RENATECH
French national nanofabrication network

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Newsletter

March 2013

Sommaire

RENATECH: science meets application

RENATECH French national nanofabrication network has been pushing the frontiers of nanofabrication forward for more than 10 years. Transcending the traditional subject boundaries of physics, chemistry, engineering, biology and earth science, our work is highly interdisciplinary and has established a number of world records in nanofabrication technology and device performance.

RENATECH provides research institutes and companies not only access to the advances capabilities and expertise existing within the network but also nanofabrication solutions delivered through its state-of-the-art technological facilities.

Strengthening its effort in openness to the socio-economic world, RENATECH is actively participating in the most important European and international events in the field of micro-and nanotechnology, such as SEMICON Europa in Dresden (2012) and Nanotech in Japan (2013). These events have been consistently recognized as the global platforms for nanotechnology, the enabling technology for leading edge manufacturing and the premier venues to reach the global semiconductor, photovoltaic and flat panel display industries. On purpose of industry development, these events boost every form of joint research and business partnership by public and private sectors. For RENATECH they represented ideal platforms for development of interdisciplinary collaborations and creation of new partnership. To encourage the interactions between research and industry, RENATECH participated at the events with its presentations providing useful and relevant information on the technologies developed at its facilities and the direction where this development is going. These actions have brought their fruit already last year when RENATECH dedicated about 40% of its technological activities to external projects, 13% of them represented collaborations with industrial partners.

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Specific technological tools

LAAS

Atomic Layer Deposition System

The equipment, a Cambridge Nano Tech – Fiji machine is an Atomic Layer Deposition (ALD) system.
It consists on a stainless steel chamber connected to several items: A vacuum system (Turbo and primary pumps), a reactive species and gases cabinet and a load lock.
The species are metal organic products. Gases can be directly injected in the reactor or can be first ionized using induced coupled plasma generator equipment.
The wafer holder in the reactor can reach a temperature of 500°C. Wafer up to 8" of diameter can be processed in this equipment. There are 5 metal organic lines, one H_2O line and 5 gases lines (O_2, N_2, Ar, NH_3, H_2) available in the gas cabinet in order to do the following material depositions: Al_2O_3, HfO_2, TiO_2, TiN, Pt and Ru.
Standard processes are made by using several sequences of different steps of metal organic injection, purges, pumping, gas or water vapour injections.
The deposition rate is around few nm per minute.

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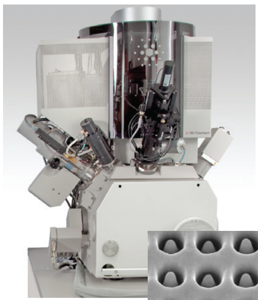
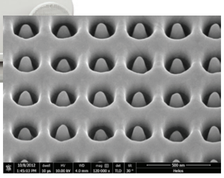
femto-st SCIENCES & TECHNOLOGIES

Ultra high resolution dual beam SEM/FIB



The equipment is a Helios NanoLab 600i from FEI company. It mainly consists of two columns which converge to one point, where it is possible to image, mill or deposit materials, alternatively or at the same time.
The electron column (SEM – Scanning Electronic Microscope) is composed of a field emission gun and an ultra high resolution immersion lens. The better achievable resolution is 0.9 nm at 15 kV and 1.4 nm at 1 kV. The ion column (FIB – Focused Ion Beam), tilted to 52° relatively to the SEM column, allows to mill the substrate thanks to the generation of high powerful Ga+ ions with a resolution up to 2.5 nm at 30 kV. The piezo-driven stage is suitable for wafer size up to 6 inches.



