbara and Sherbrooke University.

– Concrete results of the research activity and socio-economic partnerships

- Appreciation on the strategy, management and life of the team:

– Relevance of the team organization, quality of the management and of the communication policy

The overall activity and visibility of the group owes a lot to the commitment of his leader, Th. Baron, who should be acknowledged. Many publications in excellent journals such as Applied Physics Letters and the Journal of Applied Physics. The impression is that the group develops too many activities with too little scientific overlap what prevents it from establishing itself as a international reference in one or few fields. The price to pay is a relatively low visibility on the international scene.

– Relevance of the initiatives aiming at the scientific animation and at the emergence of cutting edge projects

The most structured and visible activity of this group is the semiconductor nanowire activity. The work defines in part the state of the art. Combines good materials science (elaboration) to structural, chemical and electrical characterizations, integration into devices (FETs) and a focus on mechanical properties (electromechanical sensors). Good collaboration with academic partners within ANR projects, European and French networks. Several excellent papers published.

– Contribution of the team members to teaching and to the structuration of the research at the local level

- Close collaboration and coordination of research with LETI.
- LTM contribute to courses definition at Université Joseph Fourier and allows UJF to have high-quality publications in the area of microelectronics. In return, UJF gives PhD grants to LTM students.
- Members of LTM teach many courses at Polytech Grenoble in the masters in microelectronics and in Nanosciences program.

• Appreciation on the project:

– Existence, relevance and feasability of a long term (4 years) scientific project

Overall good project which shows quite good lucidity. The committe believse that the project is too broad and too ambitious with respect to the available human resources and that the danger of spreading too much the efforts without establishing a deep scientific culture is still very present.

The project includes spinning-off anew team "Nanofabrication for colloidal and biological devices". Is it ~~is~~ adequate to create a fourth group with only 2 staff scientists at LTM without a complete reorganization (redeployment) of the resources?

It is clear that the strong partnership with LETI and STM allows this group to access to state of the art technological tools. However, the associated drawback i.e., the "pressure" from STM and LETI may inhibit long term activities in selected fields, a prerequisite condition for development of a "group culture" and the recognition of the specificities of the group by the scientific community.

– Existence and relevance of a policy for the allocation of ressources

There is a clear policy within LTM for sharing the financial resources, such that more advanced research topics can benefit from funding secured by shorter-term industrial research contracts. This policy is efficient and perceived as fair by all the members of LTM.

– Originality and existence of cutting edge projects

Most of the research projects are original cutting edge. This group works mainly on bottom-up, long-term research projects. This approach is deliberate and coordinated with LETI, where shorter-term research in complementary areas is carried out.

The staffing data for the proposed new team "Nanofabrication for colloidal and biological device" is:

- Staff members (on the basis of the application file submitted to the AERES)

	Past	Future
N1: Number of researchers with teaching duties (Form 2.1 of the application file)		0
N2: Number of full time researchers from research organizations (Form 2.3 of the application file)		2
N3: Number of other researchers (Form 2.2 and 2.4 of the application file)		0
N4: Number engineers, technicians and administrative staff with a tenured position (Form 2.5 of the application file)		2
N5: Number engineers, technicians and administrative staff without a tenured position (Form 2.6 of the application file)		0
N6: Number of Ph.D. students (Form 2.7 of the application file)		2 (known)
N7: Number of staff members with a HDR or a similar grade		1

- Conclusion :

  – Summary

The "Nanomaterials and integration" team focuses its work on the development of nanoelectronics based technologies for the (i) elaboration of nanomaterials like nanofilms, nanodots and nanowires, (ii) the positioning of nanostructures in a device using self-assembling process and (iii) the integration of nanomaterials in demonstrators and in industrial devices. Their results can be applied to nanoelectronic as well as to emerging fields such as energy, sensors, biology, etc. where nanomaterials and nanotechnologies could give rise to new developments based on their unique properties. This is "long-term" research work of excellent quality.

  – Strengths and opportunities

Acccess to LETI infrastructure and strong industrial contacts. Excellent research in fundamental and applied materials science.

  – Weaknesses and threats

Danger of dissipating the efforts or a relatively small group in too many directions.

– Recommendations

The committee has the following recommendations.

- Look around at existing research in order not to duplicate efforts and assess and identify their specificity will be and work in synergy with other existing groups.
- Other labs have expressed interest in collaboration/use of facilities (e.g. Labo de spectrométrie physique). The specificity of the new proposed activity should build on the existing LTM expertise.
- A discussion with the bio activity already existing at LETI, academic labs such as UJF and LMGP, etc. must be carried out before deciding to create a new research group in the field of "Nanotechnology for biological and colloidal nanodevices" in order to avoid redundancy of efforts.
- The group should focus on a selected set of their current research areas to develop international reputation.

