Investigation of semiconductor oxide materials performance for space environment applications - MATSPACE

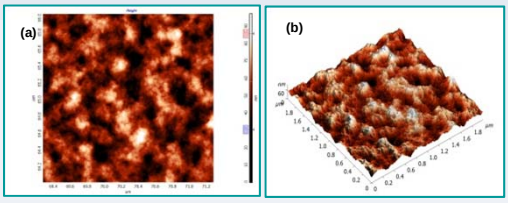
Programme for Research-Development-Innovation on Space Technology and Advanced Research – STAR
Subprogramme: S1 Research
Project Nr. 94 /29.11.2013-15.12.2015
***Coordinator*: IMT- Bucharest, Partner: National Institute of Materials Physics - NIMP Bucharest**
Project director: Dr. Rodica Plugaru
Authors: R. Plugaru, A. Istrate, I. Mihalache, R. Gavrila, B. Bita, O. Nedelcu, G. Boldeiu
National Institute for R & D in Microtechnologies (IMT), Erou Iancu Nicolae Str. 126 A, Bucharest 077190

Outline

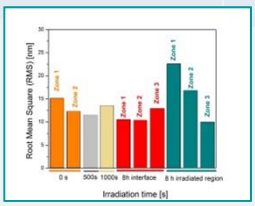
- Semiconductor oxide materials exhibit an exceptional potential for application in future generation of ultraviolet (UV) photodetectors, various types of sensors and solar cells, which are investigated for research and development of specific space applications.
- The project aims at the examination, understanding and description of the radiation response of widely investigated types of materials, through a combination of experimental, theoretical, and modeling methods.
- The obtained result contribute to the development of semiconductor technologies and materials for prospective radiation-hardened electronics.

Experimental

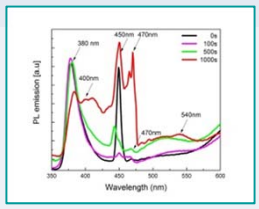
- At laboratory setup scale, the irradiation with high energy alpha particles has been used to study the effects on ZnO thin films for devices operating in space environment.
- ZnO, Li:ZnO, N:ZnO, Cu:ZnO, Mn:ZnO, (Li,N):ZnO, (Cu, N):ZnO, (Mn, N):ZnO films with wurtzite type structure, thickness of about 100 nm have been synthesized by sol-gel method. Several characterization methods were used to analyze the materials properties before and after irradiation [1-13].
- The Irradiations were performed at the U120 Cyclotron facility at the National Institute for R&D in Physics and Nuclear Engineering-"Horia Hulubei" (IFIN-HH), Bucharest, Romania.



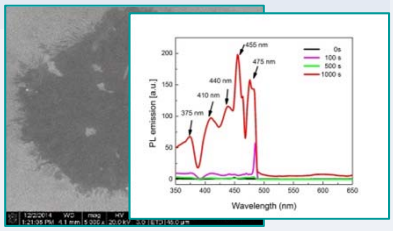
Surface morphology of non-irradiated ZnO films, showing an uniform distribution of the grains size and roughness. AFM images (a) 2D and (b) 3D.

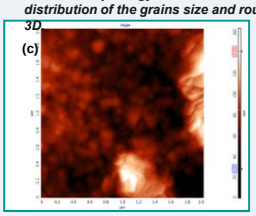


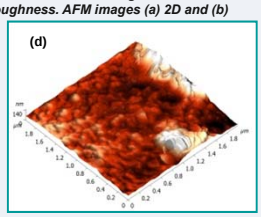
Variation of surface roughness after irradiation with 3 MeV alpha particles for 100 s, 500s, 1000 s



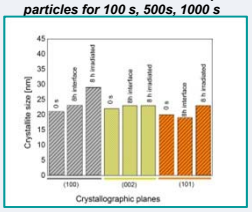
Photoluminescence emission of ZnO films irradiated with 3 MeV, 5.3 kGy/h alpha particles for: 100 s, 500 s, and



