L3:Laboratory of micro/nano photonics

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 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

- **modeling and simulation** of micro and nano photonic structures; development of simulation tools;
- **new materials for micro/nano opto-electro-mechanical systems integration** (e.g. compound semiconductors, functional polymer, hybrid organic-inorganic nano-compozites and glasses), and related fabrication processes (including mixed technologies);
- **passive and active micro- nano- photonic structures;**
- **hybrid or monolithic integrated photonic circuits and MOEMS** (including heterogeneous platforms) for optical communications, interconnects and optical signal processing;
- **micro-optics** - design and fabrication based on replication techniques;
- **optical and electrical characterization** of materials and devices;

International co-operation

FP6: Waferbonding and Active Passive Integration Technology (**WAPITI**), STREP, Priority 2 (IST), Thematic area: Optical, opto-electronic, photonic functional components.
Advanced Handling and Assembly in Microtechnology - **ASSEMIC** (2004-2008), Marie Curie Research Training Network;
Multi-Material Micro Manufacture: Technologies and Applications **4M**, NoE – priority 3, NMP;
FP7: Flexible Patterning of Complex Micro Structures using Adaptive Embossing Technology – **FlexPaet**, IP, NMP;
European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices – **MIMOMEMS**, CSA-programme capacities;

Research team has multidisciplinary expertize and is composed of 6 senior researchers (5 with PhD in optoelectronics, materials for optoelectronics, micro-sytems, physics, chemistry), 2 PhD students (with background both in physics and electronics).

Specific facilities:

Modeling 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 optoelectric characterization in UV-VIS-IR spectral range of optoelectronic components and circuits, experimental set-up for characterization of photonic devices Research and High Resolution Raman Spectrometers LabRAM HR.

New: ***Near Field Scanning Optical Microscope*** **Alpha300 S System** is a Scanning Near-field Optical Microscope (SNOM) that combining the characterization methods of SNOM, Confocal Microscopy (CM) and Atomic Force Microscopy (AFM) in a single equipment.
Applications: *imaging* the optical properties of a sample with resolution below the; diffraction limit with applications in nanotechnology, nanophotonics, nanooptics and plasmonics; *materials research*; *single molecule detection*; *life sciences*; *fluorescence characterizations;*

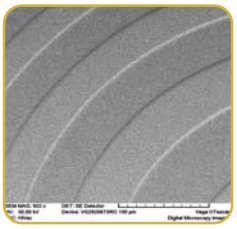
Laboratory Head — Dr. Dana Cristea (dana.cristea@imt.ro)

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 was 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 80 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, FP7). She is project manager for national and European projects.

Development of micro optical devices

- **Fresnel mirrors with 2 and 4 levels** (for the first time in Romania), and minimum feature size 2.4 μm. The chip size is 5x5 mm2, and the lens diameter is 4 mm. The etching depth is 150-160 nm for the 2-level structure (λ/4) and ~80 nm for the second etching step (for 4 level structures). Lenses with focal length of 3, 4, 5, 6 and 7 cm have been obtained for red radiation (630 nm). The structures were processed using optical lithography and reactive ion etching of SiO_2.

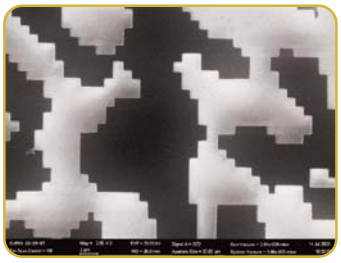


SEM images of Fresnel lens with 2 levels and 4 levels (details)

Reflected light in the focal plane: Fresnel lens with 4 levels

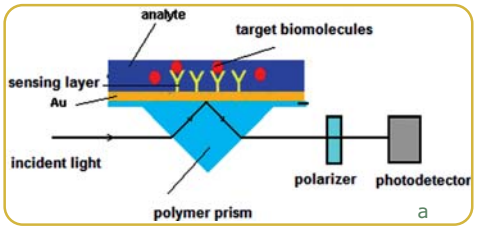
- **Diffractive optical element** for generation of IMT logo was designed using Lith software (Raith) and obtained electron beam lithography in a PMMA layer 160 nm thick (first time in Romania). The pixel size is 1 μm. The size of the DOE is 1x1 mm^2.

