McMaster – France cooperation in condensed matter physics (some examples)

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Outline:

- Overview of the cooperation between McMaster and French universities / CNRS in the field of condensed matter physics

- Joint work on neutron scattering and crystal growth (McMaster – EU) Bruce Gaulin, McMaster

- Joint work on thin film technologies for opto-electronic and photonic applications (McMaster – Rennes 1 – CNRS) Jean-Pierre Landesman, Rennes

Collaboration between McMaster and condensed matter physics groups in France

This has been particularly active for more than 30 years.

Key groups in France which have historically contributed to this collaboration:

Grenoble, Lyon, Orsay (now Paris-Saclay)

More recently: Rennes

In February 2018 McMaster organized the 1st joint workshop with the French Centre National de la Recherche Scientifique (CNRS)

This 3-days workshop received support and funding from the CNRS Bureau in Washington (Dr X. Morise) and from the French Embassy in Ottawa (Dr A. Rauzy)

Attendees from France: about 30 from different places, working in different fields including condensed matter physics, chemistry, mathematics, …

The 2nd workshop took place in Grenoble, in July 2019. During this workshop, discussions with the CNRS started to consider establishing an International Research Network between French groups and Southern-Ontario universities.

Thin film technologies for opto-electronic and photonic applications

- This project started during Jean-Pierre Landesman's sabbatical stay with McMaster Engineering Physics Dept in 2017 - 2018

- Overall topic:
  - Monitor mechanical stress effects taking place during dielectric thin film deposition processes such as used in the micro-electronics and photonics industries
  - Take benefit of this knowledge to design new stress engineering approaches beneficial for various kinds of photonic devices

- Scientists involved:
  - Dr Peter Mascher (Center for Emerging Devices Technology and Engineering Physics Dept McMaster)
  - Dr Jean-Pierre Landesman (Physics and Photonics – Rennes)
  - Dr Christophe Levallois (Photonics – Rennes)


LEGENDE
Deux voies ou plus
Voie unique
Electrifié en 1500 V CC
marchandises
Electrifié en 25 kV 50 Hz
marchandises
Electrifié en 3000 V CC
marchandises
Electrifié en 15 kV 16,7 Hz
marchandises
Autres courants
Non électrifié
En projet
Voie étroite
Electrifiée
Non électrifiée
Ligne touristique
Tiretés : en construction
Lignes marchandises non électrifiées non représentées
Dernière version et conditions d'utilisation disponibles à :
http://www.bueker.net/trainspotting
Situation octobre 2005
Dessin
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CARTE DES ILES BRITANNIQUES
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CARTE DE LA PENINSULE IBERIQUE
Voir agrandissement
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PARIS
LYON
MARSEILLE
Rennes
Ande. : Andelot
B. : Breuilpont
Blain. : Blainville-Damelevières
C. : Corbeil
Cer. : Cernay
Cha. : Chamonix
Co. : Cocherel
Comp. : Compiègne
Dn : Dourdan
Dou. : Douai
Fontvi. : Fontvieille
G. : Guîtres
Graven. : Gravenchon
H. : Hagondange
H.B. : Hombourg Budange
Hag. : Haguenau
Liv. : Livron
Lour. : Lourches
Luné. : Lunéville
M. : Marcenais
Moir. : Moirans
Niederb. : Niederbronn
Pont A. : Pont Audemer
S. : Somain
Sarre-U. : Sarre-Union
Sarreb. : Sarrebourg
St R. : St Rambert d'Albon
St Quen. : St Quentin
Tara. : Tarascon
Thi. : Thionville
V. : Valence
Valenci. : Valenciennes
Ven. : Vendenheim
Vézel. : Vézelise

