

Tehnologii mixte pentru micro/nano structuri si sisteme fotonice integrate

FOTONTECH

Contract: **16 CEEX I 03 INFOSOC /2005**

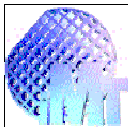
Coordonator: IMT Bucuresti

Director de proiect: Dr.ing. Dana Cristea

Buget proiect: **1425000** lei + 75000 lei cofinantare

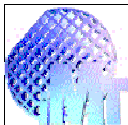
Perioada de derulare: octombrie 2005-septembrie 2008

Adresa web: www.imt.ro/fotontech



Parteneri

- Institutul National de Cercetare-Dezvoltare pentru Microtehnologie (IMT-Bucuresti)- **Laboratorul de microfotonica**
- Institutul National de Cercetare-Dezvoltare pentru Fizica Laserilor, Plasmei si Radiatiilor , Bucuresti, (INFLPR)- **Departamentul laseri**
- Universitatea "Politehnica" din Bucuresti - **Centrul de Cercetari pentru optoelectronica (UPB-CCO)**
- Institutul de Chimie- Fizica "I.G. Murgulescu" al Academiei Romane - **Laboratorul de stiinta materialelor oxidice (ICF)**
- Universitatea "A.I. Cuza" din Iasi (UAIC)
- ICEPALV S.A



Obiective

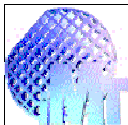
Scop principal :

Dezvoltarea de tehnologii mixte pentru micro/nano structuri si sisteme fotonice integrate cu aplicatii in comunicatii,

Obiective

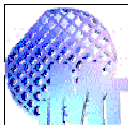
- **Crearea unei retele de laboratoare de cercetare in domeniul tehnologiilor mixte pentru micro/nano structuri fotonice**
- **Dezvoltarea de tehnologii mixte pentru micro/nano fotonica, pe baza de noi procese si materiale si pe concepte avansate de structuri.**
- **Diseminare si instruire**
- **Cooperari internationale**

Aria tematica din FP7: 3.1. Pilonii tehnologiei ICT, 3.1.1. Sisteme nanoelectronice, fotonice si micro/nano-sisteme integrate.



Nr. crt.	Denumirea indicatorului	Nr. de indicatori planificati	Nr. de indicatori realizați
1	Studii	3	3
2	Proiecte	3	4
3	Prototipuri		
4	Tehnologii - ME	3 procese tehnologice	5 procese
5	Produse informatice		
6	Alți indicatori specifici programului		
	-numar de sisteme/structuri realizate/aplicate/implementate	3	1 structura dispozitiv+2 sisteme
	- numar de servicii noi/modernizate/aliniate/aplicate/valorificate		
7	Articole publicate in tara	1	2
8	Articole publicate in strainatate	2	9
9	Brevete propuse/acceptate	-	
10	Carti publicate in tara	-	5
11	Carti publicate in strainatate	-	2
12	Comunicari stiintifice	8	>36
13	Propuneri de proiecte transmise la programe internationale cu tematica rezultata din proiectul derulat	1	3
14	Propuneri de proiecte internationale aprobate cu tematica rezultata din proiectul derulat		3

Simpozionul "Rezultatele cercetarii romanesti in domeniul tehnologiilor informationale si de comunicatii obtinute in cadrul Programului CEEX - Modulul 1", Iunie 2008



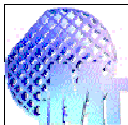
Management retea de laboratoare de cercetare

Laboratoare de cercetare din

- **2 institute nationale:** INCD - Microtehnologie, INCD –Fizica Laserilor, Plasmei si a Radiatiilor),
- **1 institut al academiei** (ICF),
- **2 universitati** (UPB, UAIC-Iasi) si
- **1 institut de cercetare privat** (IC-PALV SA) cu expertize si resurse complementare in domeniul proiectarii, tehnologiei si caracterizarii micro/nano structurilor fotonice cu aplicatii in comunicatii.

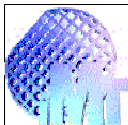
Activitati:

- *inventarierea resurselor si up-gradare dotari, achizitionare de noi echipamente pentru domeniul nanotehnologiilor;*
- *constituirea unei platforme comune si competitive pentru caracterizare materiale, procese, micro/nano structuri fotonice*
- *cooperari internationale.*



Dezvoltare procese tehnologice

- **Dezvoltare procese tehnologice individuale**
 - Procese tehnologice pe Si
 - **Tehnologia straturilor subtiri**
 - Straturi subtiri oxidice
 - Procese sol-gel
 - Polmeri
 - **Tehnologii de configurare**
 - Noi procese litografice
 - Patternare cu laser
- **Dezvoltare noi tehnici de proiectare/simulare**
- **Integrare procese mixte**



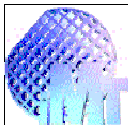
Procese de microprelucrare materiale semiconductoare

Procesare plachete SOI:

corodare Si in plasma + corodare umeda SiO_2

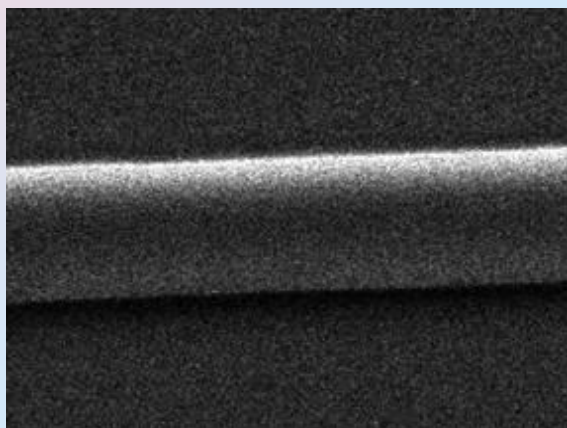
S-au experimentat si optimizat procese tehnologice de realizare microstructuri pentru componente si microsisteme fotonice (microoglinzi, membrane, cantilevere, ghiduri optice) prin microprelucrarea plachetelor de tip SOI („silicon on insulator”)

- s-a pus la punct procesul de **corodare in plasma a siliciului** pe noul echipament achizitionat;
- s-a optimizat procesul de **corodare umeda a dioxidului de siliciu** pentru realizarea structurilor suspendate.