Enhanced transmission of light through coaxial nano-structures in a silver film (Nano optic team / FEMTO-ST)

The system is also equipped with :
- 2 GIS (Gas Injection System) units for enhanced etch of metallic and insulator substrates
- 2 GIS for Platinum and SiOx local deposition
- a FIB charge neutralizer in order to mill without conductive layer on insulators
- "auto slice and view" for automated sequential mill and view to collect series of slice images for 3D reconstruction

To be fully compatible with the other cleanroom process (navigation on a gds file, overlay…) and to automate long milling process (drift correction, stitching…), a Raith Elphy Multibeam has been connected to the system. It can command the electron beam and the ion beam thanks to a router.
The main applications of the dual beam at FEMTO-ST are nano photonic, micro-nano acoustic and NEMS - MEMS characterization, but this very versatile and powerful dual beam could find applications in different fields such as 3D reconstruction of a part of an interested stone or electronic circuit correction.
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LTM

The Primaxx Monarch 3 system: a HF vapour phase etcher

The Primaxx Monarch 3 System is a single process module tool for controlled HF vapor phase etching. The Monarch 3 Process Module is able to process up to three substrates of the same size at one time (100 mm in diameter). Wafers are loaded via a semi-Auto Wafer Loader. The Primaxx Monarch 3 Module performs a vapor phase; selective, isotropic etch on sacrificial oxide to "release" membranes or other structures. No liquids are used in contact with the MEMS devices; therefore "stiction" creating conditions are avoided. The Primaxx HF Vapor process uses reduced pressure, gas phase, anhydrous HF and Alcohol to etch sacrificial SiO_2 for MEMS release processes in a non-polluting, vacuum based system. A clean, residue free release etch is accomplished without the use of liquids or supercritical drying.

By avoiding Liquid Phase etching, byproducts are removed in the gas phase, preventing contamination and "stiction." Processes including Wet Etch and Super Critical Dry are replaced by this low cost of ownership technology.
The HF Vapor process provides a wide range of etch selectivity for differing oxides; thermal oxide has the lowest etch rate followed by CVD TEOS, Plasma TEOS and then BPSG. Selectivity and etch rate are optimized by varying the temperature, pressure and HF/Alcohol ratio (etch rate in the range of a few nm/min to a few tens nm/min). With the versatile control software, a variety of process recipes can be established for programmable variable etch conditions. Optimized etch rates are both oxide type and structure dependent.

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Recent technological realizations

iemn

Reaching the "super wifi" using ingaas/inp photomixers

We have demonstrated a data transmission in sub-millimeter waves (carrier frequency at 400 GHz), with a data rate of 22 Gbit/s (= 400 x WiFi) using THz generation with devices realized within the IEMN technology facilities (epitaxy: X. Wallart team – technology: M. Zaknoune and A. Beck). These components are based on InGaAs/InP unitraveling carrier photodiodes which were introduced to go beyond the bandwidth limitations of conventional PIN photodiodes. As they are compatible with 1.55 µm optical feeding signals, already widely used in optical fiber local and core networks, these results are a first step to reach a THz "hotspot" to relay optical fiber data rate to wireless ones, to give to end-user huge data rates.

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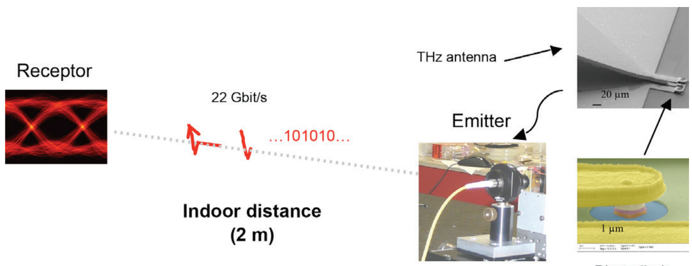

A novel method based on AFM for line edge roughness (LER) measurement

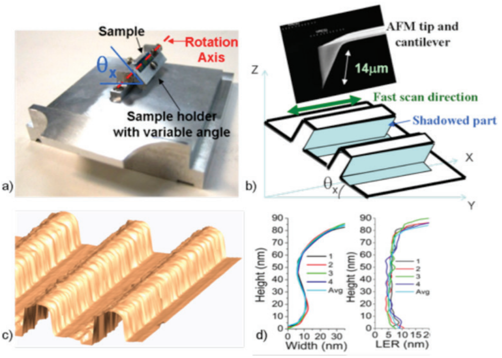

Fig. 1. Experimental set-up: a) variable angle sample holder, b) scan direction with respect to the features, c) 3D AFM image of photoresist pattern after data processing, d) Half-profiles and LER values as a function of the pattern height calculated from 3D AFM image.

