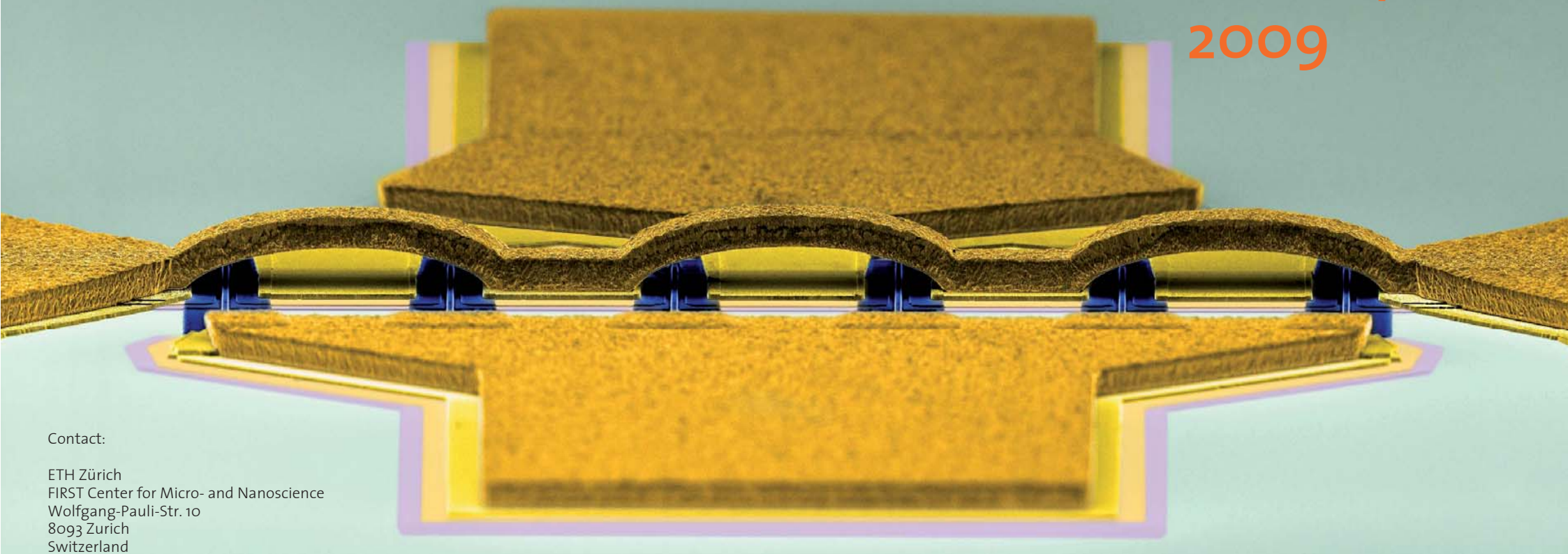
FIRST

Center for Micro- and Nanoscience

FIRST Annual Report 2009



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Cover picture:
Nanometric gate pseudomorphic high-electron mobility transistor (pHEMT)
developed by the THz Electronics Group (Bolognesi) for ESA. Courtesy Andreas Alt.

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Introduction to the 2009 annual report

FIRST – Frontiers in Research: Space and Time – is ETH Zurich's joint cleanroom lab, supporting now more than 250 researchers with state of the art unit processes from epitaxial growth and nano lithography to functional nano material integration. The rolling number of trained users in FIRST increased again by 11% from 2008 to 2009 and is now close to the limit capacity of FIRST from an operational point of view. NETL will be ready for equipment in 2011, and it may provide the necessary release for the FIRST operations. NETL (Nanotechnology Exploratory Technology Lab) is the joint project of IBM Research, Rüschlikon, and ETH Zurich to build a new research cleanroom facility. NETL will further complement the processing capabilities and research options for ETH Zurich (and IBM) researchers significantly.

FIRST is a cleanroom laboratory and a user lab allowing for excellent research results and the education and training of students. Most of the students are PhD students, but FIRST also accepts Master and undergraduate students as users, if their project work requires a substantial process or device development activity to justify training and to guarantee enough learning experience for efficiency, appropriate cleanroom behavior and safety.

Accepting users with different level of experience turns the operation of a cleanroom for both, state-of-the-art research and education, into a continuous challenge: it requires full support and considerateness of all involved persons: users, mentors, equipment responsible persons, the technical team, the operations team and the management team. A well operated infrastructure helps to maintain low particle densities, which is an important feature of a cleanroom. However, it's not all about particles, monitored by particle counters: it's about cleanroom behavior to avoid excessive particle generation at the wrong place, it's about the awareness of the impact of new materials on existing processes and device performance to avoid contaminations and it is about cleanliness in general. Therefore the user introduction procedure has been revised in 2009, the successful cleanliness seminar has been continued and integrated in the IntroDay, and a new seminar for chemistry freshmen is introduced to provide a minimum basic knowledge in chemistry for FIRST users.

FIRST proved again its operational excellence by mastering the above mentioned challenge between research and education: One example out of many successful research projects in

FIRST in 2009 is mentioned here: Prof. Bolognesi's group demonstrated AlGaN/GaN HEMTs on

silicon substrates with a switching speed of 108 GHz, breaking the existing record of 28 GHz by a factor of 4. FIRST helps to achieve such research results by its well operated infrastructure and the experience and competence of the FIRST Technical Team (FTT) and the Operations Team (FOT). FIRST operation is also supported by volunteers, called FMT staff, who spent many hours as equipment responsible users and as mentors. It is also worth to mention here that the satisfaction of all FIRST users has been high again in 2009 as it is documented by the recent user questionnaire.

At the end of my term as FIRST Coordinator, I express my sincere appreciation to all FIRST teams and FIRST volunteers for their effort and I also thank the ETH Zurich Board, which continuous supporting FIRST and all research groups in FIRST greatly.

Christofer Hierold
FIRST Coordinator

FIRST – Frontiers in Research: Space and Time

FIRST Center for Micro- and Nanoscience is the cleanroom facility at ETH Zurich serving scientists internally and externally of ETH to conduct their research. FIRST is a user lab providing hands-on experience to students and researchers. We train our users on the equipment, support them in the development of processes and hence enable our users to carry out their research projects independently. Our service covers the maintenance of the infrastructure unit and equipment, technical training on the equipment and processes as well as scientific consulting.

FIRST has been in operation since July 5, 2002. In the early days, much effort was contributed to the setup of the facility and the acquisition of new equipment. Once FIRST was in full operation the user numbers exploded and FIRST is now at its capacity servicing more than 250 users last year (Figure 1 and Figure 2).