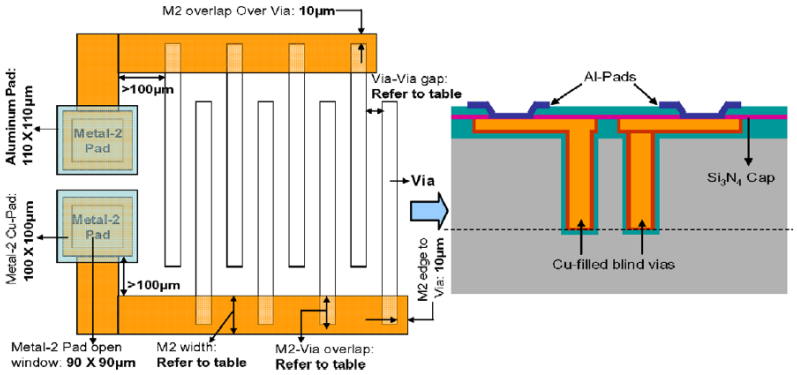
The scientific campus

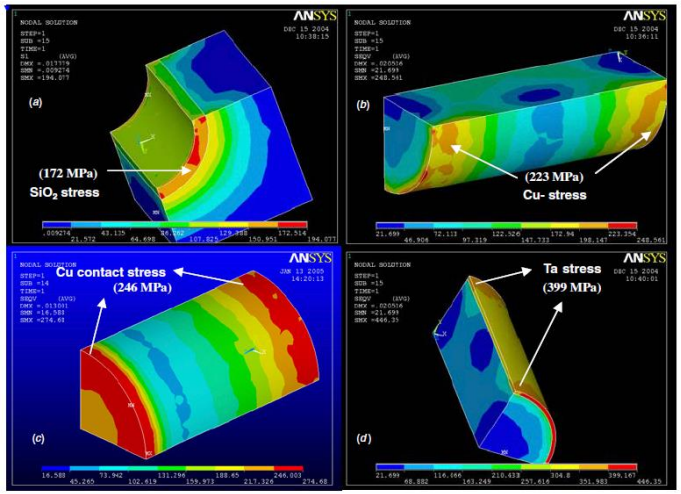
Rennes opera

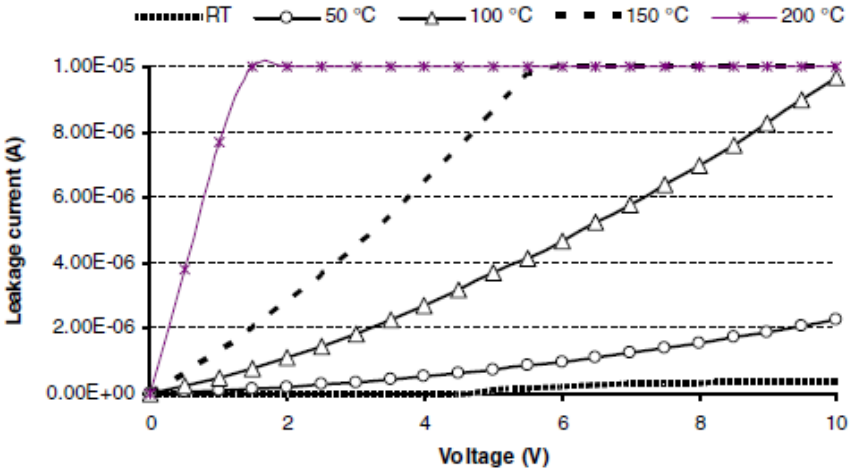
Why is mechanical stress a hot topic for semiconductor devices ?

First of all, mechanical stress at any level in semiconductor devices is a RELIABILITY concern

A study on the impact of localized stresses in the various materials that constitute “Via hole” structures in Si on the **leakage current** in a test device