The group should continue to investigate the controlled growth/positioning of nanostructures towards the fabrication of ordered structure with the final aim of being used in practical devices.

Title of the team : Plasma processes for nanoelectronics and emerging devices

The Team leader : Erwine PARGON

- Staff members (on the basis of the application file submitted to the AERES)

	Past	Future
N1: Number of researchers with teaching duties (Form 2.1 of the application file)	1	1
N2: Number of full time researchers from research organizations (Form 2.3 of the application file)	5	7
N3: Number of other researchers (Form 2.2 and 2.4 of the application file)	1	1
N4: Number engineers, technicians and administrative staff with a tenured position (Form 2.5 of the application file)	1	2
N5: Number engineers, technicians and administrative staff without a tenured position (Form 2.6 of the application file)	3	2
N6: Number of Ph.D. students (Form 2.7 of the application file)	9	2 (known)
N7: Number of staff members with a HDR or a similar grade	5	4

- Appreciation on the results:

  – Relevance and originality of the research, quality and impact of the results

Plasma processing devoted to CMOS electronics is the historical core activity of LTM since its creation in 1999, and is still a major activity of the Laboratory. The originality of the LTM is to develop R&D activities in the CEA-LETI environment, in close interaction with important actors of the microelectronics industry (ST-Microelectronics, Applied Materials-AMAT), as well as with CEA-LETI engineers. The scientific policy of LTM has been successfully pursued in continuity with that of the 2002-2005 period: research work has been carried out on industrial etching tools equipped or combined with very powerful characterization techniques, some of them being unique worldwide. The team succeeded in maintaining a good balancing between industrial application-oriented studies (4 patents, and plasma treatments transferred to ST-Microelectronics for the 90/65/45 nm CMOS technological nodes), and more fundamental research aiming at a better understanding of the etching mechanisms and interactions between plasma and reactor wall. The international leading position in the investigation of etching processes for future CMOS devices has been consolidated, thanks to the unique expertise of the team in in-situ surface analysis, and in the etching of complex gate stacks and damage-sensitive porous low-k materials. A new study on the main mechanisms degrading the linewidth roughness of 193 nm resists during plasma treatment has yielded original quantitative results appreciated by both the industry and the academic community. At a more fundamental level, the work has been mainly focused on optical diagnostics; an original absorption spectroscopy technique using UV LED, showing improved sensitivity and compatibility with time-resolved measurements and real time reactor monitoring has been demonstrated. This work has led to an impressive number of invited talks.

  – Number and quality of the publications, scientific communications, thesis and other outputs

Journal Articles	Invited talks	Conference papers	Posters	Books	Book chapters	Patents	Theses
82	26	62	12	0	0	7	7

  – Quality and stability of partnerships

The team succedeed in developing a strong, long-term partnership with the microelectronic industry. Most important examples are: exemplary collaboration with Applied Materials-US (4-year Joint Development Program -JDP, implementation in the CEA-LETI environment of a 300-mm etch cluster tool specifically customized for the coupling with an XPS chamber, and for the implementation of several diagnostics); more than 15 thesis fully or partially supported by industrial grants; creation of a common laboratory between the team and ST-Microelectronics; fruitful collaboration with CEA-LETI, leading to the transfer of young CEA-LETI engineers to LTM team in the future years to boost cooperative programs.

- Appreciation on the impact, the attractiveness of the team and of the quality of its links with international, national and local partners :

The quality of the research is assessed by the important number of Invited talks (20 international invited talks, amongst the 26 invited talks of LTM), clearly showing the fame gained by this team at the international level in the four past years. The scientific production of the team is also excellent, with more than 67 publications in rank-A peer reviewed international journals, including 7 letters, demonstrating the capacity of the team for performing real scientific breakthroughs in a domain largely driven by industry needs.

– Ability to recruit high levels scientists, post-docs and students, and more particularly from abroad

The Plasma processing group has graduated 7 (comments : the total number of graduated PhD is : 14, including the students supervised commonly with ST-Microelectronics) PhD students during the period of time under consideration. Due to the security constrains of being in the CEA/LETI and the confidentiality requirements of working closely with industry, LTM is not as flexible as it might want in the area of hiring foreign students. So the student supply ist mostly national/local originating from EEATS master speciality. On the other hand, 3 PhD students of the team have joined famous international labs for a post-doctoral experience, highlighting the fame of the team at the international level.

– Ability to raise funds, to successfully apply for competitive funding, and to participate to scientific and industrial clusters

- Strong Involvement of the team in important industrial programs (regional, national, and European FP6 and FP7), representing the major part of the total funding of the LTM laboratory.
- Less important implication of the team in more academic programs such as ANR programs. This may be due to the topic of the ANR calls that do not match the team core activity. However, this situation is changing, with recent involvement in ANR Nano-innov 2009 program.

