RENATECH
French national nanofabrication network
Newsletter

June 2012

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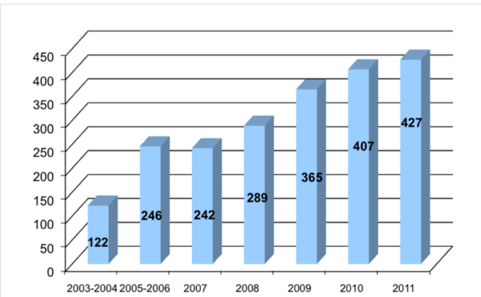
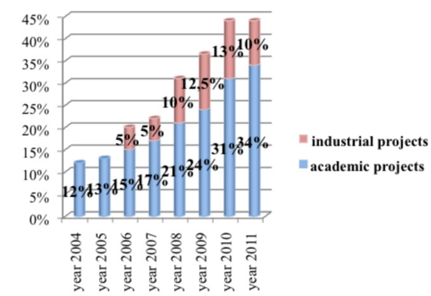
RENATECH welcomes external users form academia and industry



▲ *Number of external projects running at RENATECH facilities*



▲ *Evolution of external academic and industrial projects*

The RENATECH national nanofabrication network is a mutualized infrastructure of 7,000 m2 large technological facilities located at six academic laboratories and consisting of nanofabrication cleanrooms , heavy laboratory space, coupled with expert staff support and state of the art scientific and technological expertise . Bringing together the most advanced facilities of its kind in France, RENATECH research encompasses physical sciences, engineering and life sciences and has a strong inter-disciplinary emphasis. The network's objective is to facilitate all aspects of nanotechnology research by providing access to advanced nanotechnology instrumentation, process and training and to meet the challenge of users' needs in the context of the rapid growth and unlimited potential of nanotechnology. Over 300 external users per year use the fabrication, synthesis, characterization, and integration resources of RENATECH to build structures, devices, and systems from atomic to complex length-scales. Every week, several new users coming from academia and industry learn to use the tools available in the facilities to carry out their research projects, they can also enjoy strong staff support to complete their work. RENATECH provides the learning and practicing environment critical to successful cutting-edge research. Supporting multidisciplinary research in nanotechnology and fostering interaction between researchers and research disciplines, RENATECH has increased 3,5 times since 2004 the number of national and international external projects running in its facilities.

Remaining dynamic and attentive in its support towards the needs of the users, RENATECH holds annuals users' meetings and provides an indispensable exchange venue for the researchers and engineers from diverse disciplines and from industry to highlight new results and advanced capabilities in nanoscale science research. In 2012, RENATECH users' meeting was held on March 19 and inaugurated a new concept – the meeting was held on the same day and simultaneously at all the laboratories of the technological facilities. It was an excellent opportunity to inform the users about the latest technological competencies and equipment available in their regions, to overview the procedures of project submission and its realization as well as to visit the cleanrooms and to interact directly with the persons in charge of the technological facilities. Offering the geographically dispersed users' meeting in 2012, RENATECH provided excellent platforms for fruitful discussions between local actors of the interdisciplinary field of nanoscience whose success depends on a dialogue between diverse scientific approaches and an intense circulation of ideas.

Specific technological tools

Advanced X-ray Diffraction System

The equipment is a D8 Discover with DAVINCI design from BRUKER. The particular design stands for snap-lock alignment-free component change with real time recognition by the system.
The goniometer is a theta-2theta system, with horizontal movement (vertical sample).
The X-Ray source is a Cu 2.2kV twist tube, allowing fast switching from line to spot focus. It is mounted on a motorized stand with a 90° rotation of the source, hence suitable for in-plane measurements. α_i scans are also possible thru another motorized drive tilting the source.
A low divergence Göbel mirror collimates the X-Ray flux, which is then filtered by one of the three following monochromators :
- Asymmetric 2xGe(004) channel cut – high resolution, high intensity at angles of interest for semiconductors like GaAs.
- Asymmetric 2xGe(022) channel cut – very high intensity, even at low angles, lower resolution.
- Symmetric 4xGe(004) channel cut – very high resolution, even at low angles but low intensity.

A high flux spot focus “Polycap” optic for texture and micro-diffraction measurements can also be mounted on the primary beam.
The centric cradle can hold samples up to 6 inches, with X-Y mapping. The Chi, Phi, X,Y and Z movements are motorized. A double tilt zeta/xi motorized holder with a KEC knife edge is also available for reflectometry measurements. A DHS 1100 holder with highly X-Ray transparent graphite dome from Anton-Paar can be mounted on the cradle for measurements as a function of the sample temperature (up to 1100°C with full control of the temperature by the software).
The diffracted signal detection is made by a pathfinder optic (either high flux motorized slit + soller slit or high resolution Ge(220) analyser crytal), a scintillator, or a LynxEye 1D detector for fast reciprocal space mapping measurements.

