# RENATECH

**French national nanofabrication network**

# Newsletter

**June 2011**

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## RENATECH and users' community

RENATECH – the French national nanofabrication network – exists to facilitate all aspects of nanotechnology research by providing access to advanced nanotechnology instrumentation, processes and training and to meet the challenge of users' needs in the context of the rapid growth and unlimited potential of nanotechnology.
In order to assure that the network remains dynamic in its support, since 2010 RENATECH holds annual Users' Meetings in cooperation with its partner of the Basic Technological Research programme (RTB), French Alternative Energies and Atomic Energy Commission (CEA). This information and exchange event provides a venue for researchers and engineers from diverse disciplines and from industry to highlight new results and advanced capabilities in nanoscale science research, to inform about the latest technological competencies and equipment, as well as to overview the procedures of project submission and its realisation at RENATECH network. It is also an opportunity to meet directly the persons in charge of project reception in the network facilities and to clarify all the questions related to this aspect. For the actors of the technological facilities these meetings are also very important as they can learn more about the users' needs, expectations and interests.

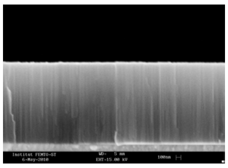
In 2011, RENATECH users' meeting was held on March 21. The programme of this event was focused on the presentation of network capacities and know-how and collaboration with partners from both academic and socio-economic fields, particular attention was given to the cooperation with SMEs and Start-ups. Invited talks of the users coming from SMEs showed the decisive role of RENATECH facilities in the development of their R&D innovative projects. The programme also included the presentation of the scientific highlights of the network in its main research domains (nanophotonics, nanobiomicrosystems, spintronics and nanoelectronics). A round table session followed by a fruitful discussion was organised with the representatives of authorities of both national and European levels: the representatives of the CNRS and CEA direction, the French Ministry of Research, the French national Research Agency and the European Commission. Some important question were also raised, namely covering of the scientific fields which are not largely served by the facilities, closer cooperation with SMEs and start-ups, European enlargement and further development.

RENATECH annual Users' Meetings become indispensable for the R&D community, covering the interdisciplinary field like nanoscience whose success depends on a dialogue between diverse scientific approaches and an intense circulation of ideas.

# Specific technological tools

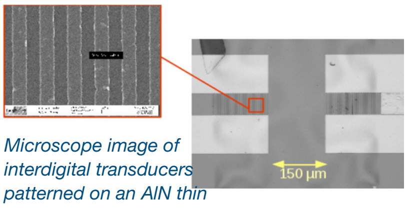
## AlN Sputter Deposition

The Mimento Technology Centre recently acquired a Sigma 200 PVD cluster system. This system was initially designed as an advanced metallization tool for the fabrication of different kinds of products requiring extremely precise layer thickness control.



*SEM image of an AlN thin film deposited atop a Ti/Pt seed layer.*

The Sigma 200 PVD cluster is a multi-chamber, fully-automated system. A robotic arm allows extracting a wafer from a pre-loaded cassette and transferring it to the selected process module for processing before returning it to the cassette. The system available at MIMENTO is composed of 3 process chambers:




*Microscope image of interdigital transducers patterned on an AlN thin film. The inset shows an SEM image of 500 nm wide transducer fingers.*

- a Hot Sputter Etch module consisting in a platen etch and an ICP coil is used to clean the wafer and to heat it up to desorb moisture prior to layer deposition,
- two Sputter Deposition modules, one for titanium or aluminum deposition, the second dedicated to aluminum nitride deposition.

This machine is especially used to provide piezoelectric aluminum nitride (AlN) in order to fabricate acoustic devices such as Bulk Acoustic Wave resonators.

The growth of piezoelectric AlN usually requires the use of a seed layer. We have chosen to work with the two materials the most commonly reported in the literature, namely Pt and Mo, both deposited on a Ti adhesion layer. As only 3 modules are available in the Sigma cluster, we have to use another sputtering machine to deposit the seed layers. The AlN deposition is performed at 400°C by means of a 16-inch target of Al (99,99 % purity) using a pulsed direct current generator and an equilibrated rotation magnetron. The sputtering DC power, the bias power, the deposition pressure and the Ar/N2 ratio are critical parameters to obtain AlN with good piezoelectric properties.

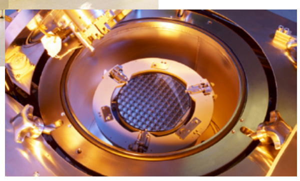
X-Ray Diffraction (XRD) analyses have been performed on different kinds of samples and show a (002) orientation which is typically the orientation of piezoelectric AlN. The (002) peak, at 36,02° in the Bragg-Brentano mode (θ/2θ), is the only one we can see in the spectra. It is a high intensity peak, with a FWHM less than 0.17°. The Rocking Curves present values ranging from 1.73° to 2.22°, which indicates a high piezoelectric performance.