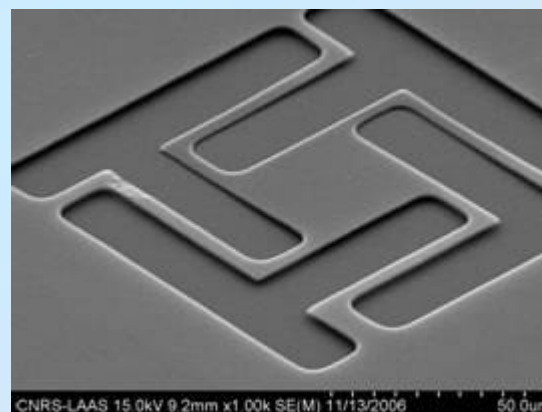


Procese de microprelucrare materiale semiconductoare

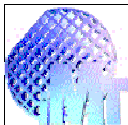
Structuri suspendate realizate pe plachete SOI (IMT)



ghid de unda din
siliciu- latime $2\mu\text{m}$



micro-oglinda mobila
cu latura de $50\mu\text{m}$
pentru "free space
interconnections"



Straturi subtiri

Sol-gel

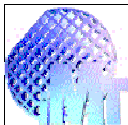
Filme oxidice si hibride in sistemul $\text{SiO}_2\text{-TiO}_2$ dopate cu pamanturi rare - Er_2O_3 depuse pe siliciu oxidat si configurate (umed sau in plasma) pentru obtinerea de circuite fotonice

Sample	Precursor	Raport molar			pH	Experimental condition	
		ROH	H ₂ O	catalizator		T °C	t (h)
		Σ precursor	Σ precursor	Σ precursor			
1	$\text{Si}(\text{OC}_2\text{H}_5)_4 + \text{Ti}(\text{OC}_2\text{H}_5)_4 + \text{ErCl}_3$	9.1	1.85	0.0174	3	50	3

Metoda de depunere: dip coating, viteza de scoatere 5cm/min.
spin coating - 2500 rpm.
substrat: plachete Si oxidat

Tratament pentru densificare: 900 °C cu rata de crestere a temperaturii 5°C/min

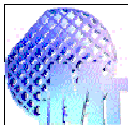
ICF + IMT



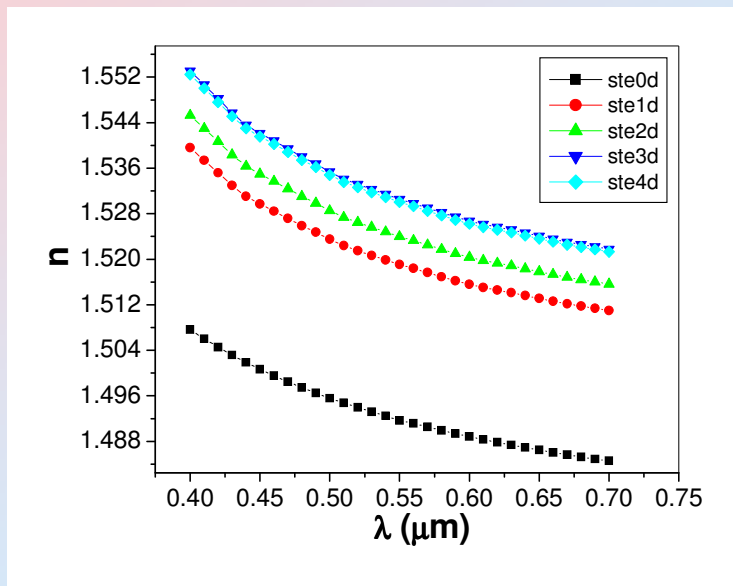
Filme oxidice si hibride in sistemul $\text{SiO}_2\text{-TiO}_2$ dopate cu pamanturi rare - Er_2O_3

Sample	Depositions number	d (Å)	SiO_2 (%)	TiO_2 (%)	Voids (%)
STE1	1	1720	88.69	5.08	6.23
STE4	4	4360	89.58	9.31	1.11
STE7	7	9403	89.74	10.06	0.2
STE10	10	14234	89.99	9.62	0.4

ICF + IMT



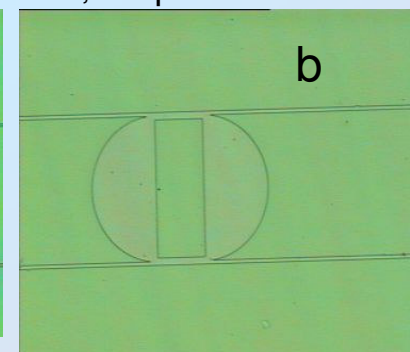
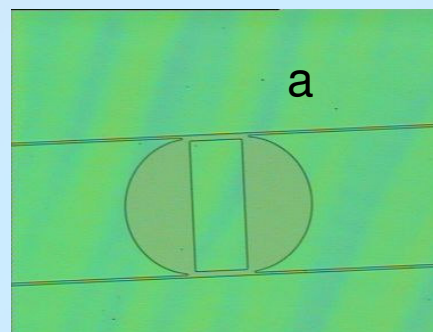
Filme oxidice si hibride in sistemul $\text{SiO}_2\text{-TiO}_2$ dopate cu pamanturi rare - Er_2O_3



Dispersia indicelui de refractie pentru filmele de $\text{SiO}_2\text{-TiO}_2\text{-Er}_2\text{O}_3$ depuse prin imersie pe suport de SiO_2/Si

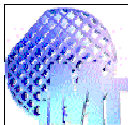
microrezonatoare inelare din $\text{SiO}_2\text{-TiO}_2$ dopat cu Er_2O_3 configurat fotolitografic si corodate:

a - solutie "buffered oxide etch" , b - plasma



Propagarea radiatiei cu lungimea de unda 1550 nm printr-un ghid liniar

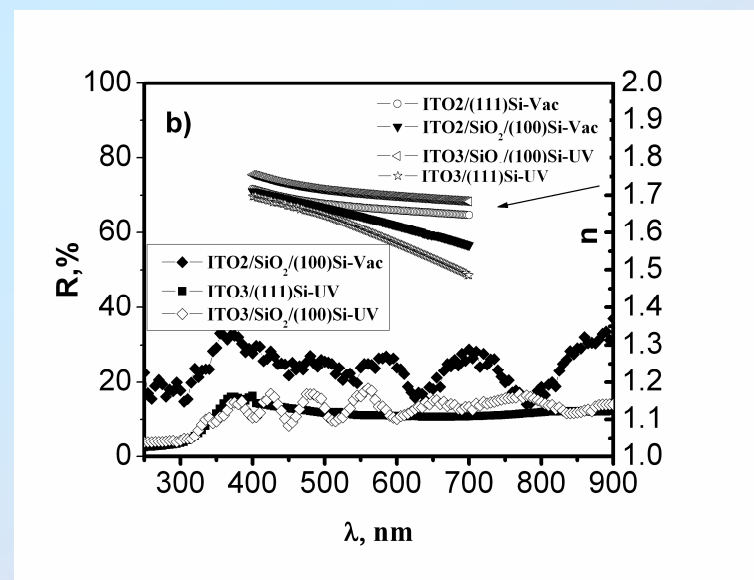
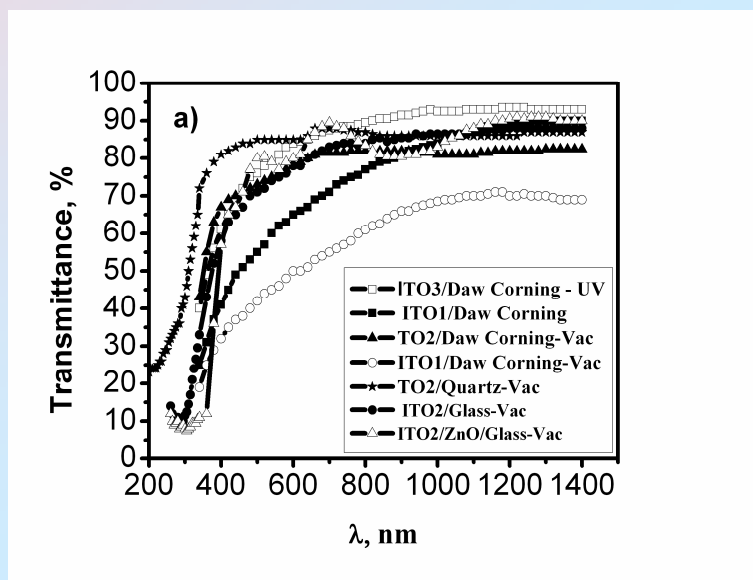
ICF + IMT



Sraturi subtiri oxidice

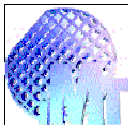
S-au obtinut si caracterizat straturi subtiri transparente si conductive de:

- ZnO (metoda "spin coating").
- ITO (metoda evaporarii termice in vid)



Influenta naturii substratului asupra: (a) transmitantei; (b) reflectantei si indicelui de refractie pentru straturi subtiri de oxizi transparenti si conductivi.

UAIC



Sraturi subtiri oxidice

Straturi subtiri de SiO₂ si TiO₂

Metode de depunere: *Reactive RF magnetron sputtering*

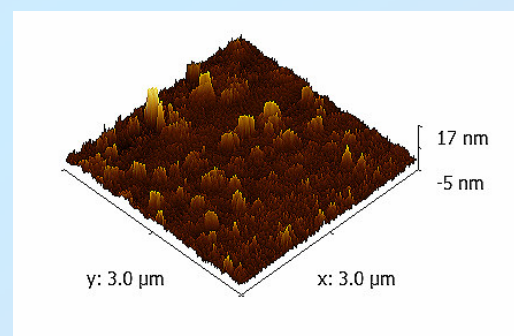
TiO₂

- Substrat de sticla incalzita 250C;
- Amestec de Ar+O₂ (0,1Pa) ;
- Gaz reactiv – oxigen (0,03 Pa)
- Puterea RF – 100W;
- Tinta de Ti

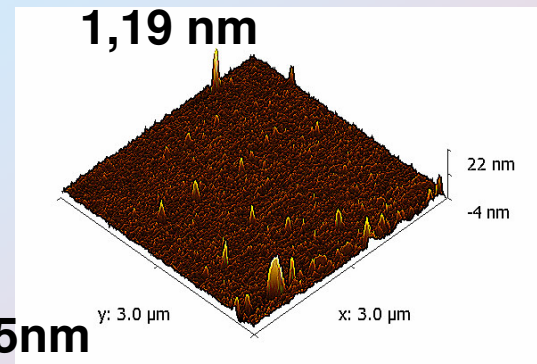
SiO₂

- Tinta Si (111);
- Amestec de Ar, O₂;
- Timpul de depunere – 90 min., 120 min.
- Grosimea – 200nm, 400nm

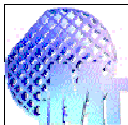
Filmele subtiri sunt nanostructurate cu nanocristale intr-o matrice amorfa;
- Filmele de TiO₂ sunt de tip anatas
- Este evidenta influenta substratului;
- Suprafata este neteda cu rugozitate medie nanometrica



TiO₂/glass RMS = 1,19 nm

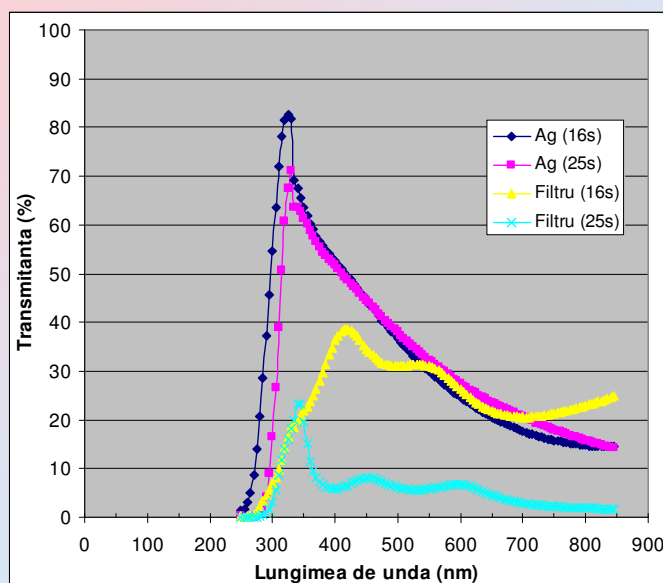


SiO₂/glass, RMS = 0,5nm



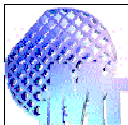
Structuri multistrat

Structuri multistrat Ag/ perechi multiple SiO₂/TiO₂/Ag



Dependenta spectrala a transmitantei structurilor multistrat Ag/SiO₂/TiO₂/ SiO₂/TiO₂/ SiO₂/TiO₂/Ag si pentru straturi de Ag depuse in timpi diferiti

Material	Indicele de refractie	Domeniul de transparenta, [nm]	Energia benzii interzise, [eV]
SiO ₂	1,56	200 - 3000	3,35 – 4,3
TiO ₂ anatas	2,59 – 2,52	450 - 5000	3,2
TiO ₂ rutil	2,93 – 2,73	450 - 5000	3