Line Width Roughness (LWR) or Line Edge Roughness (LER) is considered today as a factor limiting CMOS downscaling. Indeed, no technological solution is currently known to reach the 1.7nm gate LWR required for the sub 20nm technological node. The origin of the LWR/LER of the final transistor gate is mainly attributed to the significant roughness of the photoresist (PR) pattern printed by the lithography step, which is partially transferred into the gate stack during the subsequent plasma etching steps. No accurate and convenient metrology tools for LWR/ LER evaluation are available. Both CD-AFM and CD-SEM, the two commonly used metrology tools in the industry, fail in LWR determination at the very bottom of structures, where the key information on LWR lies.

LTM has developed a novel method based on AFM to measure LER all along the pattern sidewalls. In this technique, a sample comprising an array of features is placed on a holder that can be rotated from 0° to 90° with respect to the AFM probe; the features being parallel to the axis of rotation (cf. Figures 1a and b). For aspect ratio constraints and sticking issues, an angle of 45° is typically used. The small radius of curvature of the tip together with the low noise level of a laboratory AFM result in high resolution images. Half profiles and LER values on all the height of the sidewalls are extracted from the 3D images using a procedure that we developed (cf. Figures 1c and 1d). This technique is particularly adapted to measure LER accurately down to the bottom of features and moreover, the sidewalls of any types of profiles (anisotropic, tapered or re-entrant) can be imaged by adapting the sample rotation. It presents a great potential to better understand the mechanism of LER transfer during gate stack patterning. However, it also has some limitations. The main one is that only one side of the pattern can be imaged (cf. Fig. 1b). Thus, no information on the critical dimension nor the linewidth roughness is obtained. Another drawback is that the tip cannot enter in very dense patterns. Finally, the technique cannot accommodate full 200 or 300 mm wafers.
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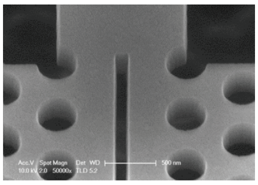
Cavities in diamond photonic crystals for chemical sensing



SEM close view of the fabricated slotted photonic crystal in polycrystalline diamond with a 135-nm wide slot and its access waveguide.

Diamond is an attractive material for integrated photonics. Indeed, diamond surfaces can be functionalized for fabricating highly stable and selective biological interfaces, a property that is particularly desirable for the realization of optical biosensors. Particularly, photonic crystals have gained attention. The fabrication of diamond photonic crystal cavities for optical detection purpose using the equipment of the technologies facility CTU-MINERVE of the IEF is here reported.
Nanocrystalline diamond films with a thickness of 400nm were deposited on two inches Si (100) wafers using chemical vapor deposition assisted by microwave plasma. Diamond growth was made at LCD-LIST. However, the surface roughness of the 400-nm thick diamond film is around 10 nm with a peak to valley roughness that can reach 80 nm. This roughness prevents the use of electronic lithography technique and the achievement of high quality factor cavities due to the strong scattering at the surface.
A new method to smooth the diamond layer was developed at the IEF, which relies on the use of an argon/oxygen plasma etching. A 200-nm thick hydrogen silsesquioxane (HSQ) layer is first spun coated on the rough polycrystalline diamond layer and baked on a hot plate. This results in a smooth surface silica-like layer on top of the sample. The layers are then etched using an inductively coupled plasma (ICP) reactive ion etching with oxygen and argon gases. A 360-nm layer of smooth diamond is finally obtained. Silica residues are removed in hydrofluoric acid. The root mean square (RMS) roughness can be less than 1 nm on a 10x10 µm² area, with a peak to valley roughness below 10 nm.

From this, the realization of diamond photonic crystals is now possible [1]. A thin layer of silicon nitride is first deposited by plasma enhanced chemical vapor deposition on the top of the smoothed diamond layer. Then, electron-beam resist is spun coated on the nitride layer. The photonic crystal and the access waveguide are patterned in the resist using a 100kV Nanobeam NB4 electronic lithography. Using successive etchings, the pattern is transferred from the resist to diamond. SEM observations have shown that the resulted holes angles are less than 3°. Finally, photonic crystal cavities with Q factor as high as 3400 are reached.

