Nanofabrication capabilities at IMT Bucharest: techniques and devices

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IMT- Bucharest

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- **Founded:** 1993
- **Personnel:** 181-total; 110 in research activities.
- **10 R&D laboratories**
- **One user facility – IMT- MINAFAB** - cleanroom with 220 m² at class 1000, 130 m² at class 10.000, 200 m² at class 100.000, 200 m² at class 1000 under construction.
Furnaces, RTP, CVD, PECVD, PVD, DWL, RIE, DRIE, wafer bonding, etc.
Ellipsometry, NSOM, WLI, micro Raman and TERS, XRD, SECM, FTIR, on wafer probing stations, network analyzer
International Joint Sinano/Nanofunction/New Member States-Eastern Europe/ENI2 Workshop

11 April 2013, Kyiv, Ukraine

“Advanced process and device integration and innovative nanofunctions in Nanoelectronics”.

Nanoscale Structuring and Characterization Laboratory

Raith - e_Line - dedicated EBL equipment

Nanoink Nscriptor - DPN

NT-MDT Ntegra Aura - AFM & STM

Tescan Vega LMU II - SEM

FEI Nova NanoSEM630 - FEG-SEM

Agilent G200 - Nanoindenter
Electron Beam Lithography equipment in IMT Bucharest

First EBL equipment in IMT - Tescan Vega LMU II and Raith Elphy Plus – installation 2006
Smallest beam diameter: 5nm @ 3pA beam current and 30kV

Raith e-Line – installation 2008
Smallest beam diameter: 1.5nm @ 200pA

- 30nm diameter holes in PMMA 950k
- 150nm
- 10nm diameter holes in PMMA 950k
Temescal FC 2000 is a clean-room compatible, bell-jar shaped, load locked PVD system equipped with both e-beam ant thermal evaporation sources.

Interdigitated electrodes with <100nm width, fabricated by e-beam lithography and highly directional metal evaporation of 10nm Cr and 100nm Au.
Acoustic devices for GHz applications

Acoustic resonators

**FBAR**

**SAW**

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A. Muller, D. Neculoiu, G. Constantinidis, G. Deligeorgis, A. Dinescu, A. Stavrinidis, A. Cismaru, M. Dragoman and A. Stefanescu,


D. Neculoiu, A. Müller, G. Deligeorgis, A. Dinescu, A. Stavrinidis, D. Vasilache, A. Cismaru, G. E. Stan and G. Konstantinidis,


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**SAW devices for microwave applications (1)**

**AIN/Si**
- Deposition by magnetron sputtering
- Sound velocity 6000 m/s
- Coupling coefficient -6%

**GaN/Si**
- Deposition by MBE and MOCVD
- Sound velocity 5000 m/s
- Coupling coefficient -2%
- Monolithic integration with HEMT transistors is possible

Collaboration IMT Bucharest – FORTH IESL Heraklion, Grece

International Joint Sinano/Nanofunction/New Member States-Eastern Europe/ENI2 Workshop “Advanced process and device integration and innovative nanofunctions in Nanoelectronics”.

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SAW devices for microwave applications (2)

- GDSII layout for contact pads and alignment marks
- Wafer patterned with Cr/Au contact pads
- GDSII layout of the IDTs
  
  Photolithography
  - Cr/Au Metallization
  + Lift off

- Detail of Ti/Au nanoelectrodes
- SAW resonator after metallization and lift off
- IDTs patterned in PMMA 950k

EBL
SAW devices for microwave applications (3)

Resonance > 5GHz on AlN


Best previous result obtained before was a SAW on AlN (but on diamond not on silicon) operating at 4.5 GHz [P. Kirsch et al. Appl Phys. Lett. 88, 223504, 2006]

A. Muller; D. Neculoiu; G. Konstantinidis; G. Deligeorgis; A. Dinescu; A. Stavrinidis; A. Cismaru; M. Dragoman; A. Stefanescu; “SAW Devices Manufactured on GaN/Si for Frequencies Beyond 5 GHz”

**IEEE ELECTRON DEVICE LETTERS** Volume: 31 Issue: 12
Pages: 1398-1400 (2010)
**SmartPower** - Smart integration of GaN & SiC high power electronics for industrial and RF applications. ([www.smart-power.com](http://www.smart-power.com))

Experiments to prove the concept of monolithic integration of MMIC and GaN T sensor.

SAW, single resonator; length 100 µm
IDTs, digit/interdigit spacing 0.2 µm;
Distance between reflectors and IDTs:
d = 0.95 µm;
IDT: 100 fingers/interdigits; reflectors
60 digits/interdigits
GaN/Si; GaN layer 1 µm thin
IDT and reflectors 0.1 µm thin Au

Sensitivity ~ 356.9 kHz/°C = 65 ppm/°C

\[ y = -0.0003569x + 5.469 \]
Exfoliated graphene

CVD graphene

Raman spectra of single and double layer graphene

SLG  2D  BLG

G    2D

Raman shift (cm\(^{-1}\))

Intensity (a. u.)

1 500 2 000 2 500 3 000 3 500 4 000

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IMT Bucharest
www.imt.ro
Array of 17 back gated field effect transistors on exfoliated SLG

The array of 17 BG-FETs on graphene ribbons

A back gated FET on graphene ribbon

The device under test, on the probing station

Back gate voltage (V)

Rds in the CNP vs irradiation dose (HV = 200V)
Similar behavior at 500V and 1kV

A. Dinescu, M. Purica, R. Gavrila, A. Avram, R. Muller, “Influence of low energy electron beam irradiation of graphene ribbon based back gated field effect transistors”, MRS 2012, April 9-13, San Francisco, USA
Plasmonic Nanostructure Enhanced Graphene-Based Photodetectors
**MSM photodetectors on silicon supported GaN membranes**

Schematic cross-section of the membrane MSM UV detector structure.

Top view of the detector

Detail of the interdigitated contacts

a) Responsivity vs wavelength for the 0.5µm finger/interdigit UV GaN detector before the silicon substrate removal.

b) Responsivity vs wavelength for the 0.5 µm finger/interdigit UV detectorst manufactured on thin GaN membrane.

Geometrical –induced rectification in two-dimensional ballistic nanodevices
Chrome on quartz masks for DUV photolithography.
Minimum line width - 300nm
Arrays of gold nanodots for Surface Enhanced Raman Spectroscopy -SERS

- Surface-enhanced Raman scattering (SERS) is a powerful microanalytical technique with several significant advantages for ultrasensitive chemical analysis and interfacial studies.
- It provides the high information content of vibrational spectroscopy (yielding a molecular “fingerprint”) while demonstrating detection down to the single molecule level.
SEM micrographs of various patterns with gold nanodots for SERS
Gold on silicon structures for AFM calibration: 5µm, 2µm, 1µm and 500nm pitch

Power spectrum of the Fourier transform of the AFM data
SEM micrographs showing platinum lines connecting a polymer nanowire to the electrical pads

L. Gence, V. Callegari, A Dinescu, S. Melinte and S. Demoustier-Champagne, “Hybrid Polymer nanowire based electronic devices correlated characterization” 14-th International Conference of Modulated Semiconductor Structures (MSS 14), 19-24 July 2009, Kobe, Japan

Structure used for electrical characterization of CNTs at high frequencies. EBL was used for patterning the small calibration line and EBID technique for fixing the CNTs.

Platinum deposition was used for fixing the CNTs across V-shaped trenches in order to measure their mechanical properties.
3D Electron beam lithography in mono-layer resists for μ- and n-optics

SEM micrographs of various DOE in SU8