L3:Laboratory of micro/nano photonics

- Mission
- Main areas of expertise
- International co-operation
- Research Team
- Specific facilities

The Laboratory of Micro/Nano Photonics is recognized at national level, and funded between 2001 and 2004, as a **Centre of Excellence in Micro and Nano - Photonics.**

• **Mission**: Research and development activities in the field of micro/nano-photonics and optical MEMS focused on the development of micro/ nano structures based on new materials and processes and photonic integrated circuits based on heterogeneous integration technology; development of materials, technologies and components for optical MEMS.

• Main areas of expertise

- modelling and simulation of micro and nano photonic structures ;
- new materials for micro/nano opto-electro-mechanical systems integration (e.g. compound semi-conductors, functional polymer, hybrid organic-inorganic nano-compozites and glasses), and related fabrication processes (including mixed technologies);
- passive and active micro-nano-photonic structures for integrating in MOEMS for bio-medical and environment applications.
- hybrid or monolithic integrated photonic circuits and optical-MEMS (including heterogeneous platforms) for optical communications, interconnects and optical signal processing;
- Optical and electrical characterization of materials and optoelectronic and photonic components.

• International co-operation

- Partener in international networks: ASSEMIC - Advanced Handling and Assembly in Microtechnology (2004-2008), EC FP6 - Marie Curie Research Training Network; 4M - Multi-Material Micro Manufacture: Technologies and Applications , NoE FP6 – priority 3, NMP;
- Bilateral co-operation with LAAS-CNRS Toulouse, France, and with University of Athens- Department for Optical Communications, Athens, Greece
- European Projects: Waferbonding and Active Passive Integration Technology and Implementation in Photonics (WAPITI), STREP- FP6, Priority 2 (IST), Thematic area:- Optical, opto-electronic, photonic functional components.

• Research team has multidisciplinary expertise and is composed of 5 senior researchers (4 with PhD in optoelectronics, materials for optoelectronics, microsytems, physics, chemistry), 2 PhD students (with background both in physics and photonics), 1 master student and an early stage researcher from Moldavia and 1 experience researcher from Bulgaria (trained in the frame of ASSEMIC network).

• Specific facilities:

Modelling and simulation: Finite-Difference Time-Domain (FDTD) simulation and design software Opti FDTD 6.0, waweguide optics design software OptiBPM 8.1, software for design and modelling of of active devices based on semiconductor heterostructures (Opti-HS); integrated and fiber optical gratings design software (OptiGrating); software for active device simulation (including transport, thermal and optical properties) - LaserMod.

Characterization: spectrophotometers for UV-VIS-NIR and IR spectral range; spectroscopic ellipsometer for materials characterization; experimental set-up for characterisation in UV-VIS-IR spectral range of optoelectronic and photonic components, circuits.

New: Research and High Resolution Raman Spectrometers LabRAM HR. High resolution confocal Raman microscope, offers unique spectral resolution and sensitivity on a bench-top microscope system.

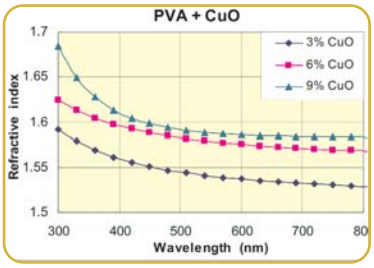
Applications: microscopy and analysis into semiconductors, nano-materials , polymers .