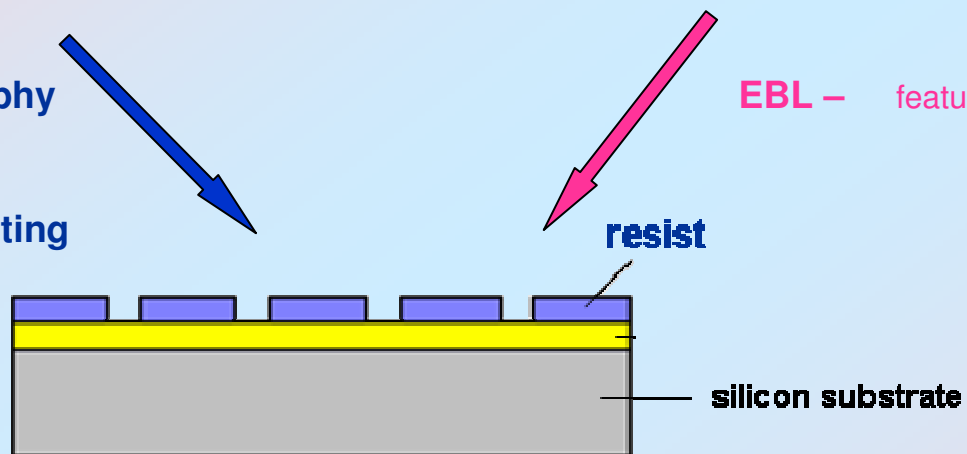
Tehnici de configurare

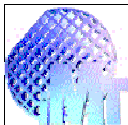
Photoresist (AZ, SU8, etc.)

Electronoresist (PMMA, SU8)

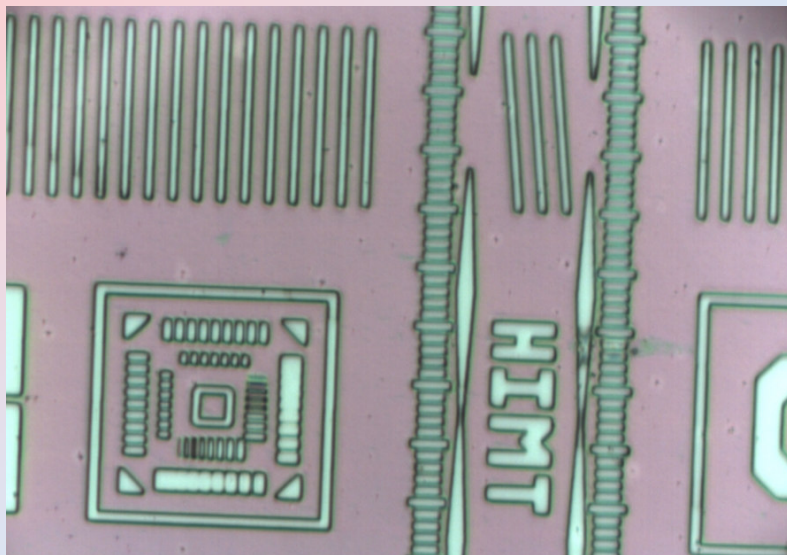
Photo-lithography
Or
Direct Laser writing

EBL – feature size $< 1\mu\text{m}$

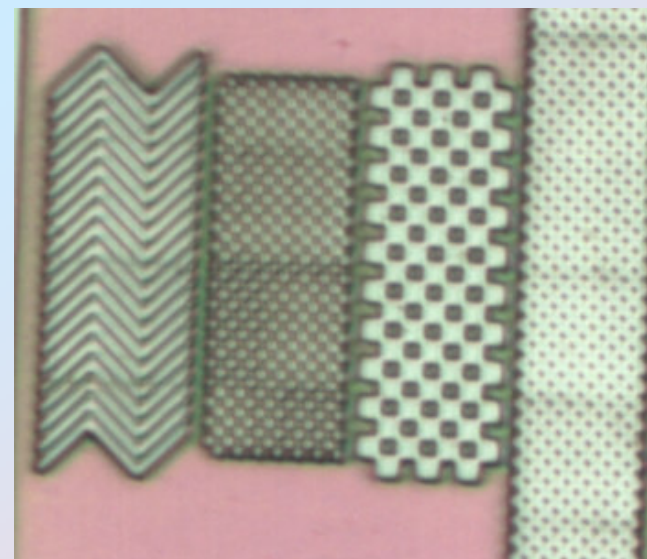




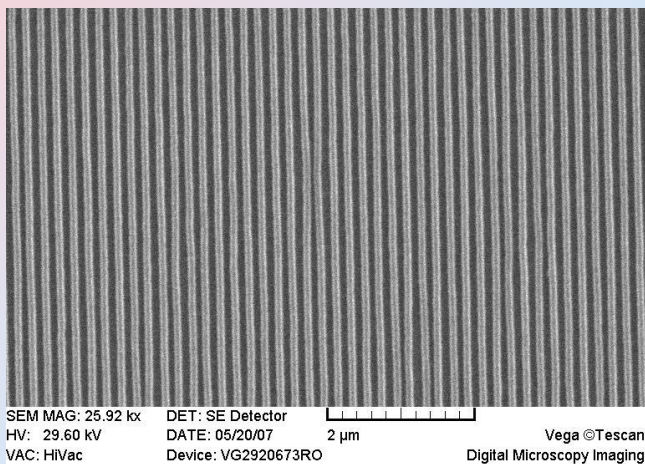
Scriere directa cu fascicul laser in fotorezist



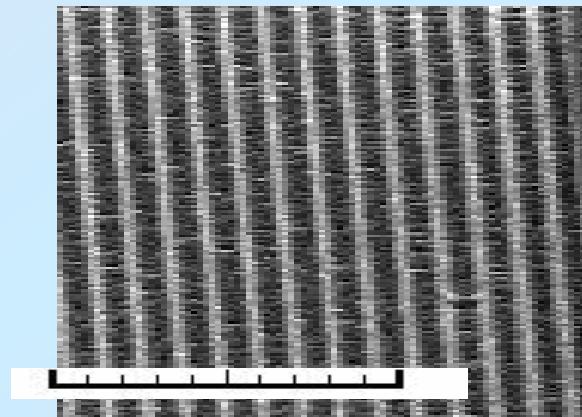
Detaliul minim: 600 nm (limita data de echipament)



EBL

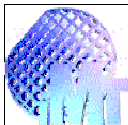


Retele de difracție din PMMA :-
perioada 200nm (linii de 100nm).