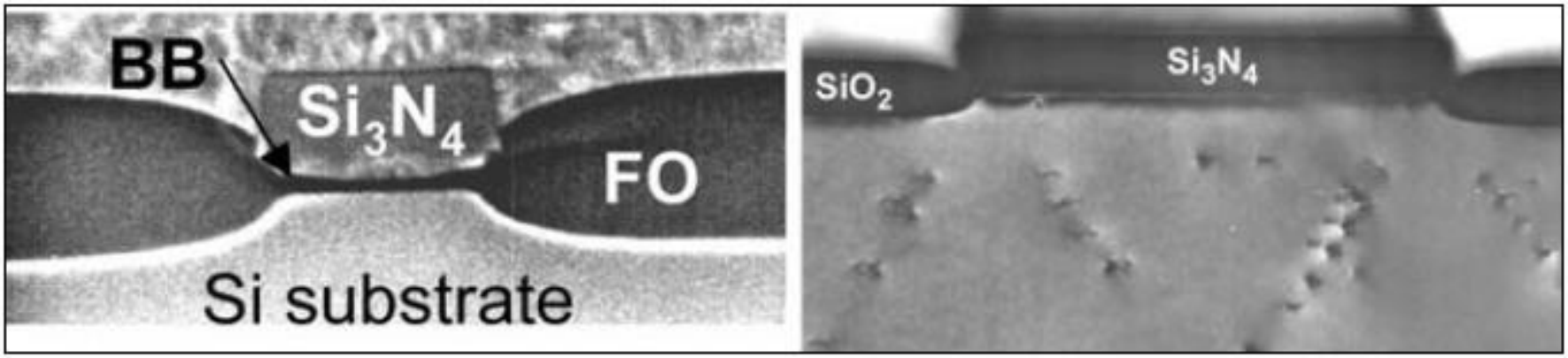


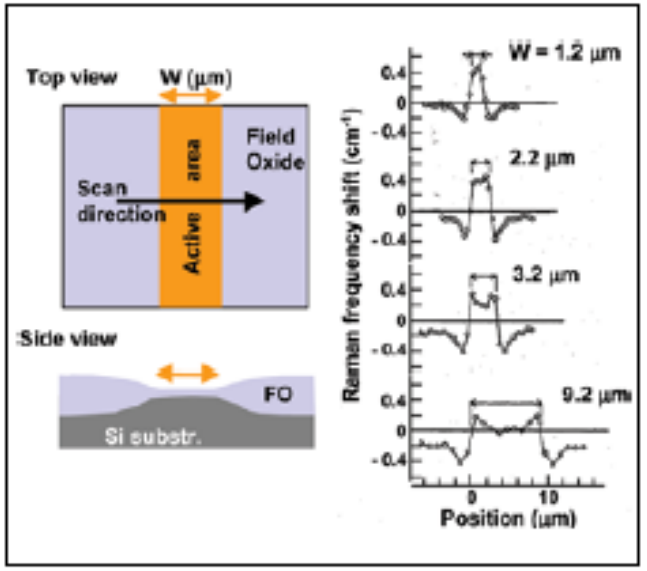




N Ranganathan, K Prasad, N Balasubramanian, K L Pey, J. Micromech. Microeng. 18 (2008)

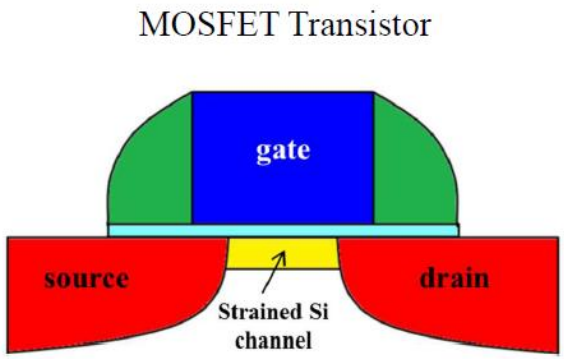
Dislocation generation in Si due to mechanical stress build-up underneath a LOCOS area. The dislocations are concentrated in zones where the shear stress is important.

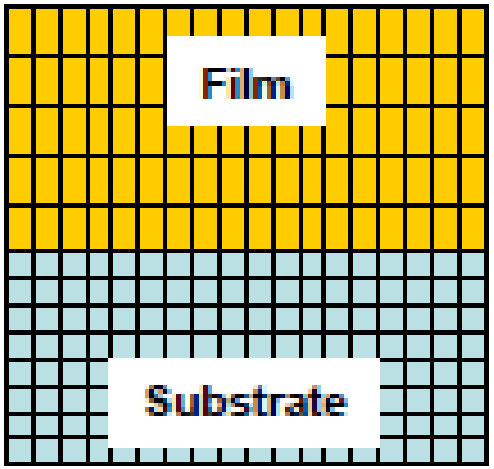


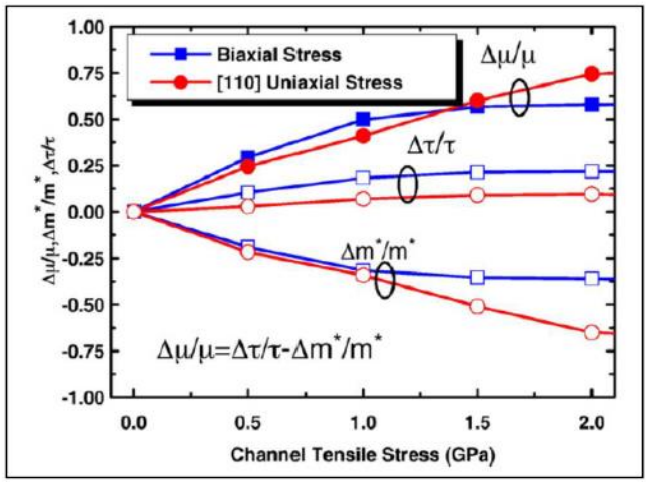


I. De Wolf, Spectroscopy Europe 15/2 (2003)

Strained materials are also introduced deliberately in some semiconductor devices resulting in improved properties (carrier mobility in Si, efficiency of III-V semiconductor laser diodes)

