THE POTENTIAL IMPACT OF CONFINED ACOUSTIC PHONONS IN SOI-BASED NANOELECTRONICS

C M Sotomayor Torres[1,2], A Zwick[2], M Prunnila[3], J Ahopelto[3], A Mlayah[2], F Poinsotte[2], J Groenen[2] and V Paillard[2]

1) National Microelectronics Research Centre, University College Cork, Lee Maltings, Prospect Row, Cork, Ireland.
2) Laboratory of Solid State Physics (LPST) UMR 5477 , Paul Sabatier University, 118 route de Narbonne, F-31062 Toulouse Cedex 04, France.
3) VTT Centre for Microelectronics, Tietotie 3, FIN-02150 Espoo, Finland.

E-mail: clivia.sotomayor@nmrc.ie

We have recently observed and simulated confined acoustic phonons in both thin silicon-on insulator films and in SOI membranes [1]. Since progress in silicon device technology is going through increasing use of silicon-on-insulator (SOI) as a strategic device material to increase the operation speed of integrated circuits [2] modifications in the phonon spectrum are of strategic interest to device engineers and scientist. There are two main reasons with origin in the electron-acoustic phonon scattering, namely, the thermal conduction [3] and the charge carrier mobility.

Here we present our work on off-resonance room temperature low frequency Raman scattering in undoped membranes [1] and thin SOI films [4].

The SOI layers studied have typically a thickness below 50 nm. In this size regime the crystalline silicon is a slab where electronic transport is subjected to several scattering mechanisms. Moreover, in thin slabs phonons are expected to be confined due to the acoustic mismatch of sound velocity in the slab and surrounding as well as the different densities of the materials [2]. In turn, confined phonons are expected to have a smaller group velocity than bulk phonons impairing heat dissipation. Thus, low frequency acoustic phonons are relevant to the understanding and modelling of novel nanoelectronic devices, such as CMOS based on SOI.

In a series of Silicon membranes of thickness between 29 and 31 nm, Raman scattering spectra show the presence of confined acoustic phonons as a series of oscillations between 3 and 40 cm^{-1}. The frequency of these phonons is inversely proportional to the membrane thickness. Depending on the interplay of the phonon cavity confinement strength and the electromagnetic cavity, adjacent peaks in the Raman spectra are seen to vary in intensity quite dramatically in the back- and forward scattering configuration. This behaviour has been simulated with a model describing the phonon-electron-photon interactions including the photo-elastic effect [5].

Raman spectra were also recorded in thin SOI films of thickness varying from 29 to 40 nm, with and without an upper oxide layer and with a buried oxide layer underneath. In these samples the spectra exhibited oscillations extending up to 80 cm^{-1} and the frequency was found to depend also on the relative thickness of the SOI, as well as on that of the upper and buried oxide layers [5]

In this talk the resuls and the model will be discussed in the context on the impact of confined acoustic phonons on nanoelectronic SOI-based devices.

References

[1] C M Sotomayor Torres et al, in preparation
[2] see, for example, MRS Bulletin **23**, Silicon-on-Insulator Technology (1998) and G C Celler and S Cristoloveanu, J App Phys **93**, 4955 (2003).
[3] A Balandin, Phys Low-Dim Struc **5-6**, 73 (2000)
[4] C M Sotomayor et al, in preparation.
[5] F Poinsotte et al, in preparation.