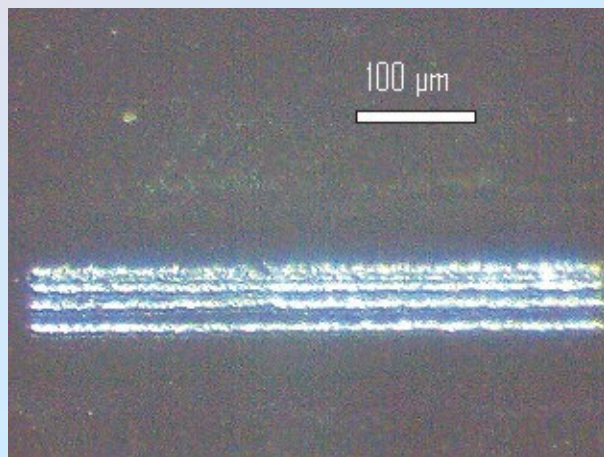
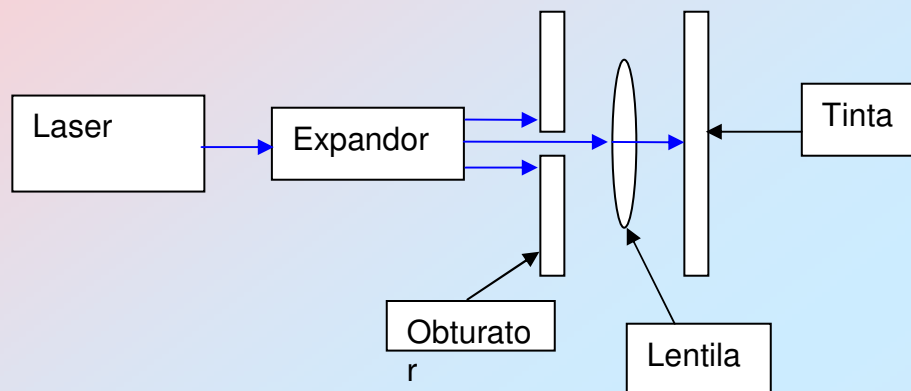


Retea de difracție (linii de
500nm) in Si obtinuta prin
EBL si corodare in plasma

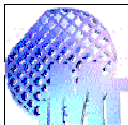
IMT



Inscriptionare cu laser in polimeri



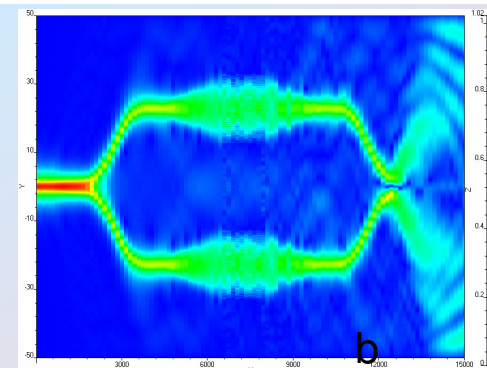
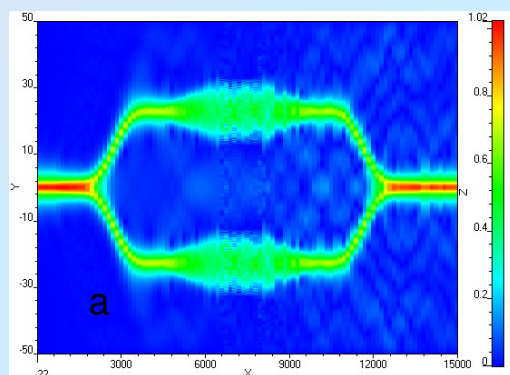
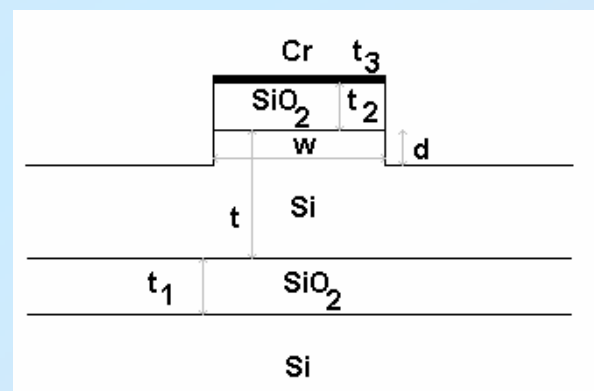
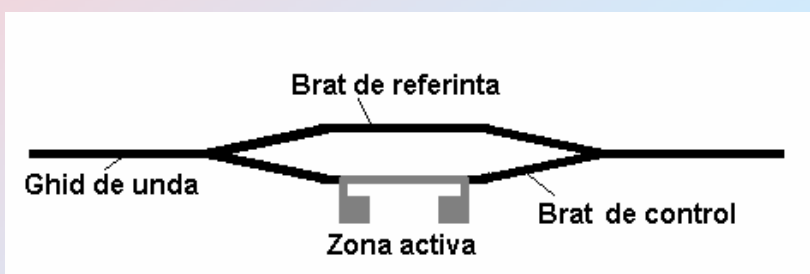
INFLPR



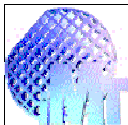
Tehnici de simulare/proiectare asistata de calculator

- Programe comerciale: OptiFDTD; OptiBPM, OptiGrating pentru simulare/proiectare circuite fotonice

Modulator termo-optic

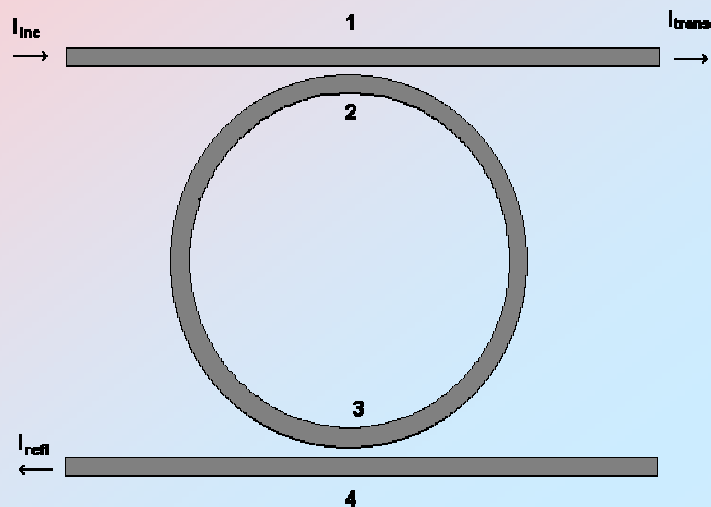


Propagarea radiatiei intr-un interferometru in cazul in care exista o diferenta de temperatura intre ghidurile de pe cele doua brate: a) $\Delta T = 0$; b) $\Delta T = 4$ K.