Laboratory Head — Dr. Dana Cristea (danac@imt.ro)

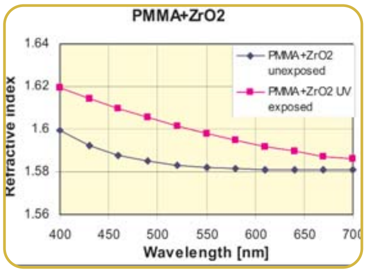
Dr. Dana Cristea obtained the MSc in Electronics (1982) and PhD in Optoelectronics and Materials for Electronics from “Politehnica” University, Bucharest, Romania. From 1982 until 1994 she was a research scientist in the Department of Optoelectronics and Sensors from the Research & Development Institute for Electronic Components, Bucharest, Romania. Since 1994 she has been a senior researcher in the National Institute for R&D in Microtechnologies (IMT- Bucharest), Romania, head of Laboratory of Micro/Nanophotonics since 1997 and head of Department for Multidisciplinary Research since 2002; since 1990 she has also Associate Professor at “Politehnica” University, Bucharest, Faculty of Electronics.
Her main research activities are in the fields of optoelectronics and photonic integrated circuits, optical MEMS for communications, chemo and bio-sensors with optical read-out.

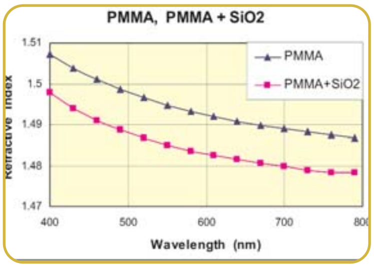
She has been more than 75 publications in international scientific journals and conference proceedings. She is also a reviewer in Romanian and international scientific journals and evaluator of European projects (FP6). She is project manager for more than 10 national and European projects.

POLYMERIC AND HYBRID NANOCOMPOSITES FOR MICROPHOTONICS

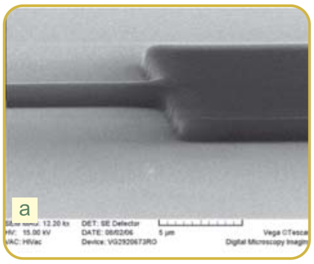


Refractive index spectra of doped PVA





Refractive index spectra of doped PMMA



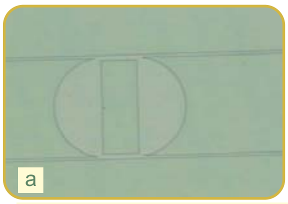
Polymeric multimode-interference (MMI) waveguide couplers: a), b) SEM images; c) light propagation

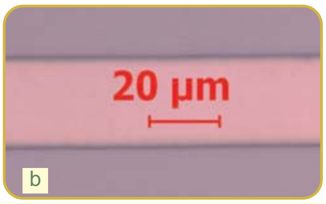
Nanocomposites for photonics app-lications, with controlled refractive index in the range 1.46-1.7 were prepared by chemical route or sol-gel process, starting from polymethyl-methacrylate (PMMA), hydroxyethylmethacrylate (HEMA), polyvinyl alcohol (PVA) and metal oxides from alkoxides or inorganic compounds.

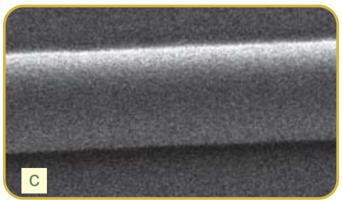
PVA was doped with CrO_3 to induce the photosensitivity, and with CuO to tune the refractive index. The refractive index of PMMA was either decreased or increased by doping with SiO_2 and ZrO_2 respectively. The optical transmission is not influenced by the dopants. These polymers can be used to fabricate waveguides and photonic circuits with the desired refractive index contrast between the core and the cladding.

MATNANTECH Project (2004-2006), Technologies for microstructures based on polymeric and hybrid composites, Coordinator: IMT Bucharest, Project manager: Paula Obreja (paulao@imt.ro)