The produced AlN thin films have been used in the frame of the European Project TAILPHOX in order to fabricate electrically-pumped phonon sources operating at a frequency of a few GHz. AlN was deposited on 400-nm thick silicon membranes and interdigital transducers were subsequently patterned on the piezoelectric film by electron beam lithography. Preliminary characterizations of the electro-acoustic transducers have demonstrated the possibility to excite and detect Lamb waves propagating through these thin Si slabs at frequency as high as 4.8 GHz.

Contact : Jean - Yves Rauch, jyves.rauch@femto-st.fr
Emilie Courjon, emilie.courjon@femto-st.fr

## Aligner (MA8) and Substrate Bonder (SB6)

The equipment is composed of a bond aligner (without the light box) and a substrate bonder.



*Substrate Aligner*
*Substrate Bonder*
*Universal transport fixture*

The bond aligner aligns wafers and substrates of various sizes up to 8 inches. The alignment method used is bottom side alignment (BSA) which permits alignments up to 1µm.

A standardized wafer transport fixture with features automatic clamping and spacers for gap control allows an easy transfer from the bond aligner to the substrate bonder and ensures that alignment is maintained through to final bond.

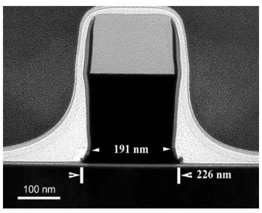
The substrate bonder is configurable for 6 inches to small pieces and stack thicknesses up to 6 mm. It supports various types of bond processes like anodic, fusion, eutectic, thermo compression…

A unique gate valve type load/unload port minimizes chamber exposure to the atmosphere and eliminates chamber contamination. Independent temperature control of top and bottom wafers compensates for different thermal expansion coefficients. The bond chamber supports both vacuum and pressurized ambient. The tool provides an optimized bond force uniformity achieving a maximum bond force of up to 20 KN. These facilities will complete all the resources in packaging and allow the development of this technology for topics such as MEMS in general and in particular RF MEMS, power electronic components, micro fluidic, etc. In particular, we wish to establish hermetic seals for different areas such as pressure sensors .

Contact: Dilhan Monique, dilhan@laas.fr
Colin David, colin@laas.fr
Charlot Samuel, charlot@laas.fr

# Recent technological realizations

## III-V MOSFET for Ultra low power applications

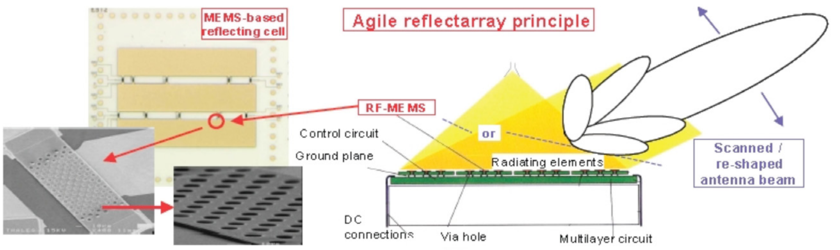



*MOSFET InGaAs 200nm*

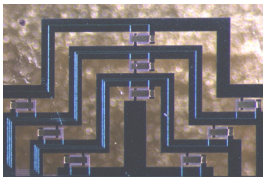
For ultra low consumption applications, N-channel InGaAs MOSFET working in inversion mode has been developed. InGaAas material offers mobility more than ten times Silicon (higher than 10 000cm²/Vs), and is a future alternative material to silicon according to ITRS. Al2O3 oxide is realized by Atomic Layer Deposition. We used a self aligned implantation wells, sidewall technology and gate length down to 200nm (figure 1). State of the art fT of 110GHz is obtained. Further works are focused on improvement of oxide quality and use of InAs material (mobility up to 30 000cm²/Vs). This work is supported by the National Research Agency (ANR) called MOS35 (http://mos35.iemn.univ-lille1.fr/) and made in collaboration with CEA-LETI, CIMAP, IEF and OMMIC.

Contact :
Sylvain Bollaert, sylvain.bollaert@iemn.univ-lille1.fr

## MEMS-controlled reflectarrays antennas




*Principle of an agile MEMS-controlled reflectarray antenna*



*Reflect array cell with 18 MEMS*

Electronic reconfigurability of antennas pattern (beam repointing, adaptive radiation pattern) is very attractive for a lot of applications. Currently, only the active phased array antennas can access this reconfigurability, but with many disadvantages (high complexity, high weight, high consumption). These restrictions limit these antennas to low-volume applications as earth observation and military telecommunications.

Operators of mobile telecommunications, or satellite would strongly request this feature if it could be obtained at reasonable cost. They can add flexibility to systems, to increase the gain antenna toward the user while being less susceptible to interference.