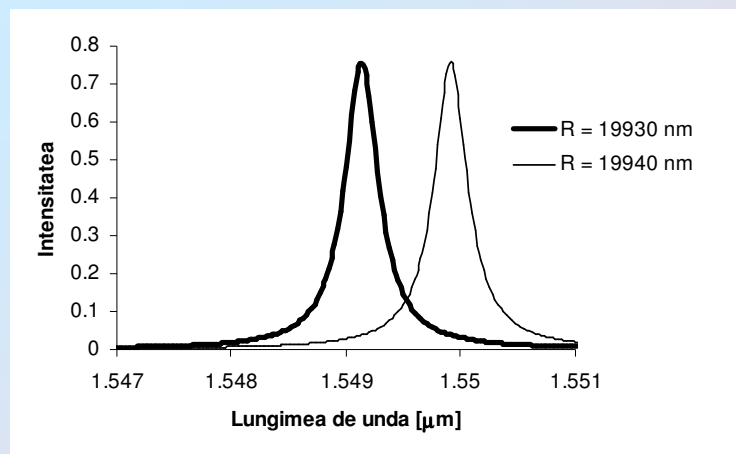


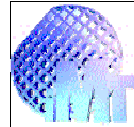
Microrezonator circular

Aplicatii: WDM (wavelength division multiplexing)



Raspunsul spectral - $I_{ref}(\lambda)$ al microrezonatorului circular pentru doua valori ale razei inelului.





INTEGRARE

Tehnologia siliciului + tehnologia straturilor subtiri oxidice (straturi multiple)

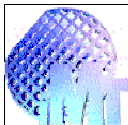


Fotodetector rapid cu raspuns spectral selectiv
(fotodioda pe Si integrata cu filtru interferential)

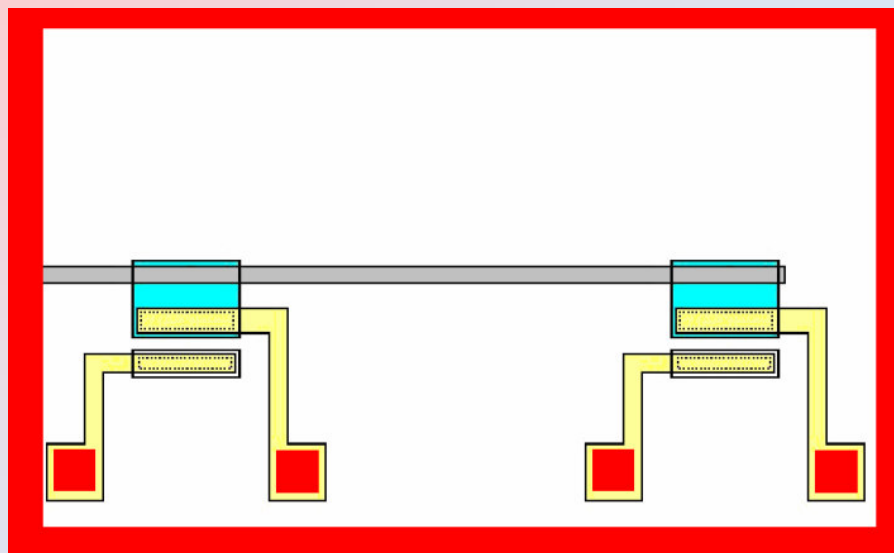
Tehnologia siliciului + tehnologia polimerilor



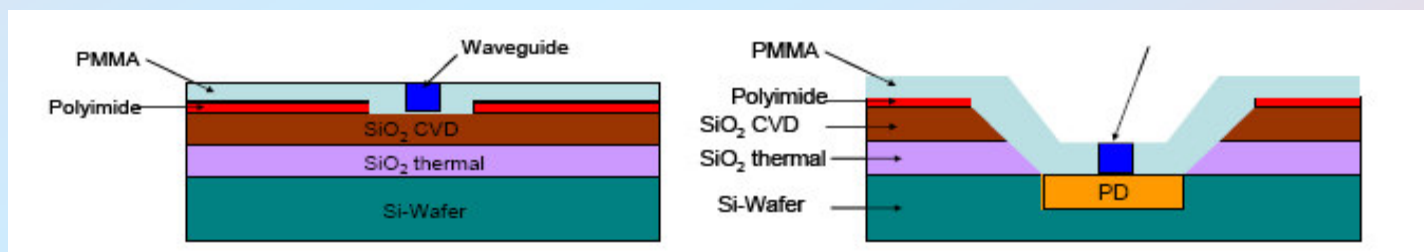
Circuit fonic integrat pentru interconexiuni optice



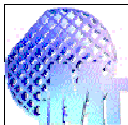
Circuit fonic integrat pentru interconexiuni optice



