Cotutelle PhD position in thin film technologies and optical properties

Control of the mechanical stress induced by dielectric thin films to engineer optical properties in semiconductor materials and devices

General information:

- Duration: 36 months
- Starting date: October 1st, 2019
- Location: Institut de Physique de Rennes / Institut FOTON (Rennes-1 University, INSA-Rennes and CNRS, France) and Engineering Physics Department, McMaster University (Hamilton, Ontario, Canada)
- Supervisors: Professor Peter Mascher (McMaster University), Professor Jean-Pierre Landesman and Professor Christophe Levallois (Rennes)

Positioning of the research project:

Changing and tuning locally, by an external stimulus, some of the fundamental properties of the materials involved in semiconductor device manufacturing is nowadays a well-established approach ("properties on demand"). Using a locally stressed thin film ("stressor") could allow for the control of the optical properties, opening the route to the development of new concepts for photonic devices. If applied for example to the tuning of the local optical index of a semiconductor material like indium phosphide, this would permit simpler manufacturing procedures for optical waveguide components such as required in the optical telecommunication industry. This has been proposed already in the early 2000s for the design of optical semiconductor waveguides ("photoelastic waveguides") but not too much developed. A number of research groups and companies are presently involved in this type of project. Common recent work between McMaster U. and Rennes-1 aimed at better understanding and modelling the mechanical stress field induced by thin films on semiconductors like InP opens interesting ways for the investigation of stressor effects.

Detailed description:

The proposed project will address different questions:

- How to control and understand residual stress during the growth of dielectric films (SiO_x, SiN_x) on semiconductor substrates? The growth technique that will be used at McMaster will be mainly plasma enhanced chemical vapor deposition, widely used in the semiconductor industry. Although this is an old problem, the understanding is still rather empirical.
- How to measure accurately the stress field induced locally in the semiconductor substrate by the stressed dielectric film? Different descriptions are available in the literature, but recent experimental developments in our groups and in other collaborators' groups (CEA-LETI Grenoble – France, University Valladolid - Spain) give evidence that more effects need to be included. In particular the anisotropic part of the crystal deformation has not been properly taken into account.
- Can we propose an accurate numerical model that could be used in the design of devices such as photoelastic waveguides? Can we also use such a model to explain effects observed by manufacturers of such devices, thus allowing for a correction?

- The project will also focus on demonstrating new applications of the stressor concept to design photonic devices based on the photoelastic effect in materials such as InP, GaAs, or even Si.

The experimental resources available at McMaster U. are the different reactors for the growth of dielectric thin films and tools for their characterization (e.g. spectroscopic ellipsometry), the clean room equipment for simple processing operations, and the facilities of the Canadian Center for Electron Microscopy. In Rennes, we will make extensive use of a unique stress measurement set-up (degree of polarization of the photo-luminescence) as well as other tools available (especially spectroscopic ellipsometry, microRaman and microPL), and also of the Comsol tool for numerical simulations. Cathodo-luminescence experiments will also be performed.

<u>Representative papers on the subject and related research :</u>

- M. Mokhtari, P. Pagnod-Rossiaux, F. Laruelle, J.P. Landesman, A. Moreac, C. Levallois, D. T. Cassidy, Journal of Elec. Mater. 47 (2018), 4987-4992.
- J.P. Landesman, D. T. Cassidy, M. Fouchier, E. Pargon, C. Levallois, M. Mokhtari, J. Jimenez, A. Torres, Journal of Elec Mater. 47 (2018), 4964-4969.
- J.P. Landesman, D. T. Cassidy, M. Fouchier, C. Levallois, E. Pargon, N. Rochat, M. Mokhtari, J. Jiménez, and A. Torres, Opt. Lett. 43 (2018), 3505-3508.
- G. Zatryb, P.R.J. Wilson, J. Wojcik, J. Misiewicz, P. Mascher, and A. Podhorodecki, “Raman scattering from confined acoustic phonons of silicon nanocrystals in silicon oxide matrix”, Physical Review B 91 (2015), 235444.
- G. Zatryb, J. Misiewicz, P.R.J. Wilson, J. Wojcik, P. Mascher, and A. Podhorodecki, “Stress transition from compressive to tensile for silicon nanocrystals embedded in amorphous silica matrix”, Thin Solid Films 571 (2014), 18-22.
- “Planar InGaAsP/InP photoelastic waveguides with low propagation loss”, X.S. Jiang, Q.Z. Liu, L.S. Yu, Z.F. Guan, W. Xia, S.A. Pappert, P.K.L. Yu, and S.S. Lau, Materials Chemistry and Physics 38 (1994), 195-198.
- “Characteristics of photoelastic waveguides in SiGe/Si heterostructures”, E. Lea and B.L. Weiss, Electron. Lett. 33 (1997), 292-293.
- “2D strain mapping using scanning transmission electron microscopy Moiré interferometry and geometrical phase analysis”, A. Pofelski, S.Y. Woo, B.H. Le, X. Liu, S. Zhao, Z. Mi, S. Löffler, G.A. Botton, , Ultramicroscopy 187 (2018), 1–12.

<u>Qualifications :</u>

M.Sc. or engineering diploma with skills in at least one of the following areas:
- physics of semiconductor materials and devices
- optical characterization
- thin film growth and processing

<u>Contact persons :</u>

Peter Mascher: mascher@mcmaster.ca
Jean-Pierre Landesman: Jean-Pierre.Landesman@univ-rennes1.fr
Christophe Levallois : Christophe.Levallois@insa-rennes.fr