Evolutia IMT-MINAFAB:
centru de micro – si nanofabricatie

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IMT: Ziua Portilor Deschise,

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(versiune prescurtata)

Planul prezentarii

- Scurt istoric al dezvoltarii IMT-MINAFAB. *Conceptul de “centru deschis”*
- *Oferta actuala* a infrastructurii si dezvoltarea acesteia prin investitia CENASIC
- *Modul de functionare* al facilitatii IMT-MINAFAB
- *Evolutii pe plan national si european.* Concluzii, **propuneri pentru dezbatere ………**

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Scurt istoric

- In prima sa perioada de existenta (1993-1997) IMT-ul a gestionat linia de fabricatie a circuitelor integrate CMOS de la S.C. Microelectronica S.A., demarand cercetarile in “microtehnologii”.
- De la inceputul anului 1997, IMT dispune de un sediu propriu (dupa jonctiunea cu ICCE si transformarea in institut national), dar baza sa tehnologica este mult mai slaba, deorece nu mai are acces la linia CMOS.
- Ideea de a folosi tehnologia semiconductorilor pentru constructia de microsenzori – microsisteme s-a dovedit pana la urma inspirata: in PC 7, IMT a avut cea mai buna participare dintre institutele nationale, principala directie de cercetare fiind cea legata de micro- nanosisteme.

Primele investitii

- Primele investitii semnificative in INCD-Microtehnologie au avut loc abia in perioada 2005 – 2009
- In 2009 infrastructura a atins o masa critica si a fost infiintat centrul de Micro- si Nanofabricatie IMT-MINAFAB (de fapt o interfata intre infrastructura de cercetare si utilizatori)
- In 2011 s-a obtinut o certificare pentru calitate ISO 9001
- In prezent continua investitiile pentru realizarea centrului de cercetare CENASIC (cu finalizare in 2015). Din punctul de vedere al serviciilor, dotarile vor fi incluse in IMT-MINAFAB.
- Totalul sumelor investite in perioada perioada 2005-2015 este comparabil cu investitia in CETAL (circa 15 mil. euro).

Centru “deschis”

- Centru experimental (al unei entitati de cercetare) accesibil utilizatorilor din exterior (cercetare, educatie, industrie).
- Primul model (2004): Cornell NanoScale S&T Facility (CNF), Cornell University, Ithaca, N.Y.; finantare (2004-2014) prin *National Nanotechnology Infrastructure Network* (NNIN)
- IMT participa la o propunere de retea de facilitati experimentale in nanoelectronica, trimisa la o competitie din PC 7 (FP 7). Propunerea nu a fost finantata.
- IMT a creat in schimb IMT-MINAFAB, lansat (8 mai 2009) la Bruxelles, ca primul “centru deschis” din estul Europei in domeniul micro- si nanotehnologiilor A functionat in paralel cu EUMINAfab, finantat de CE prin PC 7
- IMT-MINAFAB a fost inclus (2014) in EUMINAfab 2, propunere de “retea avansata de nanofabricatie”.

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IMT-MINAFAB. Technical data

A short presentation of the most important components of the research infrastructure follows.

- A class 1000 clean room (220 m^2) for the mask shop and the most demanding technological processes (in use since September 2008)
- A class 100,000 clean room, the so called “Grey Area” (200 m^2), mostly for the characterization equipments (in use since September 2008)
- A class 10,000 clean room (105 m^2) for thin layer deposition by CVD techniques: LPCVD, PECVD; DRIE; RTP etc. (fully in use since early 2012). This facility will be incorporated into the new technological facility CENASIC.

- **Photolithography** (chrome, maskless, wafer double-side alignment and exposure)

  - Pattern generator - DWL 66fs Laser Lithography System (Heidelberg Instruments Mikrotechnik, Germany)

  - Double Side Mask Aligner - MA6/BA6 (Suss MicroTec, Germany)

- **Nanolithography (EBL, EBID, EBIE, Dip-pen) and SEM**

  - Electron Beam Lithography and nanoengineering workstation - e_Line (Raith, Germany)

  - Dip Pen Nanolithography - NSCRIPTOR (NanoInk, Inc., USA)

  - Field Emission Gun Scanning Electron Microscope (FEG-SEM) - Nova NanoSEM 630 (FEI Company, USA).

