Abs. 1339, 206th Meeting, © 2004 The Electrochemical Society, Inc.

Photonics, Electronics and Silicon-Germanium : a possible convergence ?

O. Kermarrec, Y. Campidelli and D. Bensahel
STMicroelectronics
850, rue Jean Monnet, 38 926 Crolles Cedex, France

S. David, M. El kurdi and P. Boucaud
Institut d'Electronique Fondamentale
Université Paris XI, 91405 Orsay, France

Y. Chriqui, S. Bouchoule, G. Saint-Girons and I. Sagnes
Laboratoire de Photonique et Nanostructures
LPN-CNRS / UPR 20, Route de Nozay, 91460
Marcoussis, France

Optical functions on silicon substrates are attracting increasing interest in the semiconductor world. Integration of optical devices on Si can be envisioned in several ways. They can be reported or monolithically integrated on a Si chip. Indeed, an advanced silicon chip is already composed of different technological nodes (different gate oxide for instance), and integrates different functional zones (logic, embedded DRAM…). Localized SOI or Silicon On Nothing (SON)[1] areas will be a next step of this ever growing material integration. But besides these "pure" silicon based technology, differentiation will arrive with "options" such as MEMS, sensors, at the "above ICs" level. This contribution is aimed at presenting a status on how silicon-germanium (SiGe) can drive convergence between Si based electronics and photonics. Based on our own experience at ST on SiGe and our collaborative research works, we first show how industry is getting more and more skilled in handling SiGe in fabs. Then, we report parallel promising results on SiGe based optical systems at research level. Can both progresses on SiGe, know-how in industry and encouraging optical results in research, definitely drive a convergence between electronics and photonics ?

After longtime restriction to BiCMOS, SiGe alloys are now close to enter the CMOS mainstream technology, due to their possibilities for monitoring chemical, mechanical, or electrical properties of MOSFETs materials. SON technology needs thin SiGe layers, Ge integrated with high-k dielectrics is reconsidered as a possible high mobility channel material, and great potential is expected from Silicon-Germanium On Insulator (SGOI) wafers[2]. For 45 nm node and beyond, after demonstration of the advantage of strained Si layers via thick relaxed SiGe buffers, a huge effort is devoted to obtain the same effect using stress-induced process. Likewise, Si and SiGe selective processes become mandatory for raised source and drain. And most advanced devices, such as DotFET or FinFET will require SiGe or Ge layers. Being used as a sacrificial, intermediate or active material, this increasing need for SiGe alloys generates works on many technological steps

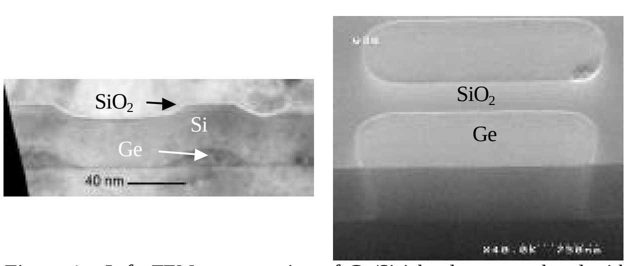

Figure 1 : Left, TEM cross-section of Ge/Si islands encapsulated with silicon and thermal oxide. Right, Ge active area grown on Si and isolated wit h SiO_2.

required for industrial integration. Specific processes have thus been developed on growth (low clean and temperature processes) of course, but also on chemical mechanical polishing (CMP), cleaning, dry and wet etching, thermal treatments… SiGe is no more limited to epitaxy and appears as a "standard" material where selectivity and hetero-epitaxy with Si open new architecture schemes. Figure 1 gives examples of realization of structures involving Ge done at ST : Ge islands for DotFET, and Ge active area isolated by SiO_2. With this growing experience, driven by need for CMOS, SiGe is more and more accepted in industrial production lines, and can thus be evaluated on increasing number of structures and devices. Photonic structures can be part of them.

At the research level, in parallel to this emerging technological know-how on SiGe, quality of SiGe optical basic demonstrators devices is improved thanks to progress in device architecture and growth. Figure 2 shows two-dimensional photonic crystal realized on Ge/Si self-assembled islands grown on silicon-on-insulator substrate (left), and a GaAs layer grown on Ge/Si buffer layer. Each of them were realized on SiGe or Ge starting

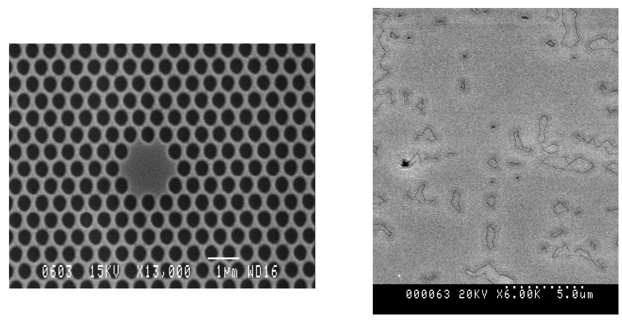

Figure 2 : left, SEM top-view of a photonic crystal realized on Ge/Si islands structure. Right, SEM top-view of GaAs layer grown on relaxed Ge/Si buffer layer.

materials grown on an industrial 200 mm single wafer LPCVD reactor. Such demonstrators give promising optical results[3], as reported on Figure 3. In these structures SiGe can be used as an active layer, but also as an intermediate to integrate III-V materials.

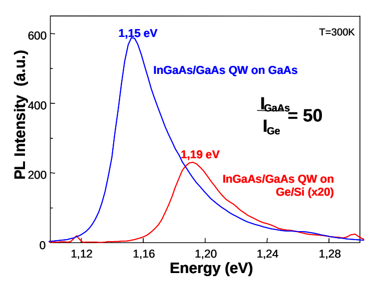

Figure 3 : Comparison of photoluminescence spectra of InGaAs/GaAs quantum well structure grown on bulk GaAs or on Ge/Si buffer layer.

Obviously, beyond optical performances, integration of optical devices on silicon remains challenging. Today, specifications regarding integration, wavelength, and performances are still unclear. But regarding status of SiGe in IC industry and progresses on SiGe based photonics, a new generic customized Si chip can be defined in which any monolithic convergence between electronics and photonics should be mediated by silicon-germanium.

References

[1] S. Monfay et al., IEDM, 2001
[2] V. Paillard et al., Microelectronic Eng., 2004, in press
[3] Y. Chriqui et al., J. Cryst. Growth, 2004, in press