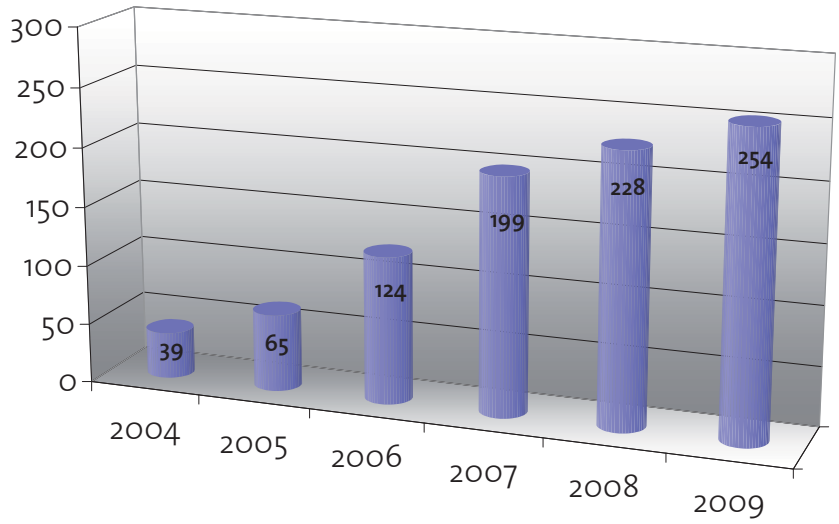
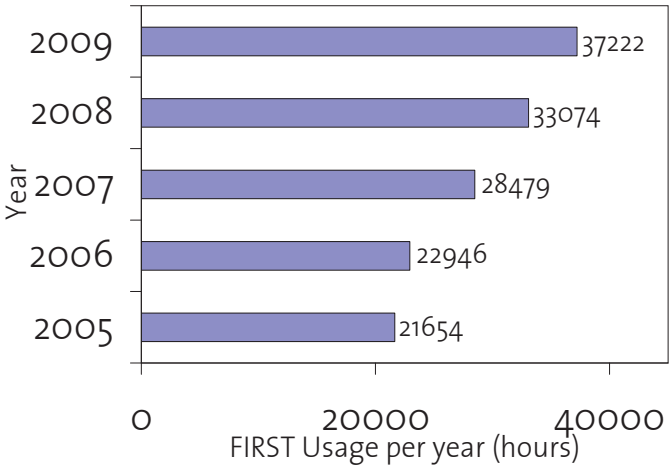


Figure 1: Number of FIRST users for the time period from 2004 to 2009.

Figure 2: Total number of hours FIRST was used per year (below).

In 2009, FIRST served users from five different departments of ETH Zurich, from the University of Zurich, Paul Scherrer Institute (PSI), Eidgenössisch-Technische Prüfanstalt (EMPA) and from industry (Figure 3).



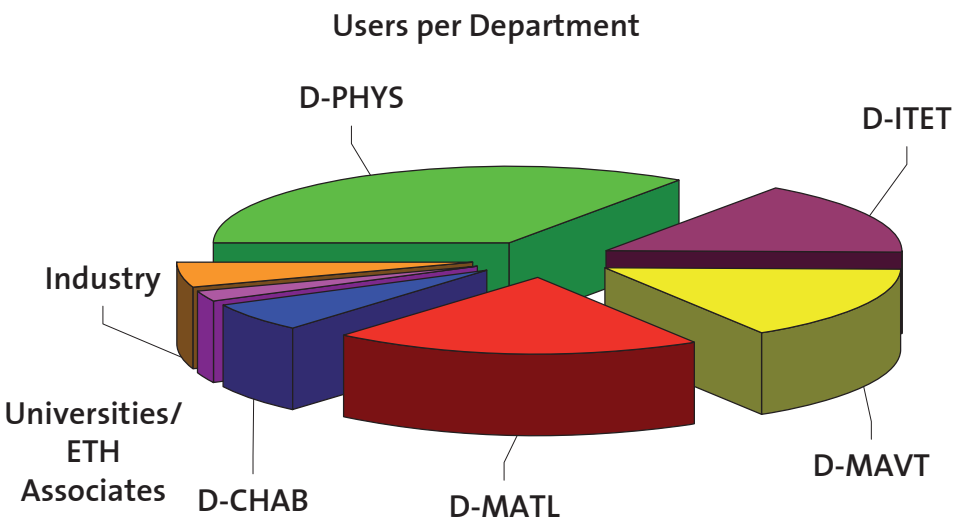


Figure 3: Number of users in FIRST allocated to their affiliations (year 2009).

FIRST is a centralized laboratory directly supported by the Executive Board of ETH Zurich under the lead of the Vice President of Research and Corporate Relations and chaired by the FIRST coordinator (Figure 4). Long-term scientific and technical orientation of FIRST is determined by the FIRST Management Team (FMT). FIRST is operated by the FIRST Operation Team (FOT) with the assistance of the FIRST Technical Team (FTT) and by the support of FIRST users (FMT staff).

