Material and interface quality analysis by surface harmonic generation (SHG) for advanced ultra-thin substrates in micro and nano electronics

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Context:
This PhD topic is in the context of research on novel characterization methods of ultra-thin films and interface quality for applications in micro, nanoelectronics, photovoltaics, photonics, etc. A special attention will be given to advanced silicon-on-insulator (SOI) substrates in particular and more generally, to semiconductor-on-insulator and other bonded materials.
In this context, a key element today is to propose and develop innovative characterization methods that do not need any physical contact, therefore avoiding any damage of the advanced ultra-thin substrates.
A very promising technique was recently proposed: the second harmonic generation (SHG)[1]. A laser emitting at the fundamental frequency generates electron-hole pairs in the semiconductor material and allows charge injection at the buried oxide surface by multi-photonic absorption: the appearance of charges at the interface allows the generation of an optical signal at twice the input frequency.
The PhD student will benefit from an innovative equipment, unique prototype in Europe, very recently developed and fabricated by FemtoMetrix, and which will be installed at IMEP-LAHC at the beginning of June 2014.

PhD objectives and work-to-do:
The first objective will consist in qualifying the measurement tool, using standard SOI wafers from SOITEC. The calibration will be done based on benchmark studies using as comparative elements other well-known measurement techniques, such as photoconductivity decay, photoluminescence, or the pseudo-MOSFET technique (intensively used today for electrical characterization of SOI). This phase will lead to the validation and the extension of models for SHG, for the extraction of material quality parameters such as the density of interface states.

The second objective of the PhD will be to enrich the SHG tool, by adding for example coupling between electrical and optical measurements, with the final aim to propose a non-contact optical pseudo-MOSFET-like method to obtain the quality parameters of SOI. Simple analytical models and simulations will also accompany this phase.

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[1] B. Jun, et al., IEEE Transactions on Nuclear Science, vol 51, 3231 (2004).
M.L. Alles et al, IEEE Transactions on Semiconductor Manufacturing, vol. 20, 107 (2007)

The third objective of the PhD will be to apply the SHG method and the previously validated models to extract material parameters for various semiconductor-on-insulator and bonded substrates: Si/SiO2, GeOI, III-V on insulators, conductive transparent oxides on semiconductors, composed semiconductor layers, high-k materials on silicon, etc. A more ambitious step will be to check the possibility to use SHG technique for structural analysis of micro-structured materials (e.g. vertically grown nanowires)

Requested competences:

This PhD is an interdisciplinary topic, in the fields of optics, micro-electronics, and material science.
The candidate must have a very good background in optics, semiconductor physics, and microelectronics.

The student must be able to conduct both experimental work and modelling. Scientific curiosity, motivation and seriousness are key qualities in order to accomplish a high level PhD and to enrich his/her technical expertise going from optics to electronics.

Collaborations:

The topic is strongly connected to the industrial world, since the calibration steps will be performed using SOI substrates from SOITEC. The student will benefit from the long-lasting collaboration of our laboratories with SOITEC, which will allow him/her to interact with highly qualified engineers.
This innovative measurement technique is highly promising for alternative materials developed today by the academic research actors (CEA-LETI, Pr. Schrimpf's group in Vanderbilt University…)
Therefore the student will be in a stimulating professional environment, in touch with both academic and industrial research actors which should be very beneficial for his/hers future career.