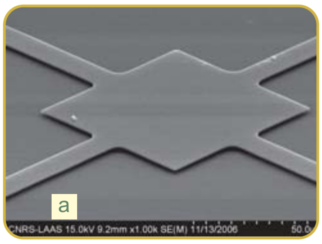
MIXED TECHNOLOGIES FOR MICROPHOTONICS

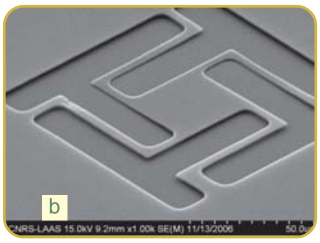


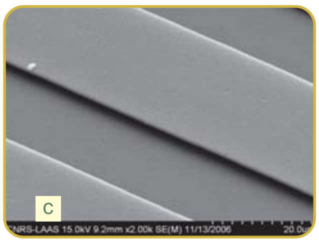




a) Microring resonators based on SiO_2-TiO_2 thin films doped with Er_2O_3
Silicon optical waveguides on SOI wafers: b) optical magine;
c) SEM imagine Si thickness: 2 µm; SiO2 thickness: 2 µm







SEM images of suspended SOI-based microstructures: a) movable micromirror 100x100 μm^2
b) movable micromirror 50x50 μm^2; c) bridge. Si thickness: 2 µm; air gap: 2 µm

Sol-gel technology

Achievements:

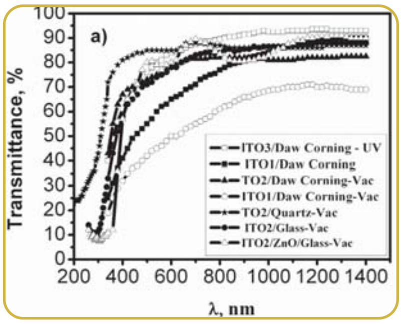
- Er doped SiO_2-TiO_2 obtained using sol-gel technique - Microring resonators based on Er Er doped SiO_2-TiO_2 layers.

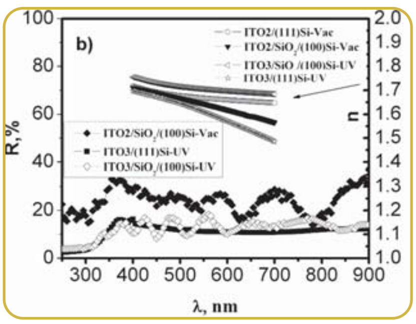
SOI – based microphotonic components

Microphotonic structures (movable micro-mirrors, optical waveguides) have been obtained on silicon-on insulator (SOI) wafers. Process steps: (i) Si etching (RIE); (ii) SiO_2 etching in HF solution.

Thin transparent conducting layers with optical and electrical properties suitable for micro/nanophotonic applications.

Achievements: Thin transparent conducting layers of ITO, ZnO, undoped CdS and doped with Mn, Se, Sb

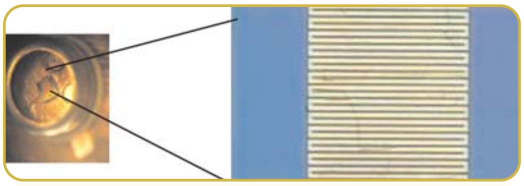




The transmitance, reflectance and refractive index of TCO thin layers deposited on different substrates as a function of wavelength.

CEEX Project 2006-2008,
Co-ordinator: IMT-Bucharest,
Co-operation with Institute of Physical Chemistry "I.G.Murgulescu" of Romanian Academy, LAAS CNRS Toulouse, France, "Al.I. Cuza" University , Iasi,
Project manager: Dr. Dana Cristea (danac@imt.ro)

SILICON METAL-SEMICONDUCTOR-METAL PHOTODETECTOR (MSM-PD) WITH ZnO TRANSPARENT CONDUCTING ELECTRODES

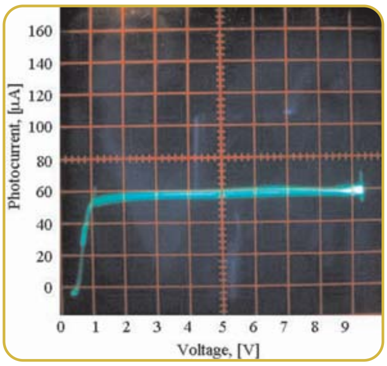


Optical image of a MSM-PD with transparent interdigitated electrodes of ZnO

MSM type structure is a fast photodetector useful in applications such as optical communications, optical interconnects, sensors by integrating with optical waveguides from polymer or other dielectric materials. Advantages compared with other high speed photodetectors like PIN or APD photodiodes: - **high frequency bandwidth** due to a lower intrinsec capacitance for the same area as PIN junction photodiode due to its planar lateral structure;