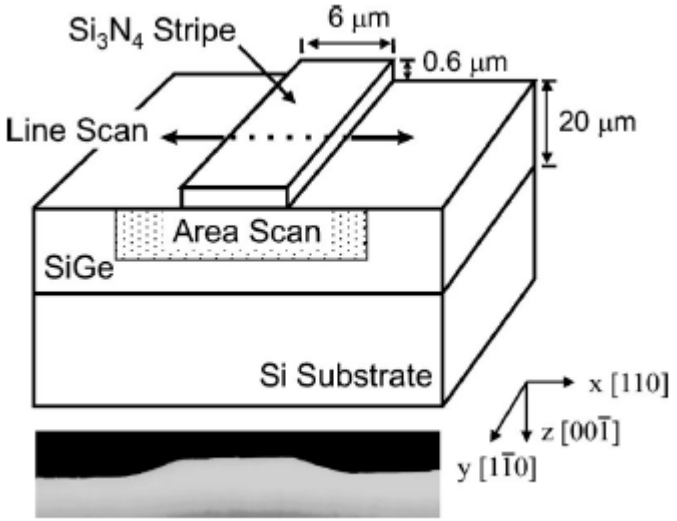


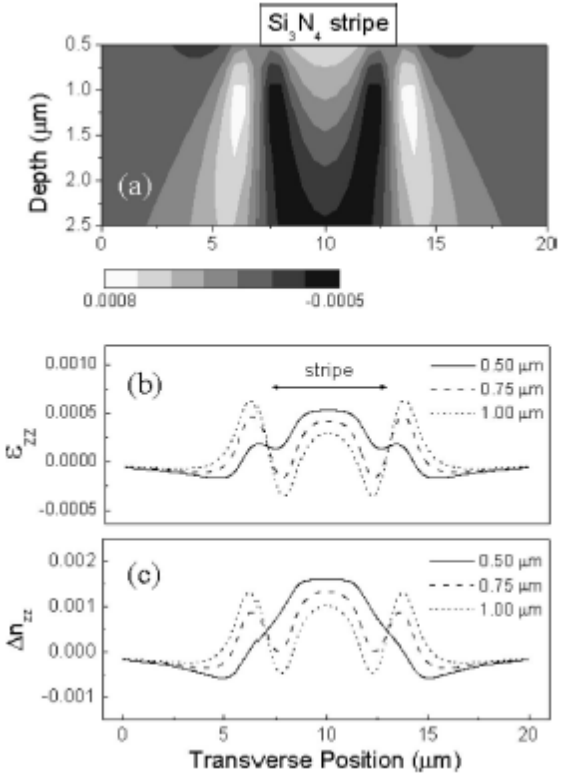




J. Huang et al. Thin solid films 518 (2010)

LOCAL stress, resulting from an external action, can also be used to tune the optical index of waveguiding structures (“Photo-elastic waveguides”)





H. Rho, H. E. Jackson, and B. L. Weiss, J. Appl. Phys. 90, 276 (2001)

Main directions for our research project

- Compare different tools for the deposition of dielectric thin films available at McMaster and Rennes, especially for the control of built-in stress

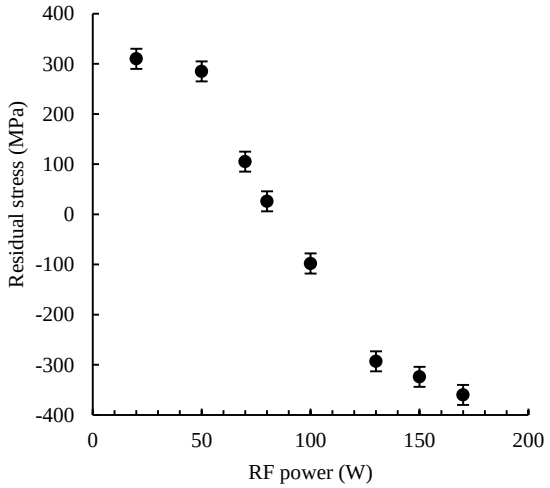
- Take benefit of the complementarity of the tools to fully characterize these thin films and their effects on the semiconductor substrate materials

- Perform accurate numerical simulations to understand the mechanical stress effects and predict possible configurations for stress engineered devices