A full set of accessories to shape the flux are also available, allowing the system to be configured for high-resolution diffraction, phase analysis, in-plane grazing incidence diffraction, reflectivity, grazing incidence diffraction, micro-diffraction, and residual stress and texture investigations.

Finally, control and analysis softwares from BRUKER have been delivered with the machine (“Diffrac Suite” for the control, “Eva / Search” and “Leptos” for the treatment and analysis, including a COD database for automated phase research).

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Hitachi SU-8000

The CFEG Hitachi SU-8000 equipped with cryo-transfer device, EBIC module and nanomanipulators

A versatile platform for SEM inspections has been integrated at the IEF-CTU MINERVE, based on a Hitachi SU-8000 (Fig. 1). The Hitachi SU-8000 is a Cold-FEG with a 5nm diameter tip operating at room temperature, combined with a 2-stage magnetic condenser lens and a Snorkel objective lens. It comes with 3 reflected electron detectors which enable selective SE, low angle BSE (LA-BSE) and High angle BSE (HA-BSE) imaging, and achieve a resolution varying from 1 nm at 15 kV to 1.4 nm at 1 kV. These features are particularly interesting to observe the topmost surface at low voltages, down to 0.1 kV, and beam sensitive samples, such as polymers and biological samples, using low probe current, down to 1.5 pA. Our SU-8000 has an additional BF-DF STEM detector, which can produce transmitted electron images with enhanced contrast at 30 kV on biological lamella and semi-conductor nanowires heterostructures, giving useful information prior to TEM observations.

Cryo-SEM: A Gatan Alto2500 cryo-transfer device has been integrated to the SEM. It comprises a freezing station in nitrogen slush, operating under primary vacuum at a temperature below -200°C. Frozen samples are transferred under vacuum to a cryo-preparation chamber which is directly attached to a SEM flange and pumped under secondary vacuum, where it is fractured with a cold knife, metalized and transferred to a cold stage mounted inside SEM chamber. The cold stage is capable of operating in the temperature range from 25°C down to -150°C without significant change of the SEM resolution, which can be used for imaging biological samples embedded inside liquid solutions. Features with sizes less than 10 nm have been observed at -150°C with a cooling gaz nitrogen flow of 2L/min in the cold stage.

Nanoprobe electrical measurements: The instrument is also capable of performing 2-probes electrical measurements, such as I-V characteristics (under secondary vacuum) and Electron Beam Induced Current (EBIC), with W probes driven by nanomanipulators.

Available tips curvature radius ranges from 500 down to 30 nm. EBIC is a kind of electron transport detection method in the structures where a depletion layer is capable of collecting the electron-hole pairs created by the primary electrons of the SEM. The carriers which are able to reach the depletion region under diffusion forces, before they recombine, will be collected by the junction and contribute to the EBIC image contrast. The spatial resolution and the current levels obtained in the EBIC image are illustrated on a silicon photonic crystal photodiode (Fig. 2). Currents down to pA have been measured with a good signal to noise ratio.

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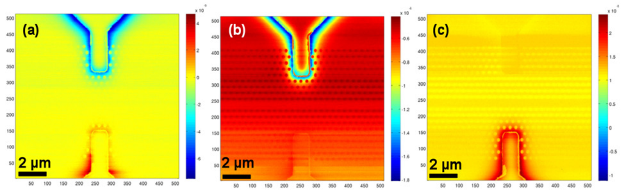

Colorized quantitative EBIC image (horizontal & vertical coordinates in pixels, color scale in A) of a Si photonic crystal located between two Pt electrodes, for different bias voltages (a) 0V, (b) 1V, (c) -1V and the following SEM conditions: High Voltage=10kV, Probe Current=27 pA, Dwell Time=2ms.

Recent technological realizations

Advanced Nanomanipulation of Single chromosomes in nanofluidic CHANNELS

Chromosomes are the universal template of genome transactions, containing the genomic code as well as structural information necessary for the regulation of expression. Their genomic content is now scanned with modern high-throughput sequencing technologies, which achieve base pair sensitivities with constantly lowering costs that yet remain prohibitive for diagnostics. On the other hand, new complementary technologies are emerging for whole-chromosome structural analysis. The manipulation of chromosomes by molecular biology approaches has remained a feat, mostly because conventional assays were designed to characterize fragments smaller than 104 base pairs, orders of magnitude less than whole chromosomes of ~107 base pairs, and nanotechnologies seem to provide a unique solution to overcome these limitations.