- **simple planar technological process**, compatible with silicon IC technology;
- **low voltage operation;**
- **high responsivity** due to transparent interdigitated electrodes;

An MSM structure of 0.143 mm² active area and finger spacing and width of 6 µm was achieved using ZnO thin films as transparent conducting electrodes. The thin layer of $Zn_{0.97}Al_{0.015}Sn_{0.015}O$ deposited on p-Si by thermal evaporation exhibits high transparency (T>85%) over a large spectral range and low electrical resistivity ($\rho \sim 10^{-4} \Omega$cm). The opto-electrical mesurements revealed an improved responsivity of 0.2 A/W in UV region (λ = 375 nm), a low capacity of 1.4pF at 10 V bias voltage and a flat response with the bias voltage for obtained MSM-PD with transparent conducting ZnO Schottky electrodes.



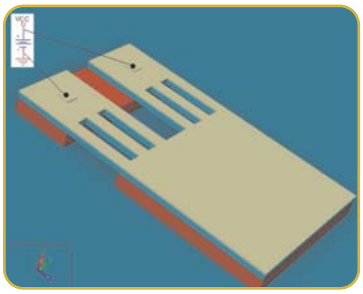
Photocurrent versus reverse bias voltage at λ = 475 nm for obtained MSM-PD structure.

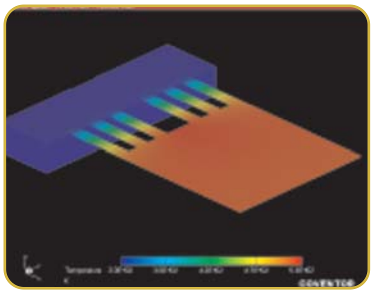
MATNANTECH project 2004-2006: New processes and photonic microstructures based on Si and AIIIBV semiconductor compounds with transparent conductive thin films. Co-ordinator: IMT-Bucharest. Project manager: Elena Budianu, elenab@imt.ro

MOVABLE MICROMIRRORS ON SILICON-ON-INSULATOR

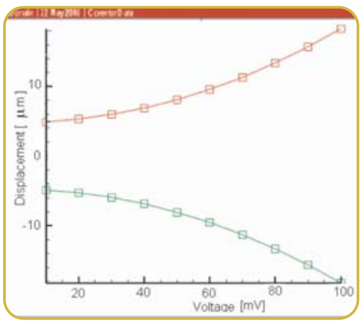
Movable micromirrors are an expending area of applications such as as miniature scanning devices, optical spectroscopy, adaptive optical systems, communication and cross connects and switches in optical systems and sensors applications. These devices can be actuated by different means, such as: electrothermal, electrostatic, piezoelectric, electromagnetic, bimorph, etc.

Achievements: Design and simulation of movable micromirrors on silicon and silicon-on-insulator substrate, thermally actuated based on bimorph layer . The response of the micromirrors, consisting in the displacement along z axe was investigated in static and dynamic regime using Coventor taking into account the material properties, structure geometry and dimensions and actuation conditions such as dc and pulsed voltage applied on device. The simulated micromirrors structures are based on two layers, one layer is gold and the other one is thermal silicon dioxide grown on silicon with rectangle and circular reflective surface sustained by to arms on silicon wafers.

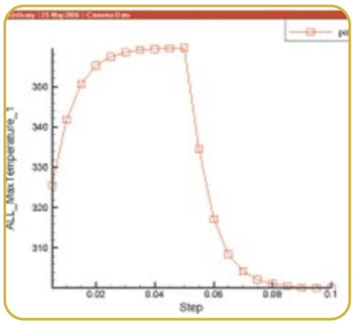




Photocurrent versus reverse bias voltage at λ = 475 nm for obtained MSM-PD structure.