MEMS-controlled reflect arrays antennas are a new solution which can fit all the requirements for mobile telecommunications. This solution is based on a planar array illuminated by a single primary source. This array reflects the incident wave with a phase shift using a phase law which can be controlled. The reconfigurability is achieved by changing the electromagnetic properties of the radiating elements by means of MEMS (Micro-Electro-Mechanical System) switches (Fig 1). These devices have the advantage of low consumption, low losses and ability to be manufactured at low cost by microtechnology techniques derived from micro-electronics.

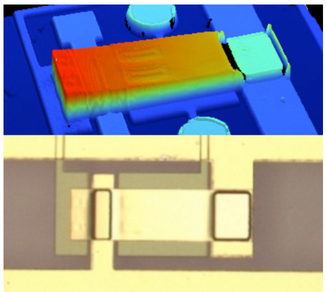
This innovative concept is studied in the framework of ANR-R3MEMS (2008-2011) project lead by Thales Alenia Space and in collaboration with three laboratories (LAAS, LIRMM, IETR) and three companies (HCM, NOVAMEMS and EPSILON).

The MEMS technology, based on capacitive contact, has been developed at LAAS platform. In order to achieve the requirements, a specific process has been studied, using :

- Fused silicate substrate to obtain low substrate losses,
- Polysilicon buried interconnections for MEMS actuation,
- 3µm thick gold patch antenna to achieve low metallic losses,
- 0.3µm thick silicon nitride for the capacitive contact,
- 2.5µm thick polymer sacrificial layer,
- 2µm thick gold cantilever

All the technological steps have been optimized with strong interaction with mechanical and RF designers. The main technological improvements were focused on the optimization of the capacitive contact quality.

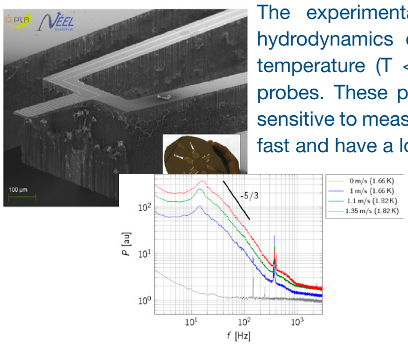
Technological, mechanical, BF and RF tests structures have been fabricated and tested to qualify the process (Fig 2). Even if the capacitive contact reproducibility is still too low for a prototype fabrication, the technological improvements have allowed to launch a demonstrator fabrication with 256 reflect array cells, including each 4 MEMS. A run with 18 wafers is ongoing and the delivery is scheduled for the end of June 2011.



*MEMS unit after cantilever fabrication*

Contact :
Patrick Pons, ppons@laas.fr

## Local velocity probe for cryogenic helium




The experimental study of superfluid turbulence, i.e. the hydrodynamics of strongly stirred liquid helium at very low temperature (T < 2.17 K) requires specifically designed local probes. These probes need to be both very small and highly sensitive to measure the small scale velocity fluctuations that are fast and have a low amplitude.

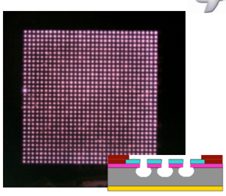
To do this, we designed a cryogenic velocity probe based on a cantilever. The sensitive element of the probe is the cantilever tip (300 µm long, 100 µm wide, 1 to 10 µm thick), etched in a bulk silicon wafer using fluoride Deep Reactive Ion Etching. This tip is immersed in the bulk of a flow and gets deflected by the incoming fluid. The amplitude of this deflection is proportional to the square of the flow velocity in the vicinity of the cantilever tip. A precise measurement of the deflection fluctuations is achieved using a radio-frequency superconducting niobium LC resonator sputtered on the tip whose resonance frequency shifts when the cantilever is elongated.

This technique disallowed the presence of any disordered dielectric materials on the sample because they would lead to phase noise of the LC resonator. This excluded us from using an oxide barrier layer. Therefore we had to devise a way to properly tune the thickness. We used the etching machine refrigerating helium leak rate as a progress indicator.

The first prototype has been cooled down and tested recently and showed good performances, similar to these of the best probes known to work in superfluid helium, and we believe that we can improve them even further in a near future.

