

FINAL REPORT

Student name: Matteo Buffolo

Cycle: XXX

Curriculum: *Information Engineering*

Supervisor name: Matteo Meneghini

Thesis title (final): Reliability of III-V laser diodes and LEDs for lighting and telecommunication applications

PART 1 - COURSES, CONFERENCES AND MOBILITY

Courses for Ph.D. students

- "Introduction to Quantum Optics, Quantum Information and Quantum Communications", CFU: 5, Prof. P. Villoresi, Prof. G. Vallone
- "Physics and operation of heterostructure-based electronic and optoelectronic devices", CFU: 5, Prof. G. Meneghesso
- "Statistical methods", CFU: 6, Prof. L. Finesso
- "Digital Processing of Measurement Information", CFU: 4, Prof. C. Narduzzi

Seminars

- "Light-emitting diodes and applications. The era of solid-state lighting", Dr. Matteo Meneghini, University of Padova
- "Multifunctional organic field-effect transistors as a technological platform for sensing and biodiagnostics", Dr. Stefano Toffanin, ISMN-CNR, Bologna.
- Seminar by Johannes Glaab, FBH, on AlGaIn devices
- Dr. Kenichiro Tanaka, Panasonic Corporation "Device physics of E-mode gate-injection transistors (GIT)"
- Agata Bojarska, Institute of High Pressure Physics, Unipress, Sokolowska: "Factors influencing InGaIn laser diodes degradation"
- Sven Besendoerfer, Fraunhofer Institute: "Material investigation on GaIn HEMTs structures"
- Mehdi Rzin, University of Normandie, Caen, France: "Impact of Gate-Drain Spacing on Low-Frequency Noise Performance of In Situ SiN Passivated InAlGaIn/GaIn MIS-HEMTs"

Participation to International Conferences and Workshops

- WOCSDICE 2015, June 8-10 2015, Smolenice (Slovacchia)
- LED PROFESSIONAL 2015, September 22-24 2015, Bregenz (Austria)
- ESREF 2105, October 5-9 2015, Toulouse (France)
- "Gallium Nitride technology in Europe", April 27-28 2016, Padova (Italy)
- LS15, May 23-27 2016, Kyoto (Japan)
- FOTONICA 2016, June 6-8 2016, Rome (Italy)
- ESREF 2106, September 19-22 2016, Halle (Germany)

Other learning activities

- CORE1 Labview programming course at IRS (Padova), January 26 – 28 2015.
- CORE2 Labview programming course at IRS (Padova), February 26 – 27 2015.
- DAQ Labview programming course at DEI (Padova), July 13 – 14 2017.

PART 2 - RESEARCH ACTIVITY

During the course of the PhD, the reliability and the degradation mechanisms of III-V laser diodes and LEDs for lighting and telecommunication applications have been investigated. The experimental activity focused on three main topics:

1. Long-term aging and catastrophic failure of GaN-based LEDs submitted to electrical overstress:
 - Experimental observation of TDDDB-like behavior in reverse-biased green InGaN LEDs
 - Failure of High Power LEDs Submitted to EOS: Dependence on Device Layout and Pulse Properties
 - Catastrophic failure of high-power blue GaN LEDs submitted to high temperature and current stress
 - Long-Term Degradation Mechanisms of Mid-Power LEDs for Lighting Applications
 - Failure causes and mechanisms of retrofit LED lamps
2. Reliability of phosphorescent materials for laser-lighting applications:
 - Reliability of blue phosphors for 405 nm excitation
 - Reliability of YAG:Ce³⁺ yellow phosphors for 450 nm excitation
3. Degradation mechanisms of heterogeneous III-V/Silicon laser diodes:
 - Degradation Mechanisms of Heterogeneous III-V/Silicon 1.55 μm DBR Laser Diodes
 - Degradation Mechanisms of Heterogeneous III-V/Silicon 1.3 μm Laser Diodes

PART 3 - PUBLICATIONS

List of publications on international journals

- J1. C. De Santi, M. Meneghini, M. Buffolo, G. Meneghesso and E. Zanoni, "Experimental Demonstration of Time-Dependent Breakdown in GaN-Based Light Emitting Diodes," in *IEEE Electron Device Letters*, vol. 37, no. 5, pp. 611-614, May 2016.
DOI: 10.1109/LED.2016.2543805
- J2. M. Buffolo, M. Meneghini, A. Munaretto, C. De Santi, G. Meneghesso and E. Zanoni, "Failure of High Power LEDs Submitted to EOS: Dependence on Device Layout and Pulse Properties," in *IEEE Transactions on Device and Materials Reliability*, vol. 17, no. 1, pp. 191-196, March 2017. DOI: 10.1109/TDMR.2016.2642167

- J3. M. Buffolo, M. Meneghini, C. De Santi, M. Davenport, J. Bowers, G. Meneghesso, E. Zanoni, "Degradation Mechanisms of Heterogeneous III-V/Silicon 1.55 μm DBR Laser Diodes," in *IEEE Journal of Quantum Electronics*, vol. 53, no. 4, pp. 1-8, Aug. 2017. DOI: 10.1109/JQE.2017.2714582