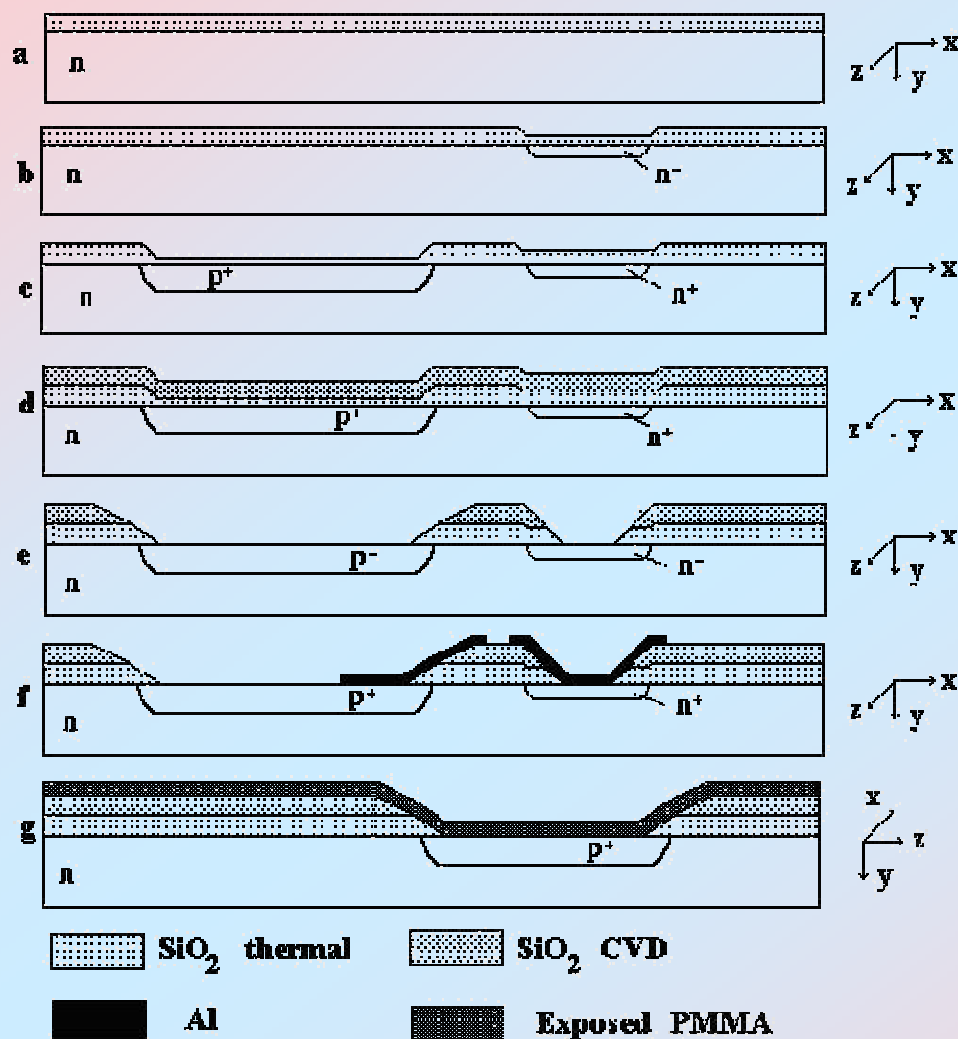
Lay-out



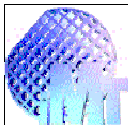
Sectioniune prin structura



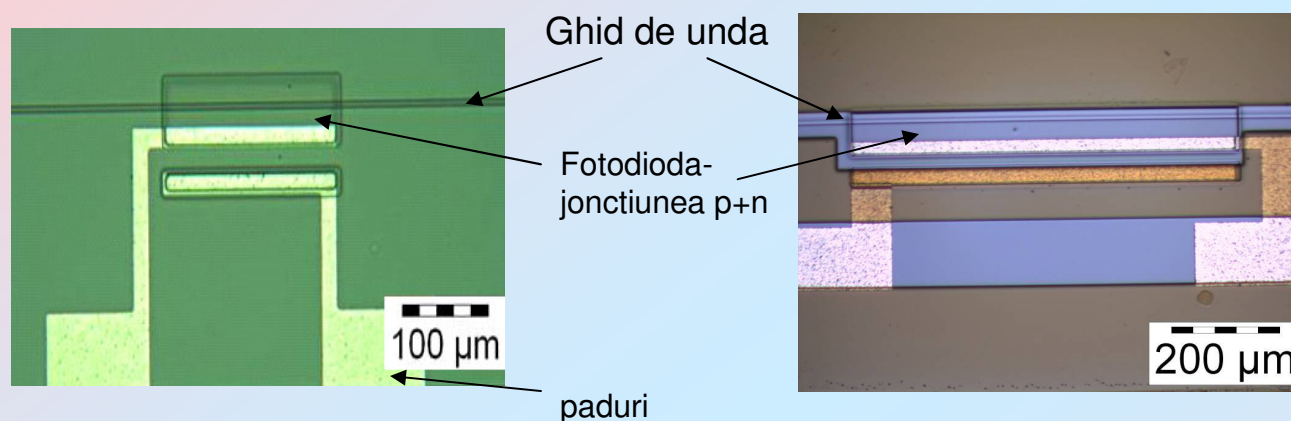
Circuit fonic integrat pentru interconexiuni optice



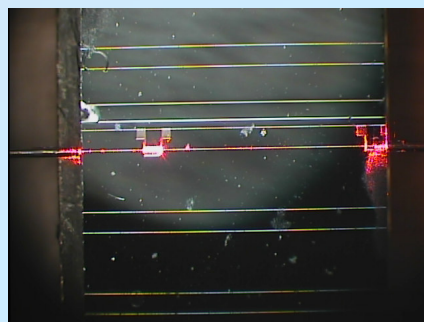
Flux tehnologic



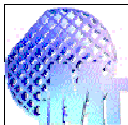
Circuit fonic integrat pentru interconexiuni optice



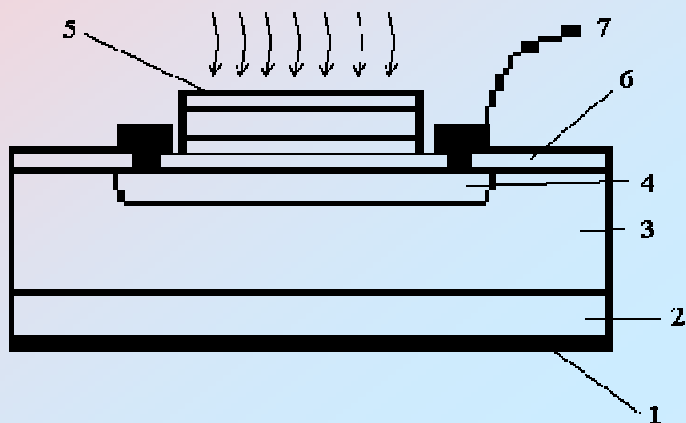
Imagini ale fotodiodei integrate cu ghidul de unda din PMMA



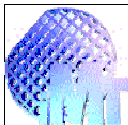
Propagarea radiatiei prin ghidurile de unda utilizate pentru conexiuni optice optice intra-cip



Fotodetector rapid cu raspuns spectral selectiv



Secțiune transversală prin structura de fotodetector rapid de tip PIN cu răspuns spectral selectiv.
1-contact de baza ; 2- strat difuzat p+ ; 3 – strat epitaxial de tip p ; 4 – zona difuzată n+ ;
5 – filtrul optic multistrat ; 6 – SiO₂ ; 7 – contact de Al.