- Perform some developments for initial demonstator photonic devices

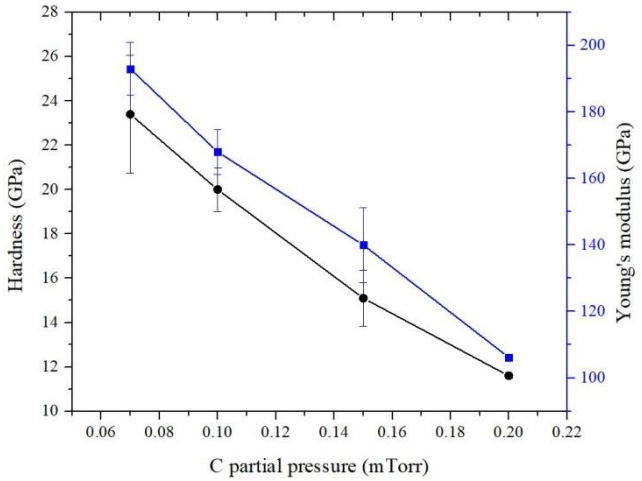
Thin film mechanical properties

Built-in stress in SiN_x films deposited on Si by PECVD, as a function of the RF power; film thickness: 500 nm; precursor gas: $SiH_4/NH_3/N_2/Ar$; deposition temperature: 280 ° C.



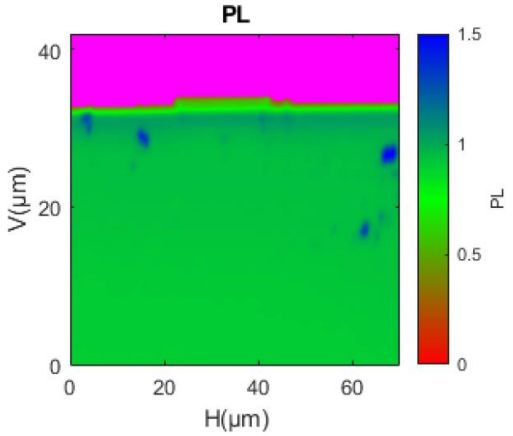
Thin film mechanical properties

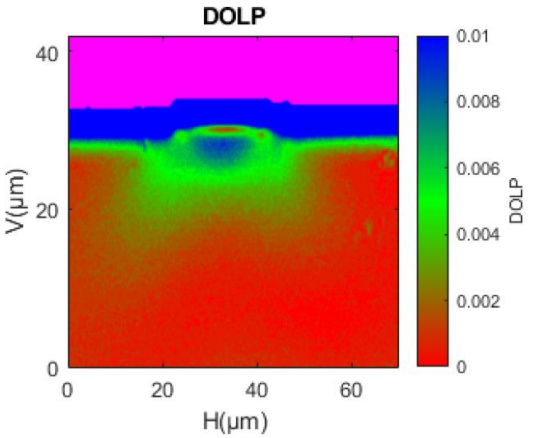
Hardness and Young's modulus as a function of C source partial pressure derived from nanoindentation tests.

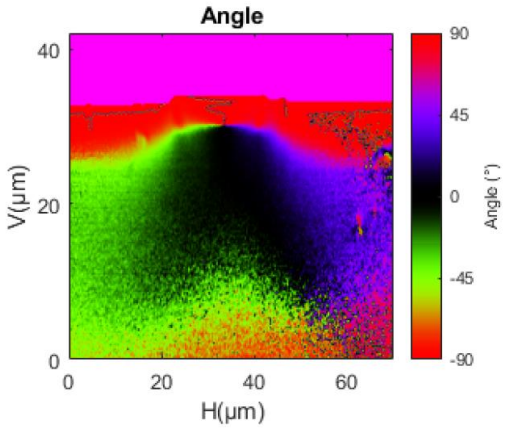


Deformation field induced in the semiconductor material substrate by the dielectric thin film

Photoluminescence maps showing the crystal deformation field generated in an InP substrate by a 20 µm – wide SiN_x dielectric stripe with compressive built-in stress







Tools which we have activitated for this cooperation and beyond

French Canada Research Fund (French Embassy)

ANR – NSERC joint call for proposals, including companies from France and Canada (unsuccessful …)

Co-supervised (co-tutelle) PhD student presently in Rennes, about to move to McMaster, with joint funding from Rennes and McMaster

Erasmus + project led by Rennes:

- 5 teaching visits to Rennes for professors from McMaster since 2019
- 2 teaching visits to McMaster for professors from Rennes since 2019
- 2 undergraduate students from McMaster hosted in Rennes for research interships in 2019 (+ 2 scheduled in 2020)
- 1 undergraduate student from Rennes hosted at McMaster for research internship in 2020

Outside the Erasmus + project, other undergraduate students are regularly hosted by McMaster professors for internships (4 to 6 per year since 2018)