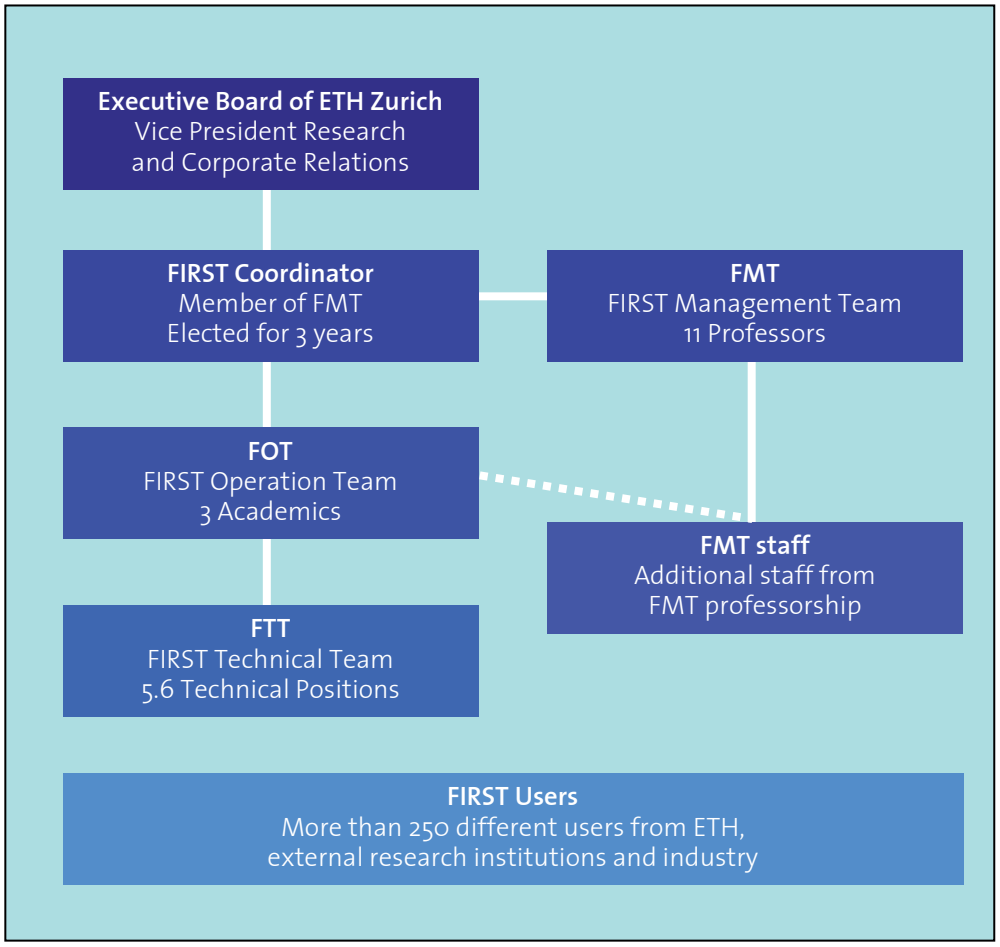


Figure 4: Organization of FIRST

FIRST Management

The FIRST-Management Team determines the scientific and strategic directions of FIRST. It consists of those ETH professors who have a major technological and scientific involvement and take a responsibility in FIRST by contributing actively to the operation of the FIRST technology lab. A list of FMT members is given below.

Each FMT professor has to contribute manpower to the FIRST lab to support its operation. This personnel support is referred to as the FIRST staff. The FMT professors and their group members are considered to be primary users of the FIRST lab.

The FIRST coordinator represents the FMT to the ETH management. He reports to the Vice President Research and Corporate Relations and represents the FMT and the FOT. The FIRST coordinator is elected for a 3-years period by the members of the FMT and appointed by the ETH Board. The FIRST coordinator is a member of the FMT.

The FMT in 2009:

Prof. Dr. C. Bolognesi
Terahertz Electronics Group
http://www.ifh.ee.ethz.ch/

Prof. Dr. J. Dual
Mechanics and Experimental Dynamics
http://www.ifm.ethz.ch

Prof. Dr. K. Ensslin
FIRST coordinator 2004–2006
Nanophysics;
http://www.nanophys.ethz.ch

Prof. Dr. J. Faist
Quantum Optoelectronics Group
http://www.phys.ethz.ch/~mesoqc

Prof. Dr. C. Hierold
FIRST coordinator 2007–2009
Micro- and Nanosystems
http://www.micro.mavt.ethz.ch

Prof. Dr. A. Imamoglu
Quantum Photonics
http://www.iqe.ethz.ch/quantumphotonics

Prof. Dr. H. Jäckel
FIRST coordinator 2002–2003
High-Speed Electronics and Photonics
http://www.ife.ee.ethz.ch

Prof. Dr. U. Keller
Ultrafast Laser Physics
http://www.iqe.ethz.ch/ultrafast

Prof. Dr. B. Nelson
Institute of Robotics and Intelligent Systems
http://www.iris.ethz.ch

Prof. Dr. N. D. Spencer
Laboratory for Surface Science and Technology
http://www.surface.mat.ethz.ch

Prof. Dr. A. Wallraff
Quantum Device Lab
http://www.solid.phys.ethz.ch/wallraff/

FIRST Operation

The daily business of FIRST is managed by a team of three scientists (FIRST Operation Team, FOT) with the support of technicians (FIRST Technical Team, FTT). The main tasks and responsibilities of the FOT are: evaluation and support of technical and scientific work in FIRST, facility management of FIRST, supervising of additional staff supplied by FMT members, and the administration of FIRST.

Prof. Christofer Hierold

FIRST Coordinator

2007 - 2009

Dr. Otte Homan

FIRST Operation Team

Thin Film Technology
Processing & Lithography
Safety

Dr. Emilio Gini

FIRST Operation Team

MOVPE, Characterization
Infrastructure
Finances

Dr. Silke Schön

FIRST Operation Team

MBE, Characterization
User Interface & Projects
Public Relations

The FIRST Technical Team consists of 5.6 full positions shared by 6 technicians, 1 secretary and 1 person for IT support. 70% of one full technical position is funded by the FMT as “FMT staff support” and is used for IT support and technical electron beam lithography support.

Dominique Aeschbacher (50%)
FIRST Technical Team

Computer Administration

Christian Fausch (50%)

FIRST Technical Team

Electronics,
Semiconductor
Characterization

Sandro Bellini

FIRST Technical Team

Wet chemistry
E-beam lithography

Petra Burkard (50%)

FIRST Technical Team

Thin film technology
Plasma technology

Martin Ebnöther

FIRST Technical Team

MOVPE support
Laboratory supplies

Maria Leibinger (50%)

FIRST Technical Team

Photolithography
E-beam lithography
CV profiling

Hansjakob Rusterholz

FIRST Technical Team

MBE support
Wire bonding
Web / Graphics

Claudine Wehrli (60%)

FIRST Technical Team

Secretary
User administration

Scientific equipment: additions and upgrades in 2009

FIRST Center for Micro- and Nanoscience enables and supports cutting-edge research projects in the field of epitaxial thin film growth, micro- and nanolithography, and processing of layers and devices. To always accomplish this ambitious goal, the FIRST Operation Team continuously analyzes future research needs in order to plan and realize additions and upgrades of the state-of-the-art infrastructure in FIRST.

In 2009, FIRST-Lab replaced the existing photo- and electron beam resist application equipment, and bought two new spinner/bake units (Figure 5) from SAWATEC AG in Ruggell, Principality of Liechtenstein. We now offer two resist spinners, six hotplates with pin-lift and vacuum holding capabilities, and two purged ovens (one vacuum, one ambient pressure), as well as a large amount of storage space for substrate chucks and tools. The new spinner benches were delivered and mounted in November. Within a week, more than 60 users were retrained, and now well over 100 users are actively using the new equipment. The majority of the users' feedback is that the quality of the films has quite drastically and reproducibly improved.