Vertical displacement of the micromirror vs. applied voltage



Thermal transient response for a period of 50 ms

MINASIST + project (2006-2008), Contact person: Dr. Munizer Purica (munizerp@imt.ro)

NUMERICAL INVESTIGATION OF LEFT – HANDED METAMATERIALS

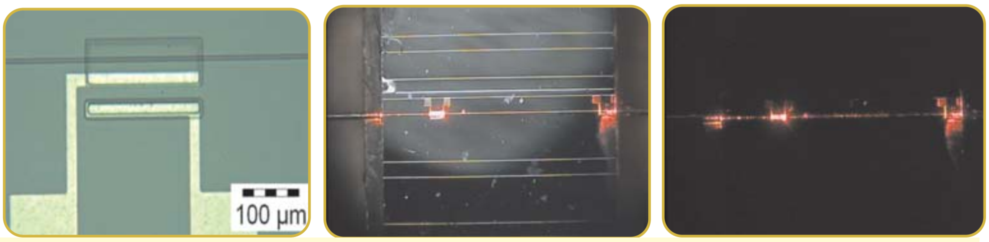
Metamaterials are novel periodic systems, patterned at micro and nanoscale, for which the effective electromagnetic properties like electric permittivity and magnetic permeability can be artificially engineered. A very interesting class of metamaterials are the left – handed metamaterials (LHM) which present simultaneously a negative permittivity and permeability, and implicitly, a negative refraction index. Besides the interesting electromagnetic and optical phenomena occurring in LHMs, there is a plethora of novel applications in imaging (perfect lens), invisibility, waveguiding, etc. We use a combination of theoretical methods and numerical algorithms to investigate and design various LHM at microwave, infrared and optical frequencies.

CEEX Project (2006 – 2008) Optical properties of nanostructured materials. Coordinator: IMT Bucharest , Project manager: Cristian Kusko (cristiank@imt.ro)

L3: International participation to research projects

INTEGRATED BIOPHOTONICS POLYMER CHIP

The goal of this project is to analyse the possibility of realizing compact biophotonic sensors for living cells by heterogeneous integration of optical waveguides, photodetectors and electronics within a polymer microfluidic chip.

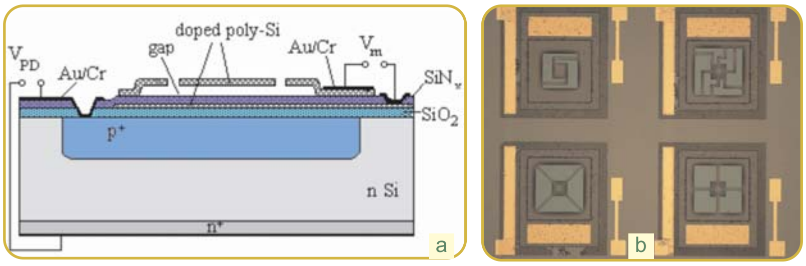


7.5 µm wide straight WG leacky-wave coupled with a Si photodiode, optical images and light propagation

Preliminary results: heterogeneous integration of PMMA waveguides with silicon photodiodes.

Joint research in the frame of the FP6 NoE MULTI-MATERIAL MICRO MANUFACTURE: Technologies and Applications (4M); Co-operation with Institute for Microstructure Technology (IMT), Forschungszentrum Karlsruhe (FZK), Germany