Nanofluidic devices consist of channels of ~100 nm or less. Here we fabricated arrays of square channels of 200 nm in cross-section, and 100 µm to 1 mm long. These nanostructures were integrated in functional allowing for the manipulation chromosomal DNA purified from mammalian cells of several Megabp. When DNA molecules enter in these nanostructures, they undergo entropic constraints that tend to spread them in a longitudinal conformation. Spread DNA molecules can then be visualized using conventional fluorescence microscopy techniques in order to provide genomic information at the genomic level. Notably, we demonstrated that the degree of elongation of DNA elongation could be precisely monitored using hydrodynamic forces (Fig): the molecule extension increases with its migration speed through the nanochannels. This conformational manipulation process has been recently patented. We are now applying this technology to characterize the process of DNA replication (the rigorous duplication of the genomic material before mitosis) in human cells. We intend to provide an integrated solution to quantify the extent of genomic instability during cancer progression that will be used as a clinical diagnostic systems.

In conclusion we have reached the level of technological expertise in nanofluidics that is required to challenge American teams, start-up companies, and we wish to demonstrate the relevance of nanofluidics for diagnostics.

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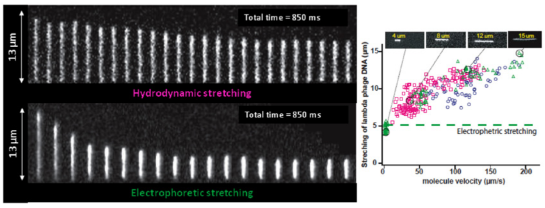

The left panel shows a time-series of a single DNA molecule as it enters in nanochannels under hydrodynamic or electrophoretic actuation (upper and lower panel, respectively). The use of hydrodynamic flow fields thus provides a lever to adjust the degree of DNA spreading, as shown by the increase in elongation with the velocity of the molecule inside nanochannels (data points in the right panel). This effect is not observed with electrophoresis (dashed line in the right panel).

Magnetic domain wall motion induced by an electrical current in ferromagnetic GaMnAsP thin tracks.

Propagation of magnetic domain walls in a narrow ferromagnetic track can be induced by injecting an electrical current, thanks to the spin transfer torque. Such a mechanism could be at the heart of novel magnetic memories or logical devices. A collaboration between the Laboratoire de Physique des Solides (LPS) in Orsay and LPN has shed some light on the mechanisms at work in current induced domain wall motion. The results were published in Physical Review Letter [1].

LPN has recently developed a new ferromagnetic semiconductor (Ga,Mn)(As,P), grown by molecular beam epitaxy for which the magnetic anisotropy can be tuned at will by adjusting the P concentration. In particular, almost defect-free layers exhibiting a strong out-of-plane magnetization can be produced. Those characteristics are essential to achieve current induced domain wall motion. To that end, a thin layer (50 nm) was processed into microtracks and contacted by Ti/Au pads (see Figure 1). The sample was then inserted inside a cryostat. The microstrack magnetic state was probed by magneto-optical Kerr effect imaging.

As seen on Figure 2, current pulses produce domain wall motion. Thanks to the (Ga,Mn)(As,P) alloy, the domain wall dynamics under current could be investigated over a large range of temperatures. In particular, different dynamical regimes were observed, creep, depinning and dissipative, even at low temperature. In the dissipative regime, we showed that the domain wall velocity is identical to the spin drift velocity of the carriers, and obtained a measurement of the carrier spin polarization.

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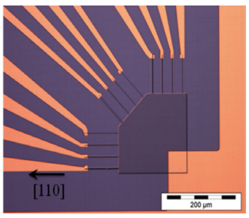
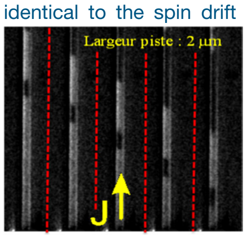


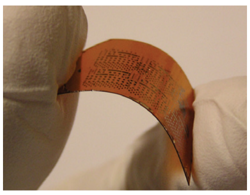
A set of 12 microtracks (4, 2, 1, 0.5 µm width) aligned along different crystallographic directions and contacted by Ti/Au pads. The microtracks were fabricated at LPN by e-beam lithography.



Five successive snapshots of the same 2 µm wide track obtained by magneto-optical Kerr effect, taken after applying five successive current pulses. Magnetic domains with opposite magnetization directions appear in black and white. The current acts on the domain walls separating the domains.