This work was presented at the MRS Boston 2012 Conference (Candice Blin1,2, H. A. Girard1, N. Cazier2, C. Gesset1, S. Saada1, X. Checoury2 and P. Bergonzo1) and a paper is in preparation.
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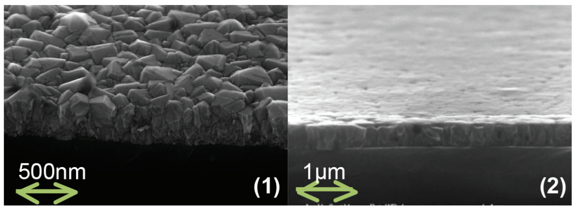
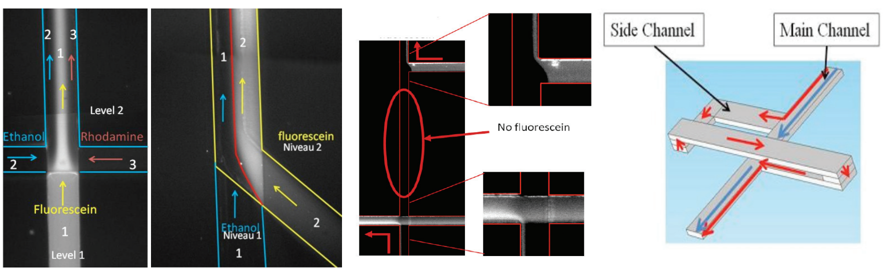


SEM view of a polycrystalline diamond layer (1) before and (2) after the smoothing process

Multilvel (3d) microfluidics as a new route toward advanced functionnalities



The left panel shows laminar streams co-flowing in 3D different configurations in order to perform multicomponent reactions. The right panel shows the cheme of the "add-and-drop" device and a general view and details of flows in the add-and-drop device : extraction of the 10% of fluorescein flow from the left side of the channel and re-injection on the opposite side. All channels are 100µm wide, 25µm deep.

The possibility to implement basic microfluidic functions, as mixing, focusing, separation, by using only fluids hydrodynamic properties has been extensively demonstrated. However, in most cases, approaches rely on 2D fluid engineering. This limitation is mainly due to the fabrication process currently used which allow the easy patterning of planar microfluidic designs but are not well adapted to complex 3D network architectures. Multi-level technologies have already proved their potential and their efficiency through some recent works. The size of devices is drastically reduced and, more relevant, a wide range of lab on chip central functions can be implemented.
The lamination of UV sensitive dry films appears as a performing way to overcome these limitations. As previously reported, we propose a generic method based on roll lamination of photosensitive films. Notably, this technique enables a fast, simple and robust level by level fabrication with excellent alignment accuracy on a wide range of hard or flexible substrate. Interestingly, this manufacturing technology opens up the possibility to explore and exploit the properties of 3D flows. Major applications could be find in chemical engineering for the study of kinetics involving 3 or 4 reagents, or may be an elegant solution for particles exchange between several flows. To demonstrate the variety and complexity of flow lay-out that can be achieved we designed two types of devices. With the first one we explored the capability of engineering multicomponent reaction devices while with the second one we demonstrated laminar flows add-and-drop in microfluidic channels. Such geometries are highly interesting to study kinetic with 3 or 4 reagents in chemical applications, or may be the place for particles exchange between several flows in biological or environmental lab on chip.
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Photonic crystal mirrors for optomechanics

Optomechanics deals with the interaction of light with a mechanical oscillator. It uses the coupling between light and the geometry of a mechanical oscillator to read or tailor the mechanical motion of the oscillator. Optomechanical coupling can be enhanced by use of an optical nano-cavity that enhances the optical power experienced by the mechanical oscillator.

One conventional optomechanical configuration consists of a miniature Fabry-Perot cavity with a movable mirror (while the other mirror is massive enough to be static). The ideal movable mirror shall combine low mass, high mechanical quality factor and near-unity reflectivity. In collaboration with Laboratoire Kastler Brossel, LPN has developed a low-mass photonic-crystal slab mirror consisting of a 260 nm-thick InP suspended membrane pierced by a square lattice of holes, thus forming a >95% high-reflectivity mirror operating at normal incidence over a broad spectral range (~ 60 nm around 1,064 µm). Such a membrane also sustains mechanical drum modes in the MHz frequency range, with mechanical quality factors up to 104 at low pressure and room temperature.