DEVELOPMENT OF PHOTODETECTORS INTEGRATED WITH MICROMECHANICAL AND PHOTONIC COMPONENTS FOR MOEMS

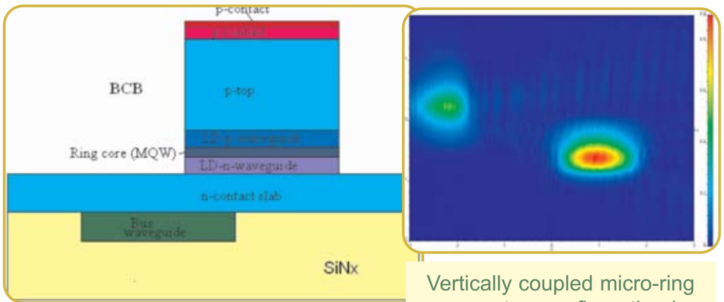


Tunable optical filter: a)structure; b)optical image

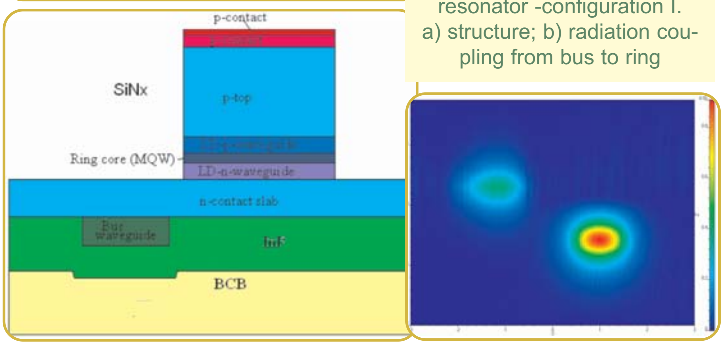
Tunable optical filter composed of a Fabry-Perot Interferometer (obtained by surface micromachining) integrated with a silicon photodiode.

Bilateral co-operation with LAAS CNRS Toulouse, France (Brâncusi project)

WAFERBONDING AND ACTIVE PASSIVE INTEGRATION TECHNOLOGY AND IMPLEMENTATION



Vertically coupled micro-ring resonator -configuration I. a) structure; b) radiation coupling from bus to ring



Vertically coupled micro-ring resonator -configuration II: a) structure; b) Radiation coupling from bus to ring

Acronym: (**WAPITI**) Instrument: STREP FP 6, Priority 2, IST
Coordinator - Fraunhofer Institute for Telecommunications, Heinrich Hertz-Institut, Berlin, Germany; Dr. **Helmut Heidrich** (Helmut.Heidrich@hhi.fraunhofer.de).
Partners: National Kapodestrian Univ. of Athens (GREECE); Cambridge Univ., Engineering Depart.(UNITED KINGDOM); EV Group, E. Thallner GmbH, Scharding (AUSTRIA); Max Planck Institute of Microstructure Physics, Halle (GERMANY);National Institute for R&D in Microtechnologies, Bucharest (ROMANIA)

Recently, optical micro-ring resonators have received considerable attention since they provide a promising route towards very large-scale-integrated photonics. The key WAPITI structure for the miniaturisation of the optoelectronic GaInAsP/InP laser circuits is the active microring resonator which is vertically coupled to one or two transparent bus waveguides. Major advantages associated are compactness of the ring cavity (diameter of a few 10 µm), the realisation of ultra short couplers (order of 10 µm), precise control of the coupling strength with epitaxial growth accuracy, flexibility in the optimum choice of the material composition and pattern of the passive and active waveguides (optical I/O ports are located in a passive, transparent optical waveguide layer vertically coupled to an active, highly confined second waveguide layer in which microring cavities are formed).

Two configurations for of the active devices (ring lasers and wavelength converters) have been studied. The ring and bus waveguides are based on the InGaAsP material system with bandgap wavelengths smaller than 1550 nm –typically in the range from 1300 to 1400 nm. The two waveguides are grown on different substrates which are subsequently bonded to produce the micro-ring structure. All InP/GaInAsP epitaxial layers necessary for the fabrication of microring resonator devices are fabricated in a single epitaxial growth step on InP substrates.

We calculated the bus-ring and the ring-bus coupling efficiency as a function of the lateral offset necessary for optimal working properties. Our theoretical and numerical results were confirmed by the experiments done upon the passive ring resonators realized by WAPITI consortium.