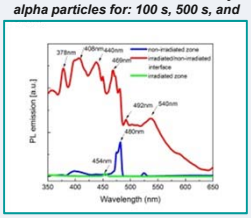




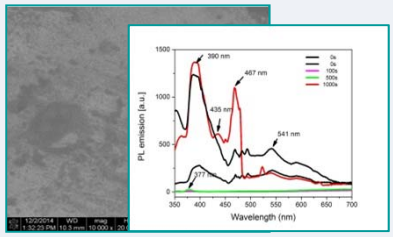
Surface morphology of ZnO films irradiated with alpha particles at 3 MeV, 5.3 kGy/h for 8 h, showing extended areas with low roughness and the formation of clusters or larger grains by thermal annealing effect following energy transfer from the incident particles. AFM images (c) 2D and (d) 3D.



Variation of crystallites size after 8 h irradiation with 3 MeV alpha particles.



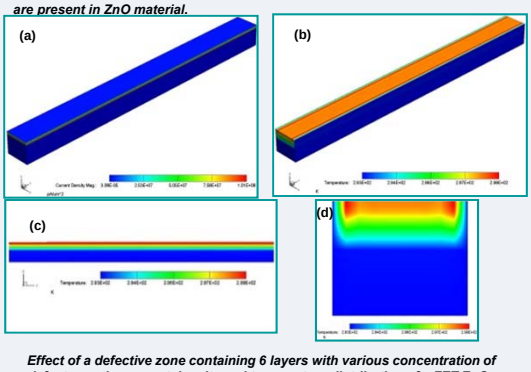
Photoluminescence emission of ZnO films irradiated with 3 MeV, 5.3 kGy/h alpha particles for 8h.



Field Emission Scanning Electron Microscopy images of Li:ZnO and N:ZnO films exposed to 3 MeV, 5.3 kGy/h alpha particles for 1000 s. Photoluminescence emission spectra of the films.

Numerical nodeling of electric and thermal behavior of defective devices

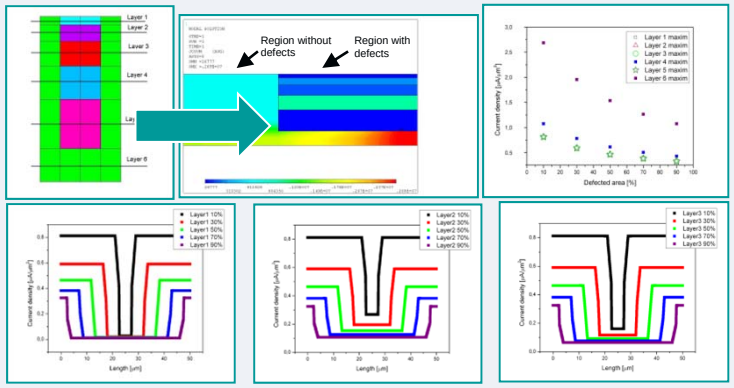
Coupled electrictro-thermal response of a FET transistors with ZnO thin films as active channel when various densities and areas of radiation - induced defects are present in ZnO material.



Effect of a defective zone containing 6 layers with various concentration of defects, on the current density and temperature distribution of a FET ZnO transistor with the channel dimensions: L=10 μm x W=600 μm

- *(a) Current density (pA/μm2).*
- *(b) Temperature distribution (K).*
- *(c) Temperature distribution (K) in longitudinal section of the channel.*
- *(d) Temperature distribution (K) in the cross section of the channel.*

Effect of a defective zone containing 6 layers with different defects concentration on the current flow in the channel of a FET ZnO transistor. The FET channel dimensions: L=10 μm x W=500 μm.



Current density as function of defected area (%) for each layer with defects considered in the model of a FET ZnO transistor.

Current density values as function of defected area size in each layer, which varies in the range 10 %- 90 % of the layer size.

Concentration of defects, their distribution and the size of the defected regions strongly affect the current density and the temperature in the FET channel.