This photonic-crystal membrane forms one end mirror of a miniature 100 µm-length Fabry-Perot cavity constructed in vacuum, the second mirror is a 200 µm radius of curvature curved mirror coated with a high-reflectivity (98,6 %) dielectric Bragg mirror. Reflection of light is very sensitive to changes in the cavity length, with a sensitivity up to 10-17 m.Hz-1/2. Such a sensitivity is four orders of magnitude larger than the Brownian motion amplitude of the membrane fundamental mechanical mode at 300 K, allowing us to observe the Brownian motion of internal modes of the photonic-crystal slab mirror. These results open the way to the experimental demonstration of the resonator ground state, by performing cryogenic and laser cooling of the membrane.
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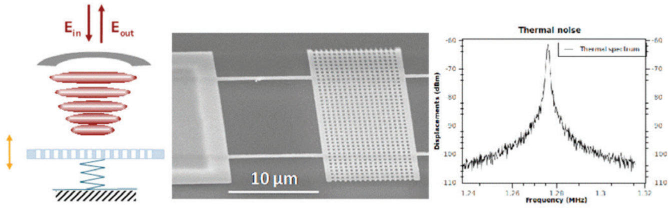

left. Schematics of the optomechanical Fabry-Perot cavity. Center. SEM image of a free-standing InP membrane pierced by a square lattice of holes and acting as mirror at normal incidence. Right. Phase noise spectrum of the reflected field (the peak reflects the Brownian motion of the resonator at room temperature).

Events

RENATECH users' information day

29 march 2013, 10h – 16h, at all RENATECH facilities

The annual users' information day has become the traditional event for the academic and industrial micro- and nano-technological community. As in 2012, this year manifestation will embrace the whole French territory and will be organised on the same day at all the laboratories of the large technological facilities. Thus the participants will have an opportunity to know better the network facilities which are located in their regions and to visit the clean rooms. Close interactions with the local actors of the large technological facilities will provide an excellent opportunity to establish new contacts and to learn more about the procedures of project submission ant its realisation in the network.

IEF and LPN facilities will welcome their users at IEF laboratory in Orsay, IEMN - in Villeneuve-d'Ascq, FEMTO-ST – in Besançon, LAAS – in Toulouse, LTM and CEA LETI – in Grenoble.

To participate at the users' information day, please confirm your participation directly at the technological facility of your choice.

JNTE 2013

Journées Nationales sur les Technologies Emergentes en micro-nanofabrication / French Symposium on Emerging Technologies for micro-nanofabrication

21 – 23 May 2013, Evian

The symposium will focus on emerging technologies for micro-nanofabrication, from fundamental to complex integration techniques. It will bring together all laboratories involved in this research field from different disciplines, and with different domains of applications. First RENATECH prize will be awarded during this symposium for the prominent thesis dissertation in the field of micro and nanotechnologies. The call for proposals as well as further information can be downloaded from the following link:
http://jnte13.lpn.cnrs.fr/index.php?Renatech=1

To perform your project with RENATECH network

1.Contact RENATECH network via:

Unique gateway: **http://www.renatech.org/projet/**
or contact directly one of RENATECH facilities to discuss your project:

IEMN technological facility
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FEMTO-ST technological facility
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IEF technological facility
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LTM technological facility
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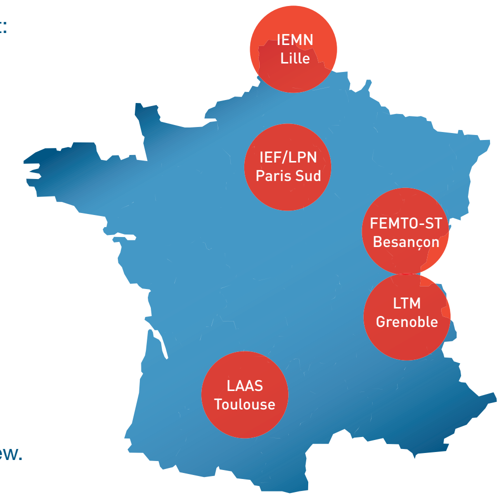

2. Project feasibility will be evaluated from a technological point of view.

3. Your project will be implemented within the network.

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