• **Physical depositions of materials in high-vacuum**

- Electron Beam Evaporation – TEMESCAL FC-2000 (Temescal, USA)
- Electron Beam Evaporation and DC sputtering system-AUTO 500 (BOC Edwards, UK)

• **Chemical depositions, thermal processi**

- PECVD - LPX-CVD, with LDS module (SPTS, UK)
- LPCVD - LC100 (AnnealSys, France)
- Rapid thermal processing/annealing - AS-One (AnnealSys, France)

• **Precision etching of materials** (plasma reactive ion, humid, shallow and deep)

- DRIE- Plasmalab System 100- ICP Deep Reactive Ion Etching System (Oxford Instruments, UK)
- RIE Plasma Etcher - Etchlab 200 (SENTECH Instruments, Germany)

- **X-Ray diffractometry**

  - X-ray Diffraction System (triple axis rotating anode) - SmartLab - 9kW rotating anode, in-plane arm (Rigaku Corporation, Japan)

- **Scanning probe microscopy: AFM, STM, SNOM, confocal, Raman mapping**

  - Scanning Probe Microscope - NTEGRA Aura (NT-MDT Co., Russia)

  - Scanning Near-field Optical Microscope, Witec alpha 300S (Witec, Germany)

- **Nanomechanical characterization**

  - Nanomechanical Characterization equipment - Nano Indenter G200 - (Agilent Technologies, USA)

• **Microarray spotting/scanning**

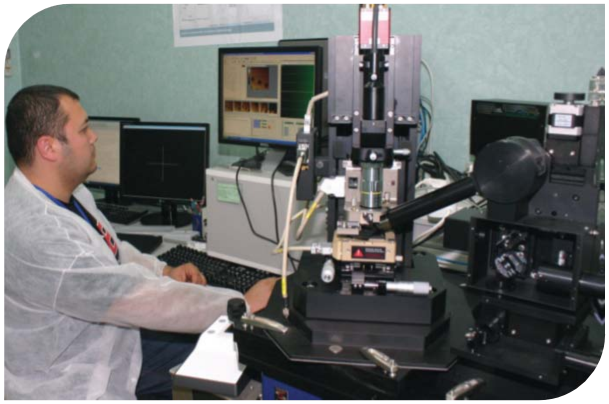
- Micro-Nano Plotter - OmniGrid (Genomic Solutions Ltd., UK)
- Microarray Scanner - GeneTAC UC4 (Genomic Solutions Ltd., UK)

• **Analytical characterization tools**

- Scanning Electrochemical Microscope
- ElProScan (HEKA, Germany)
- Zeta Potential and Submicron Particle Size Analyzer - DelsaNano (Beckman Coulter, USA)
- Fluorescence Spectrometer - FLS920P (Edinburgh Instruments, UK)

- **Interferometry/profilometry; Spectroscopy**

- High Resolution Raman Spectrometer - LabRAM HR 800 (HORIBA Jobin Yvon, Japan)
- White Light Interferometer - Photomap 3D (FOGALE nanotech, France), see next slide
- Electrochemical Impedance Spectrometer - PARSTAT 2273 (Princeton Applied Research, USA)



- Fourier–Transform Infrared Spectrometer - Tensor 27 (Bruker Optics, Germany)
- UV-Vis-NIR Thermo-Electric Cooled Fiber Optic Spectrometer - AvaSpec-2048 TEC (Avantes, The Netherlands)
- Refractometer for layer thickness measurements - NanoCalc-XR (Oceanoptics, USA)

• **Probers, on-wafer; electrical characterization**

- Semiconductor Characterization System (DC) with Wafer Probing Station - 4200-SCS/C/Keithley
- Easyprobe EP6/ Suss MicroTec (Keithley Instruments, USA; Suss MicroTec, Germany
- Semiconductor Characterization System - 4200-SCS, C-V 3532-50, DMM 2700-7700, 2002, 6211-2182 (Keithley Instruments, USA)
- Microwave network analyzer (0.1-110GHz) with Manual Probing Station (Anritsu, Japan; Suss MicroTec, Germany)
- Frequency Synthesizer up to 110 GHz (Agilent, USA)
- Spectrum Analyzer up to 110 GHz (Anritsu, Japan)

EUROPEAN UNION ROMANIAN GOVERNMENT STRUCTURAL INSTRUMENTS 2007-2013

Sectorial Operational Programme
“Increase of economic competitiveness”
"Investments for your future“
Project co-financed by European Regional Development Fund

Research Centre for Integrated Systems Nanotechnologies and Carbon Based Nanomaterials – CENASIC

a new research centre in carbon-based nanomaterials

Part of the existing clean room equipment for chemical deposition from the vapor phase in plasma and micromachining volume facility that will be built in the center CENASIC.