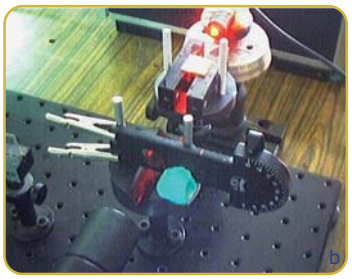
Far field recostruction image

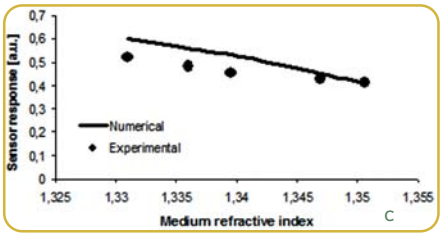


SEM image- detail of the DOE

- **Development of bio-sensing applications based on micro-optical components;** Chemo/biosensors based on Surface Plasmon Resonance (SPR) have been experimented using polimeric microprisms obtained by replication of an original (glass prism). The prism base is covered by a gold layer and a senzitive layer.







a) Sensor structure; b) Image of the characteriation set-up; c) Sensor response (chemical sensing) function on analyte refractive index. The refractive index depends on the concentration. Experimental dots are for an alcool concentration of 5, 10, 20 and 25%

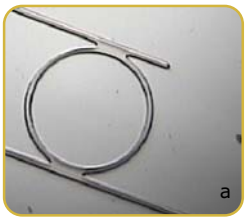
CEEX Project 2006-2008, Micro-optical devices for optical processing;
Co-ordinator: IMT-Bucharest, Project manager: Dr.Dana Cristea (dana.cristea@imt.ro)

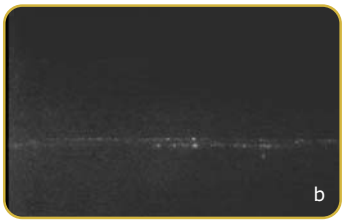
Mixed technologies for microphotonics

- **Development of sol-gel technology for micro/nano photonic applications.**

(Cooperation with Institute of Physical Chemistry "I.G.Murgulescu" of Romanian Academy, Laboratory of Oxide Materials Sciences, Laboratory of Oxide Materials Sciences

The multilayer titania and silica-titania waveguides undoped and doped with $Er3^+$ were prepared by sol-gel technology. This is a flexible and convenient way to prepare oxide films on several types of substrates. Optical waveguides and photonic circuits (microring resonators) were obtained by patterning Er-doped SiO_2-TiO_2 sol-gel layers deposited on oxidized silicon wafers (oxide thickness over 1700nm). Two techniques were used for patterning: wet etching in buffered oxide etch (BOE) solution and reactive ion etching in CF_4. Reactive ion etching offers a better control of the etching process and lower over-etching.

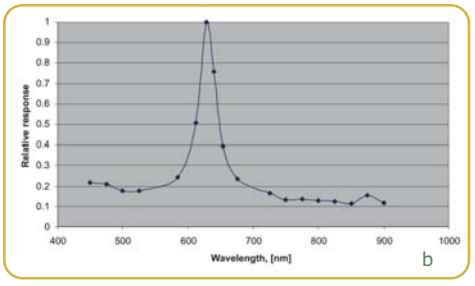




a) SEM image of a TiO_2 ring resonator;
b) IR image of an SiO_2-TiO_2-Er –based waveguide (light propagation λ= 1550 nm).

- **Multilayer structures with controlled optical properties**

Photodetector with selective spectral response was fabricated by integration of a multilayer structure with controlled optical properties with a silicon PIN photodiode with an active area of 0.6mm^2 fabricated by silicon planar technology. Multilayer structure consists in semitransparent metallic films and dielectric layer with controlled thickness.

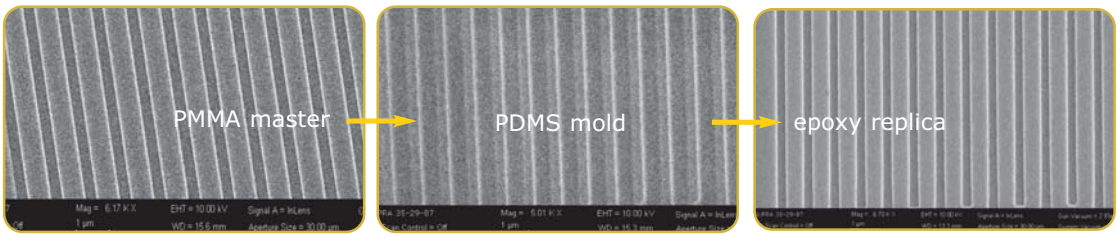


a) Optical microscope image of the structure.
b) Relative spectral response of the structure.