List of publications on conference proceedings

- C1. M. Buffolo, C. De Santi, M. Meneghini, G. Meneghesso, E. Zanoni "Mid-power LEDs for lighting applications: degradation mechanisms and kinetics", proceedings of WOCSDICE 2015
- C2. M. Dal Lago, M. Buffolo, C. De Santi, N. Trivellin, M. Meneghini, G. Meneghesso, E. Zanoni "High-Temperature Reliability of Retrofit LED Bulbs", proceedings of LpS 2015
- C3. (CONFERENCE+JOURNAL) M. Buffolo, C. De Santi, M. Meneghini, D. Rigon, G. Meneghesso, E. Zanoni "Long-Term Degradation Mechanisms of Mid-Power LEDs for Lighting Applications", *Microelectronics Reliability* 55 (9-10), pp. 1754-1758, (2015), DOI: 10.1016/j.microrel.2015.06.098
- C4. (CONFERENCE+JOURNAL) C. De Santi, M. Dal Lago, M. Buffolo, D. Monti, M. Meneghini, G. Meneghesso, E. Zanoni "Failure causes and mechanisms of retrofit LED lamps", *Microelectronics Reliability* 55 (9-10), pp. 1765-1769, (2015). DOI: 10.1016/j.microrel.2015.06.080
- C5. C. De Santi, M. Dal Lago, M. Buffolo, M. Meneghini, G. Meneghesso, E. Zanoni "Analysis of the mechanisms limiting the reliability of retrofit LED lamps", proceeding of RTSI 2015
- C6. M. Buffolo, C. De Santi, M. Meneghini, G. Meneghesso, E. Zanoni, "Reliability of mid-power LEDs for lighting applications", proceedings of FOTONICA 2016
- C7. (CONFERENCE+JOURNAL) M. Buffolo, M. Meneghini, C. De Santi, H. Felber, N. Renso, G. Meneghesso, E. Zanoni, Experimental observation of TDDB-like behavior in reverse-biased green InGaN LEDs, *Microelectronics Reliability*, Volume 64, 2016, Pages 610-613, ISSN 0026-2714, DOI: 10.1016/j.microrel.2016.07.103
- C8. M. Buffolo, N. Trivellin, M. Meneghini, D. Barbisan, N. Ferretti, G. Meneghesso, E. Zanoni, "Electrical overstress robustness of latest generation LEDs for general lighting", proceedings of LED Professional symposium 2016, Bregenz (Austria)
- C9. M. Buffolo, M. Meneghini, G. Meneghesso, E. Zanoni, "EOS-related failures of modern High-Brightness white LEDs: failure limits and correlation with device structure" proceedings of LS15, Kyoto (Japan)
- C10. C. De Santi, M. Meneghini, M. Buffolo, G. Meneghesso, E. Zanoni "Time-Dependent Breakdown in GaN-Based LEDs—Description and Physical Origin", proceedings of IWN 2016 conference, Orlando, Florida (USA)

- C11. E. Zanoni, N. Trivellin, M. Meneghini, G. Meneghesso, D. Barbisan, C. De Santi, M. Ferretti, M. Buffolo, "*LED lighting: nuove piattaforme tecnologiche per l'illuminazione ad alta efficienza*", proceedings of Luce e Design 2016
- C12. M. Meneghini, M. Buffolo, N. Renso, C. De Santi, N. Trivellin, G. Meneghesso, E. Zanoni "*Investigation of the time-dependent failure of InGaN-based LEDs submitted to reverse-bias stress*", PSPIE 10124, Light-Emitting Diodes: Materials, Devices, and Applications for Solid State Lighting XXI, 101240F (16 February 2017); DOI: 10.1117/12.2256023
- C13. (submitted) M. Buffolo, M. Meneghini, C. De Santi, M. Davenport, J. Bowers, G. Meneghesso, E. Zanoni, "Degradation Mechanisms of Heterogeneous III-V/Silicon 1.55 μm DBR Laser Diodes," submitted to PW2016 conference
- C14. (in press) N. Renso, M. Meneghini, M. Buffolo, C. De Santi, G. Meneghesso, E. Zanoni, Understanding the degradation processes of GaN based LEDs submitted to extremely high current density, Microelectronics Reliability, 2017, ISSN 0026-2714, DOI: 10.1016/j.microrel.2017.06.044
- C15. Nicola Trivellin, Matteo Buffolo, Matteo Meneghini, Enrico Zanoni, Gaudenzio Meneghesso, "*White light source based on GaN laser diode*" proceedings of WOCSDICE 2017
- C16. (submitted) Nicola Trivellin, Maksym Yushchenko, Matteo Buffolo, Carlo De Santi, Matteo Meneghini, Enrico Zanoni, Gaudenzio Meneghesso "*Laser-based lighting: Experimental Analysis and Perspectives*", submitted to the special issue "Light-emitting Diodes and Laser Diodes: Materials and Devices" of Materials

Date

28/08/17

Student signature



Supervisor signature