– Participation to international or national scientific networks, existence of stable collaborations with foreign partners

Besides the close collaborations with ST-Microelectronics (common laboratory), CEA-LETI, and Applied Materials (long-term JDP, renewed in 2009), a collaboration agreement with Hitachi Central Research Laboratory has been signed.

– Concrete results of the research activity and socio-economic partnerships

Very clear results in terms of scientific productions (many invited papers), in terms of transfers to industry and in terms pf patent applications.

• Appreciation on the strategy, management and life of the team:

– Relevance of the team organization, quality of the management and of the communication policy

- Excellent team organization, quality of the management and of the communication policy. This team carrieds out world-class research and leaders in novel plasma technology development. This is reflected by the exceptionnaly high number of invitations to conferences.
- Internal team organization: Strong cooperation exists between the members of the team, working with shared cluster tools; most PhD students are commonly supervised by 2 members of the team, and the day-to-day collaboration is also illustrated by the numerous common publications.

– Relevance of the initiatives aiming at the scientific animation and at

Many impacts of high-frequency pulsed etching on the etching results are not known. Since significant differences with continuous-wave are expected in electron temperature, ion energy, plasma dissociation, gas temperature, etc., this research activity will require a close collaboration between team members in charge of process developments and team members in charge of plasma diagnostics to achieve a good control and understanding of the etching mechanisms and the plasma surface reactions in pulsed regime. Finally, the development of pulsed etching will not only require surface characterization and optical diagnostics, but also the implementation of new time-resolved electrical diagnostics to monitor the electron temperature, or the ion energy at the walls and at the wafer surface..

– Contribution of the team members to teaching and to the structuration of the research at the local level.

- Education: Most members of the Etching team are from CNRS, and therefore not directly involved in education and training. Few of them give lectures at post-graduate levels, or for private Institutions. Most of the PhD students are supervised by CNRS staff.

- On the other hand the university staff (1 Professor) is strongly involved in education: after having being responsible of a department at Polytech'Grenoble (UJF), Pr. Inglebert has been nominated Director of Polytech'Grenoble since Feb. 2008.

• Appreciation on the project:

– Existence, relevance and feasability of a long term (4 years) scientific project

The research plan of the plasma etching team splits in three axes: one is the continuation of previous work, while two new topics have emerged. The plan demonstrates the reactivity of the team, facing now many challenges at a point where plasma patterning technologies for the future CMOS technological nodes seem to reach the limit of the possibilities of conventional plasmas.

* Research activities to be continued:

(Axis 1) - The core activity of the team, e.g. development of plasma etching processes for the future sub-45 nm CMOS technological nodes will be continued, on the basis of the strong experience acquired in the past 10 years. The important issues to be raised have been clearly identified. Consistent with the work of the 2005-2009 period, the research plan deals with the development of plasma processes for advanced gate stacks and advanced interconnects supported by in-situ surface analysis and in-situ plasma diagnostics, and with the further investigation of VUV light and plasma treatments to decrease the ultimate linewidth roughness of resist masks. The work will be performed with the historical partners of LTM in this field, mainly ST-Microelectronics and CEA-LETI, and will be supported by important national and European programs for the next 3 years.

* New research axes:

(Axis 2) - First, LTM proposes to investigate pulsed etching at high frequency in order to etch thin layers (< 5nm) with high selectivity (< 1nm recess) as specified by the ITRS roadmap for the sub-45 nm technological nodes. A solid basis exists for the development of this new activity, since the work will be conducted in close collaboration with AMAT in the frame of a new (4-year) JDP, and since the 300-mm etch cluster tool has been modified by AMAT to work in pulsed mode. Besides the expected reduction of ion energy, other impacts of RF power pulsing on plasma dissociation, plasma chemistry, passivation effects, charging effects, etc., are foreseen. Physics and chemistry of pulsed plasmas is therefore very rich and still rather unexplored experimentally for chlorine-based gas mixtures. Outputs at both applied and fundamental levels can be expected.

(Axis 3) - Second, the team will start a new activity on reactive plasma etching of magnetic materials for MRAM devices, aiming at surpassing the limits of ion beam etching. The strategy of the team in this new field follows that successfully tried for CMOS electronics: powerful industrial etch cluster tool equipped with in-situ diagnostics will be dedicated to the study, conducted in close collaboration with MRAM devices providers, in the frame of an industrial project (Matimop).

– Existence and relevance of a policy for the allocation of ressources

There is a clear policy within LTM for sharing the financial resources, such that more advanced research topics can benefit from funding secured by shorter-term industrial research contracts. This policy is efficient and perceived as fair by all the members of LTM.

– Originality and existence of cutting edge projects

The research in pulsed plasma etching and plasma etching of magnetic materials is clearly cutting edge.