CEEX Project 2005-2008, Development of mixed technologies for micro/nano structures and photonic systems with application in communications.
Co-ordinator: IMT-Bucharest, Project manager: Dr.Dana Cristea (dana.cristea@imt.ro)

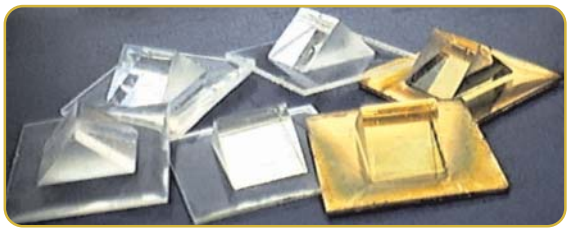
Replication techniques for micro and nano-optical components

•**Development of replica molding techniques for replication of optical elements and microfluidic structures** with feature size in the micron and submicron range.



Diffraction gratings and channels with sub-micron dimensions

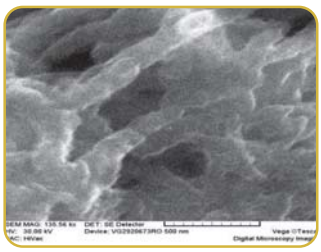
Fresnel lenses (operation in transmision) replicated in PDMS using a SiO_2 master



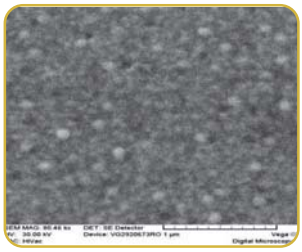
Prisms for SPR sensors obtained in epoxy rewsin using a glass original (master) and a PDMS mold (negative copy).

PN II Project (2007-2010), "Development of soft lithography techniques for micro and nano-photonics"
Coordinator: IMT Bucharest, Project manager: Paula Obreja (paula.obreja@imt.ro)

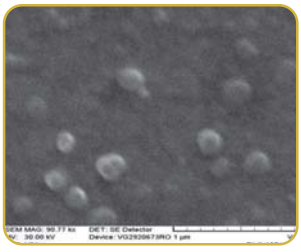
Polyaniline films for sensor applications



SEM image- PANI EB



SEM image- PANI – Ag..



SEM image- PANI – TiO_2

Possible applications: bio-chemical sensors, organic light emitting diodes, electro-mechanical actuators, anti-corrosion coatings, electro-magnetic screens, microwave absorbing material, anti-reflection coating, electro-chromic mirrors and ultra-capacitors.

Co-operation with Politehnica University in CEEX Project 2006-2008; Contact: Paula Obreja (paula.obreja@imt.ro)

Optical properties of nanostructured materials

Numerical and theoretical investigation of nonlinear left – handed metamaterials. The response of a right and left handed metamaterial based on a square array of Mie resonators has been investigated using both analytical and numerical methods (finite difference time domain). A linear metamaterial exhibits a band gap in which the electromagnetic field obeys an evanescent propagation. Due to the dependence of the material constants with respect to the field amplitude, the nonlinear metamaterial exhibits the gap solitons.

CEEX project Module II 2006-2008; Contact person dr. Cristian Kusko

Investigation of passive and active photonic devices with advanced functionalities

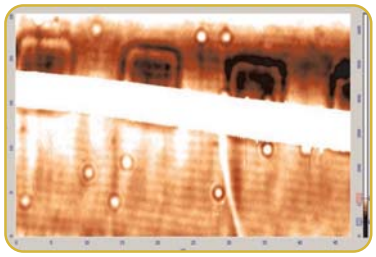
Various active or passive photonic devices based on ring resonator configurations present a variety of applications in optical signal processing, optical communications and sensing. For designing a ring resonator device with a correct functionality a series of analytical and numerical methods (transfer matrix method, 3-dimensional finite different time domain simulations) have been used in order to determine the modal nature, losses, and spectral characteristics of multimode ring resonators with small radius.

MINASIST + project No. PN06240302 (2006-2008), Contact person dr. Cristian Kusko

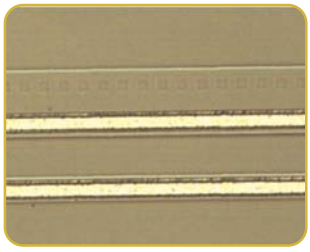
Integrated chip for sensing application

The chip is composed of SU-8 waveguides and Y junctions integrated with silicon photodetectors.
The optical coupling waveguide - photodiode is obtained with a grating realized in the bottom clading of the waveguide (pitch 4 μm). The coupling eficiency depends on the refractive index of the surrounding media.
Applications: chemo and biosensors.