Figure 5: The new workspace for photo resist and electron beam resist application, with two new spinners, six hotplates and two new convection ovens.

The low pressure chemical vapor deposition (LPCVD) system benefitted receiving another gas line. A point-of-use panel for Acetylene gas was installed in an existing gas safety cabinet and connected to the LPCVD gas distribution subsystem (Figure 6). New gas detectors (for Acetylene) were also installed (in the gas cabinet and near the deposition system), and integrated in the existing gas warning system of FIRST-Lab. Using Acetylene gas in LPCVD processes allows for the deposition of low-dimensional carbon nano tubes (CNTs) and carbon films (Graphene) at reduced process temperatures.

Figure 6: Safety gas cabinet with the new point of use panel and cylinder for Acetylene in Helium (left); new flammable gas detector for Acetylene gas (right).

The MBE system dedicated to the epitaxial growth of phosphides and antimonides was upgraded by a mass spectrometer monitoring residual gases up to mass unit 200. Furthermore, a new flow box for wafer preparation was installed.

Our Univex450 barrel electron beam evaporator system received a new evaporation rate monitor (Figure 7). It replaces the old XTC unit, and offers a better film thickness precision, more advanced monitoring functions and a large improvement in the ease-of-use for the many users of this evaporation system.

Figure 7: Evaporation rate monitor.

Figure 8: New wafer bonder.

In spring, we were informed that the renter of our wafer bonder needed the machine for his own purposes. FIRST decided to buy its own system. All future users were involved in the evaluation and selected a tool that best fits all needs. The acquisition was also supported by the board of ETH with 2/3 of the cost of around 180 kCHF. The AML-AWB04 Wafer Bonder System has been installed in October and the acceptance runs were successfully performed. The feedback of the users till now is enthusiastic (Figure 8).

Prof. Bolognesi is a heavy user of our MOVPE system and it was his wish to obtain his own equipment. The current one is limiting the maximum n-type dopant concentration for certain transistor structures in his research. The MOVPE team has evaluated possible solutions and as a result, our equipment has received a new dopant source (tBu2S) adding sulfur to the repertoire. Prof. Bolognesi has replaced Prof. Jäckel as primary user of the MOVPE system. The capacity of the equipment is still sufficient to satisfy all the growth needs of the other groups within FIRST.

Figure 9: Wire bonders in FIRST.

Our wire bonder that enjoys great popularity suffered from the large variety of bonding processes with different wires. In order to reduce the complexity of setting up the tool and the maintenance times, it was decided to purchase a second tool with a complementary setup (Figure 9). This bonder has been financed by the FMT Professors.

FIRST received the opportunity to invest in new equipment, either to meet the huge user demand for such equipment or to replace existing equipment. The management team agreed to replace our Univex500 workhorse evaporator with a new system because of the drastically increasing maintenance demand and repair efforts for this system. In 2009, we compiled the requirements for such a system based upon the users' needs, submitted a partial funding request to the board of the ETH, and started the associated GATT/WTO tendering procedure. A final decision on which alternative system will be purchased will be made in early 2010, leading to the delivery of a new system by fall 2010.

Due to the huge number of users (more than 100) on our electron microscope, FIRST management also approved the purchase of a second electron microscope. Many users responded to our questionnaire on their demands and needs, a partial funding request to the board of the ETH was submitted and approved, and a GATT/WTO tendering procedure was completed. We are now in the final evaluation of the submitted quotations and expect a final purchasing decision by early 2010, so that the new system may be delivered by mid-2010.

FIRST equipment: general overview

Molecular beam epitaxy (2 Veeco/Applied EPI Gen-III MBE systems, VG V80H system)

- Epitaxial growth of phosphides, arsenides, antimonides and dilute nitrides on up to 4-inch substrates with Si-, C- or Be-doping for active and passive semiconductor devices, e.g. quantum cascade lasers, surface emitting lasers, optical switches, saturable absorbers, and for quantum dot growth and nanocoil fabrication.
- Three growth chambers with diffuse reflectance spectroscopy (BandiT), pyrometers, reflectometry (Laytec EpiR) and reflection high-energy electron diffraction (RHEED) for in-situ growth monitoring (Figure 10).
- Analysis chamber with X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES) including Argon sputter source for depth profiling and an atomic hydrogen source for surface oxide reduction processes.

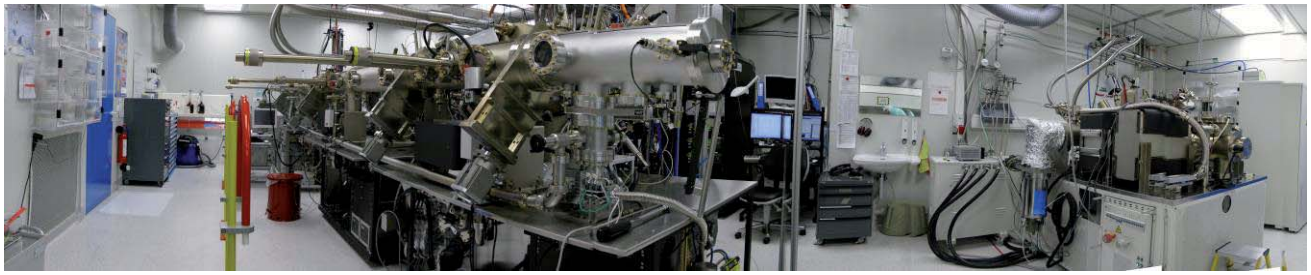


Figure 10: MBE systems in FIRST: 2 Veeco GEN III systems and a VG V80H system.

Metal-organic vapor phase epitaxy (AIX 200/4)

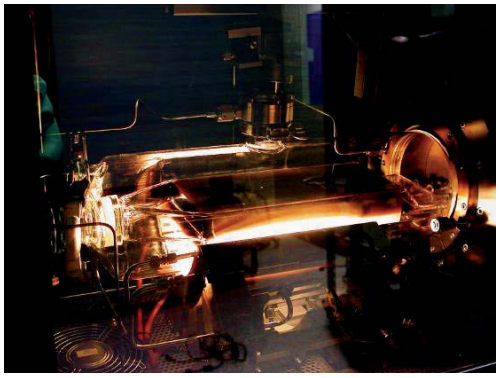


Figure 11: MOVPE reactor.