Publications

[1] Investigation of acceptor centers formation in (N, Li) codoped ZnO films
R. Plugaru, A. Danciu, I. Mihalache, N. Plugaru
Oral presentation: Electroceramics XIV *2014, Bucharest, Romania, 16-20 June 2014*

[2] EPR probing with Mn^{2+} ions of ZnO nanostructures
M. Stefan, D. Ghica, S. V. Nistor, C. Ghica
Oral presentation: EURODIM *2014, University of Kent, UK, 13-19 July 2014*

[3] Effect of Li, Cu and N doping on the morphology, optical and electrical properties of ZnO thin films prepared by spin- coating technique
A. Danciu, I. Mihalache, B. Bita, R. Plugaru
Presented at *14th International Balkan Workshop on Applied Physics and Materials Science, Constanta, Romania, 2-4 July 2014.*
Under publication: *J. Optoelectron. Adv. Materials.*

[4] Study of annealing in nitrogen atmosphere of the structural, photoluminescence emission and electrical properties of Li and Cu doped sol-gel ZnO films
A. Danciu, I. Mihalache, M. Danila, B. Bita, R. Plugaru
Presented: CAS Conference 2014, *Sinaia, Romania, 13-15 October 2014.*
Publised*: CAS 2014 Proc. p 77-80.*

[5] Structural and functional properties of (Cu, N) co-doped ZnO films
Oral presentation*: The 3rd Global Conference on Materials Science and Engineering (CMSE 2014), Oct. 20th-23rd, Shanghai, China.*

[6] First principles study of the semiconductor to metal transition, dc conductivity and magnetism in (Al, Ti) codoped ZnO, *Rodica Plugaru, T. Sandu, N. Plugaru*
Oral presentation*: E-MRS 2014 Fall Meeting, 15-18 ptember, Warsaw, Poland.*

[7] Numerical study of electronic and thermal behavior of defective ZnO thin films
Oana Nedelcu, George Boldeiu, Rodica Plugaru
Presented: *18th International School on Condensed Matter Physics (ISCMP) September 1-6, 2014, Varna, Bulgaria.*

[8] GGA+U study of RMn2O5 (R=Bi, Y, Gd, Tb, Dy, Ho), *N. Plugaru*
Presented: *CECAM/ Psi-k Research Conference: Frontiers of first-principles simulations: materials design and discovery, February 1-5, 2015 in Berlin, Germany.*

[9] Study of point defects in ZnO thin films irradiated with alpha particles
Rodica Plugaru, A. Istrate, I. Mihalache and R. Gavrila
Presented*: Conference on Defects in Semiconductors-ICDS, July 27–31, 2015, Helsinki, Finland.*

[10] Study on the porosity of Mn and Ga doped ZnO films synthesized by sol-gel method
A. Istrate, M. Danila, B. Bita, I. Mihalache, F. Comanescu, R. Plugaru, M. Purica
Presented: *E-MRS 2015 FALL, Fall Meeting of the European Materials Research Society, 15-18 September 2015, Warsaw, Poland.*

Best Poster Award Symposium L, E-MRS 2015 Symposium L: Towards oxide-based electronics: growth and applications of oxide thin films and heterostructures II

[11] Manganese ions distribution in doped sol-gel deposited ZnO films
Mariana Stefan, Daniela Ghica, Sergiu V. Nistor, Adrian V. Maraloiu, Rodica Plugaru
Presented: *E-MRS 2015 FALL, Fall Meeting of the European Materials Research Society, 15-18 September 2015, Warsaw, Poland.*

[12] Exchange Interactions and Magnetic Structures of RMn2O5 by First-Principles Calculations
R. Plugaru, N. Plugaru, L. Filip, ***Presented****: Ψk-2015 conference, 6-10 September 2015, San Sebastian, Spain.*

[13] Investigation of structural, optical and electrical properties of (Li/Cu,N):ZnO codoped thin films
Oral presentation*: Advances in Nanophysics and Nanophotonics, Workshop at National Institute of Materials Physics, 31st of August-2nd of September 2015, Bucharest, Romania.*