Optical image of the waveguide coupled with the photodiode



AFM image of the coupling region (waveguide placed on the grating)



Optical image: grating etched in SiO_2

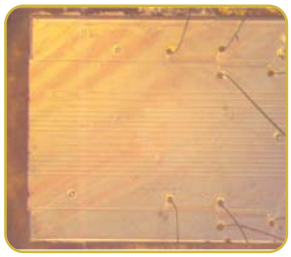


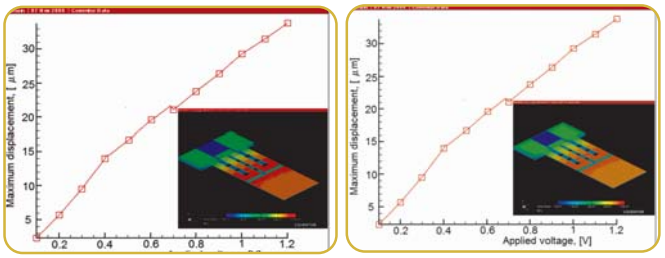
Image of the chip with bondig wires for the photodiode

MINASIST+ PROJECT (2006-2008)
Contact person dr. Dana Cristea (dana.cristea@imt.ro)

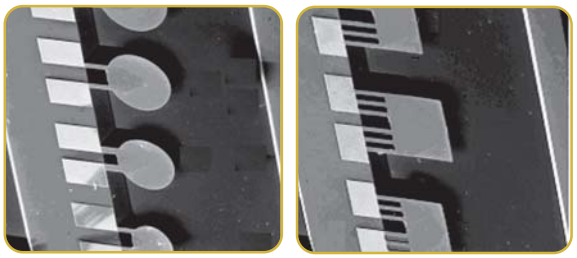
Development of reflective microoptics components on silicon substrates movable micromirrors

Movable micromirrors represents one of optical- MEMS devices which are widely used in different types of applications such as cross connects and switches in optical systems, laser adjustable cavities, miniature scanning devices, communication and sensors applications. Movable micromirrors can be actuated by different means, such as electromagnetic actuation, electrostatic actuation, piezoelectric actuation and thermal actuation based on bimorph layer or a resistance integrated on silicon substrates .

After performing micromirrors simulations using Coventorware software, the micromirrors with different geometry were obtained on on silicon or SOI substrates by wet etching, RIE, thermal oxidation, lithography and metal deposition by vacumm evaporation technique.



Displacement versus applied voltage for micromirror with different geometry on silicon substrate (inside-stress distribution on structures)



SEM image of micromirrors with circular and rectangular geometry obtained on silicon substrates

MINASIST+ project No. PN06240303 (2006-2008):contact person dr. Munizer Purica (munizer.purica@imt.ro)

SERVICES OFFER:

(i) Analysis and characterization of the nanometric thin films and multilayered structures from different materials –dielectrics, conductive oxides, polymers, semiconductors. Measuring the index of refraction (n) and the extinction coefficient (k) for a single layer permits one to determine the material composition and modeling of optical performance.

(ii) Testing the optical properties of samples for the ability to reflect or transmit light by spectrophotometric measurements-transmistance, absorbance spectra [T(λ),A(λ)], surface reflectivity of the texturized and porosified layers.

(iii) Raman spectroscopy for physical and chemical material analysis of solids, liquids and solutions for chemical identification, characterization of molecular structures; composition and phase (crystalline/amorphous) of composites materials (compound semiconductors, oxidic semiconductors); polymers characterizations and polimer nanocomposites; chemical and biological detection using SERS technique; micro/nano structures characterization (micro/nanorods). - **Contact person: Dr. Munizer Purica (munizer.purica@imt.ro); Florin Comanescu**;

(iii) modelling, simulation CAD for active and passive micro/nano-photonic devices and micro-optics.

(iv) concept & design studies, development of new tools (customized) especially for "linking" different commercial software to offer a coupled simulation (opto-electro-mechanical analysis)for optical MEMS and sensors.
- **Contact persons: dr. Cristian Kusko (cristian.kusko@imt.ro); dr. Mihai Kusko (mihai.kusko@imt.ro)**