OpAL ™
Systems for thermal and remote plasma ALD

ALD Product Family

Oxford Instruments

Unique system benefits

- Remote plasma enables the widest possible choice of precursor chemistry and enables low temperature ALD processes while maintaining low damage.
- Fits in compact space of less than 1 x 1.5 m
- Integral ports to allow the addition of ellipsometry measurement tools.
- Optional glovebox surrounding top of tool for nitrogen purged loading of samples.

Unique precursor delivery system

- Precise precursor temperature control with fan-assisted oven
- Optimised heated delivery lines
- Precursor modules can be fitted to extraction lines for assured health and safety compliance
- Integral glove box on precursor modules for in-situ change-over
- Compatible with all standard bubblers from 20-200 g precursor fills.

Example applications

- High-k gate oxides
- Storage capacitor dielectrics
- High aspect ratio diffusion barriers for Cu interconnects
- Pinhole-free passivation layers for OLEDs and polymers
- Highly conformal coatings for microfluidic and MEMS applications
- Coating of nanoporous structures
- Fuel cells

OpAL thermal system with two precursor delivery modules

Photograph showing the precursor module door open

Magnetron Sputtering Deposition – PlasmaPro System400

Oxford Instruments Plasma Technology - AIMS Group

- Single chamber with up to 4 × 200 mm targets
- Deposit from 2 nm to 20 µm films
- Pulsed DC, DC or RF deposition
- Oscillation capability for thin, uniform films
- High vacuum for quality deposition
- Rotating shutter for target & wafer preparation
- RF bias for substrate cleaning
- Up to 4 gas channels for reactive sputtering
- Precise gas control for stoichiometry variation

System400 with lid open

Mode	Deposition rate	Uniformity
Static	65 nm/min/kW	< ± 15%
Oscillation	15 nm/min/kW	< ± 5%
Rotating	5 nm/min/kW	< ± 5%

Diameter of substrate	Uniformity 200 mm magnetron	Uniformity 150 mm magnetron	Uniformity 100 mm magnetron
100 mm	< ± 3%	< ± 5%	< ± 10%
150 mm	< ± 5%	< ± 10%	-
200 mm	< ± 10%	-	-

Property	Repeatability
Thickness	< ± 5%
Resistivity	< ± 5%
Reflectivity	< ± 5%

Plasma Enhanced Chemical Vapour Deposition (PECVD)

Oxford Instruments

Nanofab Systems

Nanofab700

- Controllable growth of nanotubes and nanowires with flexible temperature up to 700°C
- Compatible with a wide range of process gases including oxygen
- Plasma pre-treatment of the catalyst and chamber cleaning capability
- PECVD – Standard and high temperature deposition

Nanostructured materials:

C, Si, Ge, ZnO, Ga2O3, GaN, GaAs, GaP, InP, InN

PECVD Films:

SiO2, SiNx, a-Si, SiON, poly-Si, SiC

Nanofab800Agile

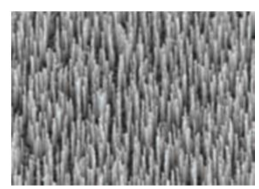
- Development opportunities exist to incorporate additional magnetic or electrical fields, to influence the growth of the nanostructures.
- Controllable growth of nanotubes and nanowires with flexible temperature up to 800°C
- Agile heating and cooling for rapid turnaround
- PECVD – Standard and high temperature deposition
- Electrode Features

– Fast cycle times: ramp rates up to 130°C/min

– Excellent temperature uniformity

– Low thermal mass

Si nanowires using Au nanoparticles as the catalyst



ZnO nanowires / Courtesy of Nanoscience Centre, University of Cambridge

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Cum functioneaza facilitatea?