- Growth of phosphides, arsenides and antimonides on InP and GaAs substrates with zinc carbon for p-type, silicon or sulfur for n-type doping and iron for semi-insulating material (Figure 11).
- Growth of nanowhiskers.
- EpiRAS in-situ growth monitoring.

Thin film deposition and annealing

- Plasmalab 80+D plasma deposition (PECVD) of SiN_x and SiO_x films (Oxford Instruments).
- Three electron beam evaporation systems for metals, superconductors and dielectric materials (Leybold, Plassys).
- DC/RF magnetron sputter deposition system for metals and dielectric films (PVD Products).
- Rapid thermal annealing system with N2 and N_2/H_2 gas supply (JIPELEC).

Materials characterization

- Two 4-crystal, high resolution, X-ray diffraction systems (Seifert 3003 PTS-HR, Figure 12, and Philips Expert).
- Rapid photoluminescence mapping system (Accent RPM 2000).
- Digital scanning electron microscope (Zeiss).
- C-V doping profiler (Dage).
- Hall-effect measurement system Accent HL5500.
- Spectroscopic ellipsometer (Sentech SE850).
- Stylus force step profiler (Alphastep 500).
- Atomic force microscope (MFP-3D, Asylum Research).
- Optical microscopes (Nikon Eclipse L200 and L200D).

Figure 12: Seifert X-ray diffraction system.

Optical lithography

- Karl Süss MJB3 manual contact printing mask aligner, also suited for IR back-side alignment. It uses 365 nm and 405 nm UV-light. Optical resolution is approximately 0.4 µm.
- Karl Süss MA6 semi-automatic contact printing mask aligner with split field optics. Currently configured for 2/3/4-inch substrates and 3/4/5-inch masks. It uses 365 nm and 405 nm wide-band UV-light. Optical resolution is approximately 0.4 µm.
- New photoresist spinners, furnaces and hot plates (see above), wet processing area.

Electron beam lithography

Two electron beam lithography systems (Raith150 and Raith150TWO), dedicated control software environment. Thermal Schottky field emitter source with 2 nm beam resolution, and with variable beam energy between 0.2 keV and 30 keV, with beam currents between 15 pA and 3.8 nA. Maximum sample size is 4 inch on the Raith150 and 6 inch on the Raith150TWO. Write field stitching and overlay accuracy are better than 40 nm for 200 µm write field size. The Raith150TWO system also offers wafer height measurement and control, as well as a fixed-beam moving-stage exposure option for very long structures. It has a new 20 MHz pattern generator, equipped with very efficient data object fracturing algorithms.

Atomic force microscope lithography

Atomic force tip oxidation of Ti, GaAs and graphene films, using a scanning force microscope in atmospheric conditions. Write fields are approx. 10 µm x 10 µm, and sub-micron to nm line width has been demonstrated.

Wet and dry etching

- 20m^2 wet benches with ultrasonic baths, spin-dryer, heater/ chiller, solvents, acids, base liquid handling.
- 2x RIE systems (Oxford PlasmaLab 80) with fluorine based chemistry for dielectrics and metals (Figure 13).
- ICP system (Oxford PlasmaLab 180): Chlorine based chemistry, 13.56 MHz RIE and synchronous ICP power sources, load lock.
- Technics Plasma 100E down-stream micro-wave oxygen asher.

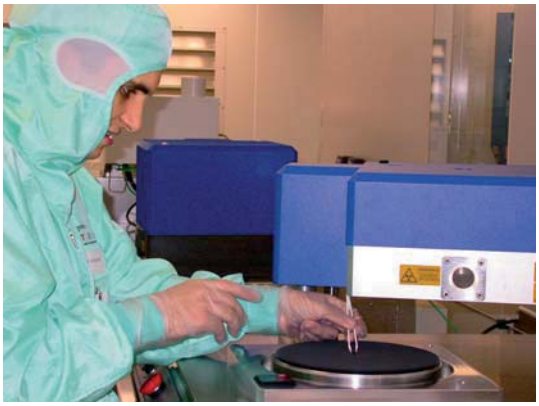


Figure 13: Reactive ion etching (RIE).

LPCVD nanotube and nanowire deposition

Figure 14: Low-pressure chemical vapor deposition (LPCVD).

Carbon nanotube and silicon nanowire research is boosted by our LPCVD system from ATV Technology (Figure 14). It allows catalytic growth of single- and multiwalled carbon nanotubes (CNTs) from methane gas, as well as silicon nanowires (SiNWs) from silane gas on structured substrates (e.g. MEMS and NEMS devices) at low process pressures. If desired, low frequency plasmas can be generated by dipole antennas inside the reactor. Novel built-in micro-heaters allow localized CNT deposition on individually heated areas on substrates.

Atomic layer deposition

MEMS and NEMS processes, as well as basic chemistry research, profits from the atomic layer deposition system in FIRST, bought from Picosun (Figure 15). It is configured for the controlled and defect free deposition of Al_2O_3 and ZnO_2 from metal-organic precursors and pure water, one atomic layer at a time. In 2008, a novel heated source for solid and low pressure liquid precursors and a special receptor for powder coating applications were purchased, installed and tested, allowing HfO_2, TiO_2 and powder coatings.

Figure 15: Atomic layer deposition (ALD).

FIRST infrastructure and safety

FIRST's total area of 860 m^2 contains 10 cleanroom cabins with an area of 400 m^2. The air in the cabins is controlled and monitored with respect to particle concentration, temperature and humidity and is exchanged up to once per minute. Various loops with different water qualities are installed. Over 20 different media are distributed throughout FIRST: water of different qualities, neutral and reactive gases and large amounts of liquid nitrogen. Several kilometers of cables distribute electrical power or collect data from controllers and sensors. An automatic surveillance system with over 800 data points monitors the status of the facility including the very important safety infrastructure. Expressed in numbers:

- fresh air input: 45'000 m^3/hour
- maximum cooling power: 650 kW
- installed electrical power: 350 kW
- liquid nitrogen consumption: 500'000 liters/year
- 28 toxic gas sensors

As long as the infrastructure works well, hardly anyone will notice its complexity. The FIRST operation team is in close contact with the users in order to optimize the cleanroom conditions in respect to air quality and economy of resources.

The technical installations have now been in operation for 8 years and we observe an increased need for service and replacement during our regular inspections that take place every two months. We also replaced the entire illumination of the lab. Additional injections in the building walls were necessary to prevent water intrusion. For the increasing number of users, we enlarged the capacity of our changing room in terms of available cleanroom overalls and shoes.