Activitati de instruire

Instruire studenti- specializarea optoelectronica , MOEMS (UPB-CCO; IMT- colaborare: ore de laborator

Programe de master

- Optoelectronica- organizat de UPB-CCO; IMT- colaborator (2 cursuri: Circuite fotonice integrate; tehnologii pt. MOEMS)
- Tehnologia straturilor subtiri- organizat de UAIC

Programe doctorat- UPB-CCO si IMT colaborator

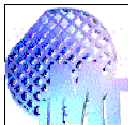
Participarea tinerilor cercetatori/doctoranzi la scoli internationale:

- **ePixnet School** , martie 2007-Elvetia si mai 2008- Italia
- “New frontiers in optical technologies” organizata de Centrul de cercetari optoelectronice (ORC) al Universitatii Tehnologice din Tampere, Finlanda

Diseminare

Articole

1. P. Obreja, D.Cristea, E. Budianu, R. Rebigan, V. Kuncser, M. Bulinski, G. Filoti "Effect of dopants on the physical properties of polymer films for microphotronics", **Progress in Solid State Chemistry** 34 92-40, 2006 p.103-109,
2. Dana Cristea, Paula Obreja, Mihai Kusko, Elena Manea, Roxana Rebigan, „ Polymer micromachining for micro- and nanophotonics", **Materials Science and Engineering - C** 26(5-7), (2006), p. 1049-1055
3. F. Iacomi, I. Salaoru, N. Apetroaei, A. Vasile , C.M. Teodorescu, D. Macovei, "Physical characterization of CdMnS nanocrystalline films grown by thermal evaporation technique", **Journal of Optoelectronics and Advanced Materials**, vol.8, (2006), p.268-270.
4. Felicia Iacomi, M. Vasilescu, S. Simon, "Studies of MnS Cluster Formation In Laumontite Zeolite", **Surface Science** 2006
5. V.Kuncser, M.Bulinsky, S.Kratwald, D.Cristea, P.Palade, C.Plapcianu, G.Filoti– Optical and electronic properties of (Fe+Sb):PVA for real time holography, **Journal of optoelectronics and advanced materials** 8 (2006), p.1225-1229.
6. M. Purica, F. Iacomi, C. Baban, P. Prepelita, N. Apetroaei, D. Mardare and D. Luca, Investigation of structural properties of ITO thin films deposited on different substrates, **Thin Solid Films**, 515, (2007), pp. 8674-8678
7. F. Iacomi, M. Purica, E. Budianu, P. Prepelita and D. Macovei, Structural studies on some doped CdS thin films deposited by thermal evaporation, **Thin Solid Films**, 515, 2007, Pp.6080-6084
8. P. Obreja, D. Cristea, M. Purica, R. Gavrilă, F. Comanescu, Polymers doped with metal oxide nanoparticles with controlled refractive index, **Polymer** 52 (2007), p.679-685.
9. Mihai Kusko and Dana Cristea Theoretical and numerical analysis of the microring resonator refractometers, **Proc. SPIE Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies, Vol. 6635**, (2007), p .663504 (8 pagini)
10. E. Budianu, M. Purica, F. Iacomi, C. Baban, P. Prepelita and E. Manea , Silicon metal-semiconductor–metal photodetector with zinc oxide transparent conducting electrodes, **Thin Solid Films**, 516 (2008), pp 1629-1633
11. M.Kusko, A.Kapsalis, C. Kusko, D.Alexandropoulos, D. Cristea, D. Syvridis , *Design of single-mode vertically coupled microring resonators* **J. Opt. A: Pure Appl. Opt.** 10 (2008)

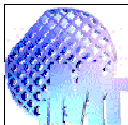


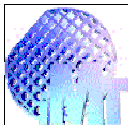
Diseminare

Carti

- O. Iancu, I. Cristea, *Memorii fotonice de mare capacitate* / ISBN 973-685-877-4, MATRIX-ROM, 2005
- Adrian Manea, *Sisteme optice pentru comunicatii* / ISBN 973-755-007-2, MATRIX-ROM, 2006
- Paul Schiopu, Velizar Sorescu, *Senzori si traductoare*, MATRIX-ROM, 2006e
- Valentin Feies, Andrei Dragulinescu, *Optoelectronica. Probleme* / ISBN (10) 973-755-024-2, ISBN (13) 978-973-755-024-8, MATRIX-ROM, 2006
- Monica Nadasan, Paul Schiopu *Cristale si pensete fotonice* / ISBN (10) 973-755-052-8, ISBN (13) 978-973-755-052-1 MATRIX-ROM, 2006
- Ovidiu , Iancu, Adrian Manea, Paul Schiopu, *Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies II* / ISSN 0277-786X, ISBN 0-8194-5991-7, SPIE-The International Society for Optical Engineering, SUA, 2005
- **Lucrari prezentate la conferinte internationale- peste 36: E-MRS IUMRS ICEM 2006 Spring Meeting- Nice, France; E-MRS Fall Meeting 2006- Varsovia, Polonia-; International Conference Advanced Topics in Optoelectronics, Microelectronics and Nanotechnologies ATOM-N 2006- Bucuresti; WAPITI/PICMOS Symposium, 7-8 December 2006, Halle, Germania; CAS 2006 si 2007; European Conference on Integrated Optics, April 25-27, 2007, Copenhagen, Denmark; European Conference and Exhibition on Optical Communication - ECOC 2007 September 16-20, 2007 - Berlin, Germany; XIVth International Sol-Gel Conference, September 2-7, 2007, Montpellier, Franța; Semiconductor Laser Workshop 2007, Berlin, September 14-15 2nd European Optical Society Topical Meeting, Capri (Napoli), Italia, 30 September – 3 October 2007, EMRS Spring Meeting 2008**

Simpozionul "Rezultatele cercetarii romanesti in domeniul tehnologiilor informatinale si de comunicatii obtinute in cadrul Programului CEEX - Modulul 1", Iunie 2008





Cooperari internationale

Participare in proiecte europene

- **FP6: WAPITI, 4M, PATENT, ASSEMIC, 4M;**

Proiecte europene castigate in perioada de derulare a contractului

- **Integrated Biophotonics Polymer Chip – Feasibility study** (colaborare cu FZK, Karlsruhe, Germania)- **Proiect finantat in cadrul retelei de excelenta 4M**
- **Proiect de colaborare bilaterala cu Italia- Trento Univ. – domeniul “nanophotonics”**
- **FP7: MIMOMEMS (Centru de excelenta European in RF si Optical MEMS)- perioada de derulare 2008-20011**