- Primul motiv al unificarii ofertei de servicii este necesitatea ca dotarile experimentale sa poata fi folosite de catre toti cercetatorii din IMT.
  - Cvasitotalitatea echipamentelor noi au fost obtinute prin proiecte gestionate de catre laboratoarele de cercetare. Majoritatea acestor echipamente sunt deservite de catre cercetatori care fac parte din diverse laboratoare CD
  - Multe dintre aceste echipamente sunt amplasate in “spatii comune” gestionate la nivelul institutului (de regula in “spatii curate”, care dispun de diverse facilitati); ele sunt considerate “laboratoare experimentale” (locatii cu un anumit gen de dotari si nu colective de cercetare)
- IMT-MINAFAB este o interfata cu utilizatorii, asigurand:
  - Centralizarea si diseminarea informatiei legate de infrastructura
  - Aplicarea procedurilor de certificare a calitatii
  - Relatiile contractuale cu utilizatorii din afara IMT etc.

Ce fel de servicii se asigura pentru firme?

- Executie de servicii stiintifice si tehnologice la comanda (procese individuale sau suita de procese)
- Amplasarea de echipamente proprii in spatiile IMT, cu asigurarea utilitatilor (de exemplu pentru Honeywell Romania)
- Acces direct la echipamente, dupa o instruire prealabila (se evita problemele legate de proprietatea industriala).
- Asistenta pentru executie de lucrari tehnologice complexe, inclusiv proiectare si testare (one-stop shop)
- Posibil in viitor: acces la o linie pilot
  - *Obs. Avantajele aranjamentelor facute cu o institutie publica*.

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Infrastructurile in SNCDI si PNCDI

- SNCDI acorda atentie:
  - Infrastructurilor majore si celor deja in constructie
  - Clusterelor
- PNCDI (proiect, versiunea octombrie 2014) prevede finantarea pentru:
  - Completarea investitiilor anterioare
  - Optimizarea gradului de utilizare a unor infrastructuri cu utilizatori multipli
  - Stimularea formarii clusterelor de inovare in jurul marilor infrastructuri de cercetare
  - Crearea Registrului National al Infrastructurilor de Cercetare-Dezvoltare

In Romania s-au facut si se fac investitii majore in echipamente: sunt aceste echipamente folosite eficient? Care este practica mondiala?

- Universitatile – furnizeaza *platforme experimentale pentru cercetarea interdisciplinara*; aceasta infrastructura este folosita si de doctoranzi
- *Retele de infrastructuri la nivel national*: colaborarea intre infrastructuri (facilitati) complementare; este vorba si de preocupari si expertize complementare, nu neaparat de echipamente diferite.
- *Ecosisteme de cercetare, care practica “inovarea deschisa” sau clustere regionale orientate spre anumite domenii*; acestea cuprind firme mari si mici, IMM-urile inovative au acces la facilitatile organizatiilor mari.

In Romania s-au facut si se fac investitii majore in echipamente: sunt aceste echipamente folosite eficient? Care este practica mondiala? (continuare)

- UE a sustinut si sustine implementarea de retele paneuropene focalizate pe anumite domenii.
- In versiunea “retea avansata” (Orizont 2020), aceste retele de infrastructuri trebuie sa aiba un rol important in inovare, asigurand servicii tehnologice si transfer de cunostiinte pentru IMM-urile inovative.
- In paralel cu sprijinirea *liniilor pilot* (vezi initiativa public-privat ECSEL), UE incearca sa dezvolte *platforme tehnologice dedicate KET/TGE la care sa aiba acces IMM-urile inovative*

Ce ar putea sa se mai intreprinda in Romania?

- Recunoasterea faptului ca IMM-urile inovative nu au nevoie numai de consultanta si de spatii de lucru
- Deschiderea infrastructurilor de cercetare pentru firme, accesul la tehnologii.
- Recunoasterea rolului infrastructurii in transferul de cunostiinte si in transferul de tehnologie (CTT-urile pot asigura si servicii)
- Realizarea de retele de infrastructuri
- Specializarea pentru anumite tehnologii

- Alte detalii:
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