There is no spare room left in FIRST for new equipment. However, there is still a need for new systems or upgrades. In order to fulfill the needs for supplies of additional tools we have to increase the capacity of certain media. In 2009, we successfully changed the programming of the cooling water supply. As a result, the enhanced cooling water flow can be guaranteed without any loss in pressure.

Since the inauguration of FIRST, the number of FIRST staff has increased from 5 to 11 people. Unfortunately, the available office space has not changed and has become an increasing problem. We have been able to find a solution in collaboration with the Institute of Chemical and Bioingeneering that provided us an additional room. Unfortunately, this solution is limited in time and we are continuing searching adequate office space for our team.

Centralization of Liquid Nitrogen Supply

The ETH Executive Board decided to centralize the liquid nitrogen (LN_2) purchase for all consumers at ETH. An LN_2 commission was established to evaluate, propose and proceed upon approval with the centralization of the LN_2 purchase at ETH. FIRST contributed to the concept of centralization. To date, each institute or infrastructure unit of ETH negotiated the LN_2 delivery with respect to supplier and price independently. Depending on the amount of consumption, the prices varied by a factor of three and more. Hence, a scenario was developed and approved by ETH to reduce the costs and also to guarantee the most reliable supply in the future. FIRST experienced a reduction in costs for liquid nitrogen by 85 kCHF which mostly benefits the MBE users.

Nano Particle Safety

The low pressure chemical vapor deposition (LPCVD) system was also separated from the rest of the clean room by an additional (hermetically sealed) clean room wall, and by an additional air extraction system (Figure 16). This is a dedicated ventilation unit which extracts the air from the LPCVD mini environment and filters it with ULPA-15 particle absorbing filters before releasing it into the plenum of the clean room. The encapsulation of the LPCVD, together with the exhaust air filtering, significantly reduces the risk of exposure of other laboratory users to potentially released carbon- and silicon nanowires from the LPCVD system.

Figure 16: A separate clean room cabin (left) for the LPCVD (middle left) was built inside the laboratory. The clean room air for the LPCVD room is extracted through a separate ventilation duct (middle right) and returned to the plenum through its own ventilation unit (right) equipped with ULPA15 particle filters.

Safety Trainings

FIRST staff actively participated in the fire fighting trainings offered by the ETH Zürich to its students and staff (Figure 17). Members of the FOT contributed 3 training sessions in English, and thus trained approximately 80 laboratory users in the theoretical and practical aspects of

combating various types of fires. It is foreseen that this collaboration between ETH Zurich's Health, Safety and Environment Department and FIRST-Lab will continue in the future. FOT members also actively participate in the Safety Committee of the HCI building (where FIRST-Lab is situated), and contributed significantly to the latest version of the Health, Safety and Environment Manual for the Department of Chemistry and Applied Biosciences (the home Department for the HCI building).

Figure 17: FIRST users must regularly participate in practical fire fighting courses. Apart from the basics about fire prevention, they learn to extinguish real fires with proper fire fighting equipment.

In 2009, we introduced a regular laboratory evacuation drill. The laboratory will now be evacuated twice per year, giving laboratory users the chance to actually experience an evacuation alarm and to see the emergency exit. Students learn where to go when a serious alarm would appear, increasing their confidence in case of a real emergency situation. Further, safety measures for the maintenance of the MBE system with phosphorous were improved by purchasing a special vacuum cleaner for safe handling of flammable materials and special fire-proofed personal protection, e.g. overalls (Figure 18).

Figure 18: Personal fire protection for MBE maintenance.

FIRST is confronted by a potential of accidents due to its technical infrastructure, chemicals, gases and the high number of users with varying levels of education in the field of working with chemicals. FIRST developed a concept for information and people care management in

the case of a heavy accident in a centralized lab of this size in collaboration with the safety department and corporate communication of ETH Zurich. It is planned to transfer this concept to other centralized infrastructure units of ETH Zurich. Additional experience was gained by participating in the crisis training project "JANUS" of ETH and Zurich police department in September 2009.

Education and use of the lab

General seminars

In April 2009, our new concept for the general user training was implemented. The contents and organization of the introduction seminar was adapted to deal with the constantly high user number with respect to proper clean room behavior and safety (Figure 19). The introduction seminar was extended to an introduction day to cover the additional training on general clean room behavior, mentor system and safety test. Further, the cleanliness seminar was implemented into the introduction day.

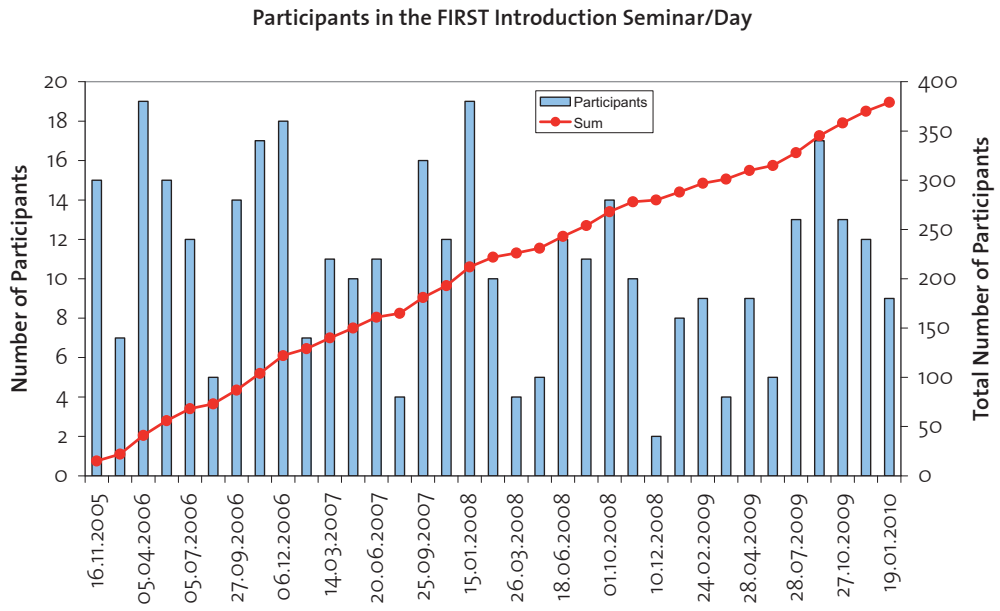


Figure 19: Number of participants of the FIRST introduction seminar/day during the past 5 years.

Mentoring

FIRST offers mentoring for all new clean room users to complement the general training. Mentors are experienced users of FIRST who help new users with proper cleanroom behaviour and with organizational and technical processes in the beginning.