Microwave performance of 100 nm-gate electron mobility transistors on plastic flexible substrate

Today InP-HEMT offers the cutoff frequency world record, offering possibility of integrated circuits with frequency up to THz. InP HEMT with gate length of 100nm was realized on flexible substrate by a transfer technique. The cutoff frequencies of extrinsic current gain of this transistor is fT=120GHz and oscillation frequency fmax=280GHz. With the same transistor made by a similar process on rigid substrate, the fT and the fmax are respectively of 203 and 215GHz. The degradation of the fT was identified, and results from the back interface of the transferred transistor. Solutions were brought to this problem and will be soon published. One can however note a fmax in the state of the art, which corresponds to the highest frequency of cutoff frequency reported for a transistor on flexible substrate. This high cutoff frequency allows to envisage applications on flexible in range of millimeter wave, in particular at 94GHz, for which the passive elements must be now developed with the aim of manufacture of circuits.



Microwave performance of 100 nm-gate $In_{0.53}Ga_{0.47}As/In_{0.52}Al_{0.48}As$ high electron mobility transistors on plastic flexible substrate

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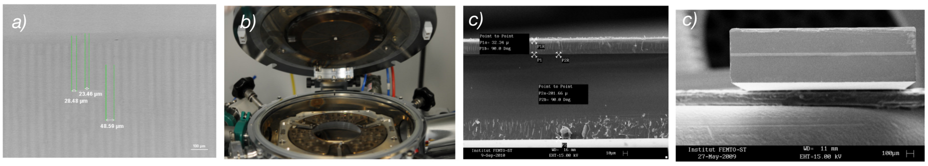
Acoustic resonator based on periodically poled transducers

This works consists of studying and fabricating waveguides resonators exploiting composite substrates with periodically poled ferroelectric materials capable of meeting the need of high-frequency sources for the concerned applications (radar detection). The idea consists of using a waveguide based on a Periodically Poled Transducer (PPT) realized on a ferroeclectric single-crystal substrate such as lithium niobate or tantalate inserted between two single-crystal substrates allowing the guidance of waves without losses.



Figures : Resonator fabrication steps : (a) Optical microscope picture of domain inversion for λ=50µm, (b) Wafer bonding, (c) SEM view of a silicon wafer bonded on a periodically poled lithium niobate layer, (d) SEM view of the silicon/PPLN/silicon stack

We have developed all the fabrication steps in FEMTO-ST Institute. At first, a poling bench allows to invert ferroelectric domains (Fig. a) by application of an electrical field on a ferroelectric wafer which overcomes the intrinsic coercive field of the material (21kV/mm for LiNbO3 and LiTaO3 material). This ferroelectric material is then bonded on a silicon wafer using a wafer bonding technique developed in our group based on a metal-metal adhesion at room temperature promoted by a high pressure applied to the material stack (Fig. b). Lapping and polishing steps allow to thin the PPT layer of about 30µm for our application (Fig. c). Finally this stack is bonded on a second silicon wafer in order to define the desired compact Si/PPT/Si structure (Fig. d).

An oscillator stabilized by a waveguide resonator operating at 131MHz appeared with encouraging characteristics. A phase noise has then been measured at -165dBc/Hz at 60kHz from the carrier with an input power of 2mW and a frequency stability of 10^{-9}.

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Events

RENATECH at MNE 2012 in Toulouse

RENATECH will be present as exhibitor at the 38th International Micro & Nano Engineering Conference (MNE 2012) which will be held in Toulouse-France at the « Pierre Baudis » Congress Centre from 16 to 20 September 2012.
The MNE Conference focuses on micro and nano-fabrication and manufacturing using lithography and other nano-patterning related approaches. The Conference brings together engineers and scientists from all over the world to discuss recent progress and future trends in the fabrication, manufacturing and application of micro and nano-structures and devices. Applications in electronics, photonics, electromechanics, environment and life sciences are discussed

Inauguration workshop of UMI-LN2

The inauguration workshop of the international laboratory UMI-LN2 is scheduled from 14 to 18 July 2012 in Quebec. More information concerning this event could be found on the website www.labn2.ca starting from January 2012.

For further information contact:
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Realize your project with RENATECH network

1.Contact RENATECH network via:

common entrance point: renatech-accueil@cnrs-dir.fr
or contact directly one of RENATECH facilities to discuss your application:

IEMN technological facility
Contact: plateforme@iemn.univ-lille1.fr

FEMTO-ST technological facility
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IEF technological facility
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LAAS technological facility
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LPN technological facility
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PTA technological facility
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2.The application will be worked through and evaluated by the reception team at each facility.

3. Realize your project

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