- ## Conclusion :

– Summary

The research activity is excellent as illustrated by the level and number of publications, and the good balancing between mid-term application-oriented research and long-term more fundamental studies on new etching mechanisms or new plasma diagnostics. The team has proven the efficiency of the LTM strategy, aiming at conducting academic research in close interaction with industrial partners, embedded in an industrial environment. This scientific policy gives LTM a unique position in the academic French community.

The visibility of the team has significantly grown at the international level, with world-recognized expertise in plasma etching and in-situ surface analysis. State-of-the art results and leading position has been achieved in many domains.

– Strengths and opportunities

- Scientific quality.
- World-class research and leaders in novel plasma technology development.
- Exemplary long-term cooperation with industry and technology transfer. In particular, the cooperation with industrial partner AMAT-US has been reinforced. First LTM benefits from unique tools to conduct state-of-the-art research through this partnership. Second the JPD mainly running at LTM/CEA-LETI site in Grenoble, will be extended to AMAT site in US in the coming years: closer collaboration, common research program, staff exchanges, etc., may be expected.

Collaboration with ST-Microelectronics, CEA-LETI or industrial actors as Rohm-and-Haas allows LTM for participating in very important European and national (Nano2012) programs, including otherwise only very few academic laboratories

- Very convincing project proposed for the next 4 years.
- The diversification of the activities and the development of new collaborations build new routes for the team towards promising economical sectors: MRAM devices/spin electronics, and photovoltaics (the latter under discussion with CEA). The foundation of a plasma expertise center with LETI also comes to mind.

– Weaknesses and threats

- Despite recent recruitments (2 CNRS researchers in 2005-2009 period), the permanent staff is rather restricted. The diversification of the activity should be accompanied by a careful management of the human resources, with concerted policy of the different supporting organizations.
- The Joint Laboratory between ST-Microelectronics and LTM has not been officially launched yet. Efforts of the supporting organizations should concentrate on solving this issue, to the benefit of LTM lab (with easier funding of PhD or post-doc grants, etc.)
- Leading of partnership/ collaboration with academic partners is rare (which impacts on the exposure of the team members to the national scientific community).
- Doubling of the operation costs expected (more research topics, and acquisition of costly equipments), not fully supported by CEA-LETI any longer.

– Recommendations

- Keep inforcing the fruitful industrial cooperation policy.
- Maintain the good balance between application-oriented research and more fundamental studies; maintain a good synergy between process developments and plasma diagnostics development
- Try to further develop collaboration with the French cold plasma community or academic community in general.The development of new research axes (pulsed plasmas, spin electronics, or photovoltaics, ..) may give the opportunities for such collaborations.

Note de l'unité	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A+	A

Nom de l'équipe : Advanced lithography

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A	A	A+	A	A

Nom de l'équipe : Nanomaterials and integration

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A	A+	A	A	A

Nom de l'équipe : plasma processes

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A+	A+

PRESIDENCE

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UNIVERSITE JOSEPH FOURIER
SCIENCES.TECHNOLOGIE.SANTÉ.
GRENOBLE 1

Grenoble, March 24th 2010,

AERES
Mr. Jean François Dhainaut

Subject : Comments of University Joseph Fourier Grenoble 1 on AERES preliminary report
Laboratoire des Technologies de la Microélectronique (LTM) – UMR 5129

Mr. Chairman of the visiting committee, Dear Colleague,

We have examined the preliminary assessment report dated March 4th 2010 for research unit :
Laboratoire des Technologies de la Microélectronique (LTM) – UMR 5129

On behalf of the University and all members of this laboratory, we would like to express our thanks for this thorough assessment.

First of all, LTM has very much appreciated the work of the evaluation committee and organization by AERES : this preliminary assessment report will be very helpful. LTM agrees with the report made by the AERES evaluation committee concerning its scientific activities. The positioning of the laboratory has been well analyzed and more generally the global environment has been well captured. The strength and opportunities of LTM in this environment are also well analyzed. We are also in phase with the scientific appreciation of each team and agree with the comments and recommendations.

In particular, the management team will create a steering committee and try to increase the involvement of LTM members in national networks. In the field of advanced lithography, application of nano-imprint lithography to non-microelectronics fields is already ongoing. We also believe that the visibility of the group can be improved. In the field of Nanomaterials and integration a better focus on well defined and key topics with the appropriate critical mass will be achieved. Finally, in the field of the plasma processes, improved collaboration with the cold plasma community is already on going.

Besides, you will find enclosed in a separate document, some additional comments related to technical inaccuracies.

Yours faithfully.

P/ Le Président de
l'Université Joseph Fourier Grenoble I
Farid OUABDESSELAM

P/O Le Vice-président
du Conseil Scientifique de
l'Université Joseph Fourier Grenoble I
Laurent DAUDEVILLE

Enclosed : Some additional comments related to technical inaccuracies.