The annual mentor meeting took place in June 2009. Tasks of mentors, needs for additional trainings for the mentors, feedback and open questions were discussed. The mentors

addressed the challenge of mentoring new users of different groups with non-familiar technological processes. Further discussion points were the sharing of common processes between different groups to save costs and time, and suggestions for improvement of equipment and processes.

Special seminars and technological experience exchange

Currently, FIRST has about 150 wet bench users. The majority of these users did not receive a basic training in chemistry. However, they are required to carry out challenging processes for semiconductor processing with mostly hazardous materials. Therefore, FIRST developed a basic chemistry seminar on chemical processes, handling of chemicals and safety that applies to all wet bench users in FIRST. So far, 60 users took part in the seminar and a very positive feedback was received by them.

In September 2009, FIRST also offered a special seminar on photolithography. Dr. Christian Koch from Microchemicals GmbH in Ulm/Germany discussed, with 25 attending users, the processing of photo resists especially for lift off processes. The seminar also addressed topics like the optimization of photolithographic processes for all kind of structuring.

On September 8th, FIRST had invited Mr von Kahlden from CCI von Kahlden GmbH (Contamination Control Instruments). All users and colleagues from companies, e.g. IBM Research GmbH, were invited to the demonstration of a cleanroom model and to learn about air flow and pressure settings in clean rooms. A particle counter which was especially altered to not only measure particles in the air, but also on surfaces was also presented. The seminar resulted in informative discussions.

FIRST introduced a database for lithography processes added to the already existing database for wet-chemical processes. The goal was to make the know-how achieved in FIRST available to all current and future users. This database already proved to be very helpful, particularly for our new users in FIRST.

User questionnaire

In November, all users in FIRST were invited to participate in a user survey, with the goal to identify problems and other issues with our equipment, infrastructure and/or organization. A large number of users responded. The survey will be evaluated in 2010 and the users will receive direct feedback on a user meeting. It is always a goal of the FIRST Teams to improve the laboratory towards the users' needs wherever possible.

Visits and Public Relations

The Committees for Science, Education and Culture (CSES) of The Council of States of Switzerland visited FIRST in February 2009. Prof. Dr. Peter Chen, Vice President of Research and Corporate Relations of ETH Zurich, reported on recent efforts in science and technology by ETH to enable and support cutting-edge projects in micro- and nanoscience (Figure 20). FIRST team members guided the representatives of the Swiss parliament, the President of the ETH Board, Dr. Fritz Schiesser, and the President of ETH Zurich, Prof. Dr. Ralph Eichler, as well as the members of the Executive Board of ETH through the lab and explained research projects, scientific equipment, training concept and education in FIRST.

Figure 20: Visit of the Committees for Science, Education and Culture of The Council of States of Switzerland. ETH's Vice President of Research and Corporate Relations presents in front of the FIRST entrance (left). FIRST team members guide the representatives of the Swiss parliament through the lab.

Many researchers and students, industrial partners and colleagues from all over the world visited FIRST over the past years and also in 2009 (Figure 21). We welcome them and appreciate their interest in our facility

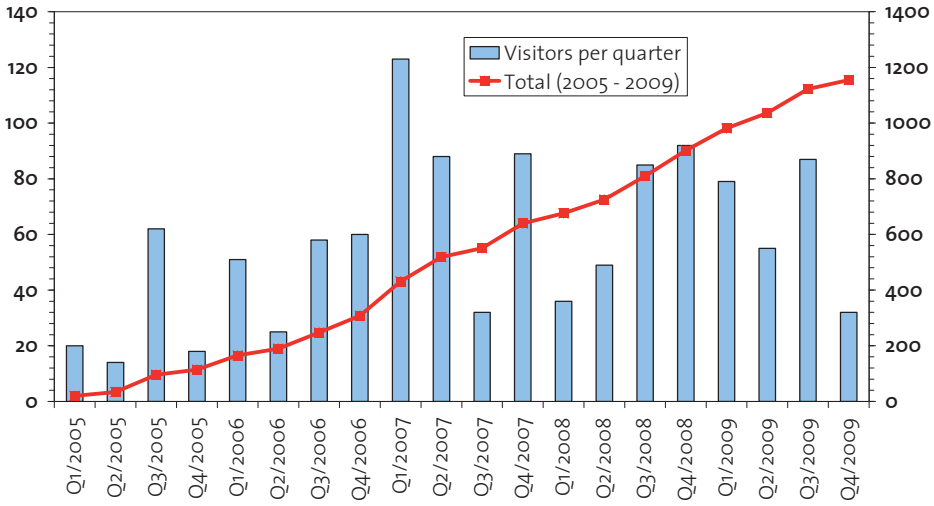


Figure 21: Number of visitors in FIRST over the past five years displayed by number per quarter (blue bars, left axis) and summed (red line, right axis).

Research in FIRST

FIRST welcomed 37 different groups with approximately 50 projects to use our superior technical infrastructure for their research. In the following, a list of all projects with the coordinates for the groups is provided.

ETH Projects (FMT)

Prof. C. Bolognesi, Terahertz Electronics Group, D-ITET:
http://www.ifh.ee.ethz.ch/
- Terahertz InP/GaAsSb Double Heterojunction Bipolar Transistors (BOL1)
- InP/GaInAs Low-Noise Pseudomorphic High Electron Mobility Transistors (BOL2)
- AlGaN/(Ga,In)N Heterostructure Field-Effect Transistors (BOL3)

Prof. J. Dual, Institute for Mechanical Systems, D-MAVT:
http://www.ifm.ethz.ch
- Mechanics of Micro- and Nanostructures (DUA4)

Prof. K. Ensslin, Nanophysics, D-PHYS:
http://www.nanophys.ethz.ch
- Nanophysics (ENS5)

Prof. J. Faist, Quantum Optoelectronics Group, D-PHYS:
(http://www.phys.ethz.ch/~mesoqc)
- High performance, single frequency quantum cascade lasers (FAI1)
- Short wavelength and highly tunable QCLs (FAI2)
- Terahertz Sources and Photonic Crystals (FAI3)

Prof. C. Hierold, Micro and Nanosystems, D-MAVT:
http://www.micro.mavt.ethz.ch
- NEMS (HIE1)
- CNT growth (HIE2)
- Flywheel gyro (HIE3)
- Gas sensors (HIE4)
- Resonators (HIE5)