Contact : Cryogenic Hydrodynamics Team, Institut Néel, CNRS/UJF (per@grenoble.cnrs.fr)

## Arrays of microplasmas spatially confined in silicon micro-cavities.




Microplasmas are of interest for many applications in various areas such as radiation sources, environmental analysis, local processing, MEMS, µTAS, … The utilization of microfabrication techniques used for semiconductor processing appears judicious to create silicon microcavities to confine plasmas at atmospheric pressure. We have designed a process flow to realize arrays of microcavities in silicon. They consist of two electrodes (one in silicon and the other in nickel) separated by a thick (few microns) SiO2 layer (see figure). The fabrication part of this project is performed at IEF. Nickel is electrodeposited. Cavities are formed by plasma etching of SiO2 and Silicon. The nickel is also used as a hard mask to etch the structure. Different cavity diameters were tested from 25 to 150 µm. Ignition experiments were carried out in Helium at different pressures from 100 to 1000 torr. An example of a 1024 microdischarge array (100 µm diameter holes) is shown operating in DC regime in helium (350 torr). Characterization of the plasma is carried out at GREMI using spectroscopy and electrical diagnostics. This work is financially supported by the French National Research Agency (ANR) through the contract n°ANR-09-JCJC-0007-01 under the name SIMPAS project.

Contact: Remi Dussart, GREMI Orleans,
remi.dussart@univ-orleans.fr

## Self-scrolling thin-film nanotechnology for three-dimensional helical nanobelts

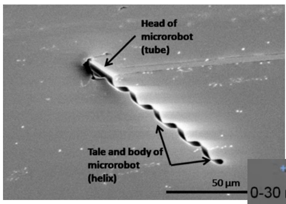



*Fig.1: Three-dimensional helical nanobelts (photo SEM)*

Three dimensional (3-D) nanostructures have wide potential applications to nanoelectromechanical systems (NEMS) and flexible nanoelectronics. However the fabrication of thin-film and NEMS process are the major challenges to realize such structures.

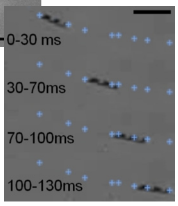



*Fig.2: Remote actuation of HNB swimmer*

LPN has recently developed the self-scrolling nanotechnologies using thin-film crystal growth such as molecular beam epitaxy (MBE) and (MOCVD) which are both available in LPN. 3-D helical nanobelts (HNBs) with 20 nm thickness bilayer III-V compounds have been realized (Figure 1) for their wireless actuations in liquid environment and large range force sensing applications. There have been key technological steps of thin-film growth technologies like MBE and MOCVD to grow 20 nm InGaAs/GaAs bilayers to achieve the strain engineering of such films. Then high-resolution lithographic patterning, isotropic etching, release by under-etching the sacrificial buffer layer and careful drying were followed. Additional metallic and semiconductor and dielectric layer depositions have also been realized to the surface of HNBs using proper and available technologies in LPN.

As an example, these thin-film 3-D helical nanobelts were demonstrated as wireless actuators to overcome the low Reynolds number physics in the liquid environment by mimicking bacteria flagella propulsion (Figure 2). Compared to other existing artificial swimmers, the electro-osmotic propulsion of HNBs recently demonstrated the highest efficiency and performance. Their swimming performance (24 times body length per second) is now comparable to the e. coli bacteria propulsion.
We are currently further studying their swimming inside micro and nanofluidic channels in the team of nanoflu of LPN.

Contact: Gilgueng Hwang, hwang@lpn.cnrs.fr

# Events

## RENATECH at MNE 2011 in Berlin

Strengthening its position at European micro and nanotechnological landscape, RENATECH will be present as an exhibitor at the 37th International Conference on Micro and Nano Engineering (MNE 2011) which will be held on September 19-23 in Berlin. The conference which brings together about 700 engineers and scientists from all over the world to discuss recent progress and future trends in the fabrication and application of micro and nano structures and devices is an excellent opportunity for RENATECH to raise international awareness of the French top-level infrastructure.

RENATECH welcomes at its facilities international academic and industrial users providing the open, interdisciplinary, hands-on environment that enables them to use the advanced instruments of nanotechnology to bring their ideas to fruition.

## Next NANO-TEC Workshop

**«Benchmarking of New Beyond CMOS device /design concepts»**
**13-14 October, Athens, Greece.**

The objectives of FP7 NANO-TEC Project <www.fp7-nanotec.eu> are: to identify the next generation emerging device concepts and technologies for ICT as well as to build a joint technology-design community to coordinate research efforts in nanoelectronics.
Its tentative program is available on line <www.fp7-nanotec.eu/node/473> and the registration is open.

For more information contact Elena Hoffert: Elena.Hoffert@cnrs-dir.fr

# 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
Contact: mimento@femto-st.fr

IEF technological facility
Contact: ctu@ief.u-psud.fr

LAAS technological facility
Contact: plateformertb@laas.fr

LPN technological facility
Contact: centrale-techno@lpn.cnrs.fr

PTA technological facility
Contact: accueil@pta-grenoble.com

2.The application will be worked through and evaluated by the reception team at each facility.
3. Realize your project
For further information concerning RENATECH newsletter contact: Elena.Hoffert@cnrs-dir.fr

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