Tehnici nanolitografice pentru fabricarea dispozitivelor nanoelectronice

Adrian Dinescu, IMT Bucuresti

Workshop “Parteneriat pentru inovare: cercetare – industria electronica”
Nanoscale Structuring and Characterization Laboratory

Raith e_Line - dedicated EBL equipment
Nanolink Nscriptor – dip pen nanolithography
NT-MDT Ntegra Aura AFM & STM
Tescan Vega LMU II
Thermionic (tungsten) SEM
FEI Nova NanoSEM630
FEG-SEM
Agilent G200 - Nanoindenter
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

~ 10nm diameter holes in PMMA 950k
Mix and match lithography: photolitography & EBL
Acoustic devices for GHz applications
Acoustic resonators

FBAR

SAW


18 October 2012
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
SAW devices for microwave applications (2)

GDSII layout for contact pads and alignment marks

Photolithography Metallization (Cr/Au) Lift off

Wafer patterned with Cr/Au contact pads

GDSII layout of the IDTs

EBL

Detail of Ti/Au nanoelectrodes

SAW resonator after metallization and lift off

IDTs patterned in PMMA 950k

18 October 2012
SAW devices for microwave applications (5)

Results 2009

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]
SAW devices for microwave applications (7)

**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**

\[ y = -0.0003569x + 5.469 \]

\[ Q = 400 \]
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.
MSM photodetectors on silicon

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

E. Budianu, M. Purica, A. Dinescu, E. Manea “Metal-Semiconductor-Metal photodetector on silicon insulating wafers based on nanoscale interdigitated electrodes”, EMRS Fall meeting 2009, September 14-18, Warsaw, Poland
EBL for graphene based devices


AFM image of the SLG
Equipment: NT-MDT N-Tegra Aura

Raman spectra of a few selected points of graphene flake used for FET fabrication
Substrate: p++ silicon, boron doped, resistivity 0.005 Ωcm, covered with 300nm dry thermal oxide
SLG areas surrounded by alignment marks
Patterned electrical contacts on graphene flakes

18 October 2012
CPW structures on SLG
E-beam lithography patterning of graphene flake

RIE etching (oxygen plasma) of graphene flake

Electron resist deposition

EBL exposure

RIE (oxygen plasma)

Electron resist removal

Cutting process for SLG

Electron resist

SLG

Silicon dioxide

Silicon
Electrical contacts for source and drain fabricated by e-beam lithography, metal evaporation (Ti/Au-5-30nm), and lift-off
Graphene ribbons

Pristine SLG

Graphene patterned for RIE

Patterning in the PMMA before metal coating

The structure with 20 transistors after lift-off

A back gated FET on graphene ribbon

Array of 17 back gated FETs on graphene ribbons

18 October 2012
The device under test, on the probing station


Rds (kΩ) vs Back gate voltage (V)

Rds in the CNP (kΩ) vs Dose (µC/cm²)

Rds in the CNP vs irradiation dose (HV = 200V)

Similar behavior at 500V and 1kV
EBID module

SEM micrographs showing platinum lines connecting a polymer nanowire to the electrical pads

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.