Prof. A. Imamoglu, Quantum Photonics Group, D-PHYS:
http://www.iqe.ethz.ch/quantumphotonics
- Quantum dots in a nano-cavity (IMA1)
- Electrical control of optically active quantum dots (IMA2)

Prof. H. Jäckel, Electronics Laboratory, D-ITET:
http://www.ife.ee.ethz.ch
- InP-double heterojunction bipolar transistors for +100 Gb/s integrated circuits (JAE1)
- Photonic bandgap engineering for dense optical integration / Photonic crystals for active optical devices (JAE2)
- InP-based all-optical sub-ps switches for Tb/s optical communication (JAE4)

Prof. U. Keller, Ultrafast Laser Physics Lab D-PHYS:
http://www.ulp.ethz.ch
- Ultrafast diode-pumped solid-state lasers (KEL2)
- Passively Mode-Locked VECSELs (KEL3)

Prof. B. Nelson, Institute of Robotics and Intelligent Systems, D-MAVT:
http://www.iris.ethz.ch
- CNT-based NEMS (NEL1)

Prof. N. Spencer, Laboratory for Surface Science and Technology, D-MATL:
http://www.surface.mat.ethz.ch
- Microfabricated surfaces as platform to study adult and stem cells in designed microenvironments(SPE1)
- Self-assembly of micron size particles combined with molecular assembly patterning techniques to produce ordered arrays of nano-sized features (SPE2)

Prof. A. Wallraff, Quantum Device Lab, D-PHYS:
http://www.solid.phys.ethz.ch/wallraff/
- Superconducting Qubits (WAL4)

ETH Projects (non-FMT)

Prof. A. Baiker, Institute for Chemical and Bioengineering, D-CHAB:
http://www.baiker.ethz.ch
- Preparation of thin film model catalysts for in situ PM-IRRAS at solid-liquid interfaces *(BAI1)*

Prof. B. Batlogg, Physics of New Materials, D-PHYS:
http://www.pnm.ethz.ch
- Organic thin-film and single crystal transport (BAT1)
- (In,GA,Al)N epitaxial layer by LEPEVPE (BAT2)

Prof. P. Dittrich, Laboratory of Organic Chemistry, D-CHAB:
http://www.dittrich.ethz.ch
- Fabrication of microfluidic master structures *(DIT1)*

Prof. L. Gauckler, Nonmetallic Inorganic Materials, D-MATL:
http://www.nonmet.mat.ethz.ch
- OneBat – micro solid oxide fuel cell (GAU1)

Prof. P. Günter, Nonlinear Optics Lab, D-PHYS:
http://www.nlo.ethz.ch
- Structuring of thin ferroelectric films for electro-optically active photonic devices (GUN2)

Prof. J. F. Löffler, Laboratory of Metal Physics and Technology
(http://www.metphys.mat.ethz.ch/), D-MATL:
- Composite doped meta-materials (LOE1)

Prof. H. G. Park, Institute of Energy Technology, D-MAVT:
http://www.iet.ethz.ch/
- Microfabrication of Carbon Nanotube Nanofluidic Platforms (PAR1)

Prof. D. Poulikakos, Laboratory of Thermodynamics in Emerging Technologies, D-MAVT:
http://www.ltnt.ethz.ch/
- Measurement of Thermophysical, Electromechanical and Transport Properties of Individual Carbon Nanotubes (POL1)

Prof. V. Sandoghdar, Nano-Optics, D-CHAB:
http://www.nano-optics.ethz.ch
- Nanooptics (SAN2)

Prof. B. Schönfeld, Laboratory of Metal Physics and Technology, D-MATL:
http://www.metphys.mat.ethz.ch/
- Near-surface microstructure of Ni-Pt (SCH1)

Prof. P. Smith, Polymer Technology, D-MATL:
http://www.polytech.mat.ethz.ch
- Substrate preparation (SMI1)

Prof. R. Spolenak, Nanometallurgy, D-MATL:
http://www.met.mat.ethz.ch
- Combinatorial thin metal film deposition (SPO2)

Prof. W. Stark, Functional Materials Laboratory, D-CHAB:
http://www.fml.ethz.ch
- Functionalization of graphene sheets (STA1)

Prof. G. Tröster, Electronics Laboratory, D-ITET:
http://www.ife.ee.ethz.ch/
- Flexible temperature sensors (TRO1)

Prof. P. Uggowitzer, Laboratory of Metal Physics and Technology, D-MATL:
http://www.metphys.mat.ethz.ch
- Magnetron sputtering of magnesium on a titanium substrate (UGG1)

Prof. J. van Bokhoven, Heterogeneous Catalysis, D-CHAB:
http://www.vanbokhoven.ethz.ch
- Catalysts (BOK1)

Prof. J. Vörös, Laboratory of Biosensors and Bioelectronics, D-ITET:
http://www.lbb.ethz.ch/
- 3D Micro-/Nano-Structured Surfaces for Proteomics (VOE1)
- Development and Characterization of Nanowires for Applications in (Bio-)Electronics (VOE2)

Prof. V. Vogel, Biologically Oriented Materials, D-MATL:
http://www.nanomat.mat.ethz.ch
- Micro- and nanofabrication for biological applications (VOG1)

Prof. E. Windhab, Institute of Food Science and Nutrition, D-AGRL:
http://www.agrl.ethz.ch
- Nanomembranes for dynamically enhanced dispersion processes (WIN1)

External Projects

Dr. J. Gobrecht, PSI:
- Field emission electron gun (GOB1)

Prof. G. Patzke, Institute of Inorganic Chemistry, University of Zurich
http://www.aci.uzh.ch/
- Metal oxide nanowires for application in portable sensors (PAT1)

Prof. A. Schilling, Physik-Institut, University of Zurich
http://www.physik.uzh.ch/groups/groupschilling
- Physics of Superconducting Thin Films and Nanostructures and Applications as Single-Photon Detectors (SCI1)

Collaboration with Industry

The ETH Zurich Board supports collaboration with industry. The main goal is not production, but collaboration in research and development. For this purpose, the industrial partners can profit from attractive rates for the use of the FIRST-lab infrastructure.

In 2009, FIRST supported researchers from the following companies:

- EpiSpeed AG
- Enablence Switzerland AG
- Huber & Suhner AG
- IBM Research GmbH
- Kistler Instrumente AG
- Sensirion AG
- Spectrosolutions AG
- SUV-Detectors

The type of collaboration ranged from standard inspection and processing to prototype epitaxial layer delivery, and to proof-of-concept support for innovative processing techniques.

FIRST Publications 2009

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Nature Photonics 3 (2009) 586.

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