Silicon … beyond silicon: beginning of the end or end of the beginning

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The early 1960s were at the beginning of the electronics revolution where silicon integrated circuits built their current dominance, fundamentally and pervasively on tailor-made materials, starting at the atomic level. Thin-film deposition techniques, particularly chemical vapor deposition (CVD) and molecular-beam epitaxy (MBE) were developed. These developments allowed the control over material constituents "in atomic amounts", in order to form the active part of high-performance devices.

The focus of these techniques – and particularly CVD – was, and still is, to achieve a structure in which the modern CMOS technology, the mainstay technology and workhorse of the electronics revolution, can be affordably implemented, using devices with ever-increased speed, wider bandwidth and lower power dissipation. In this context,

- new materials and highly-engineered novel structures with silicon-germanium and silicon-on-insulator as a substrate for high performance computing devices and processors have demonstrated incremental improvement in performance; and
- integration of silicon-on-sapphire and silicon-germanium, although initially met with major challenges, led to truly outstanding device performance.

The purpose of this presentation is to analyze major developments of the last few years in the context of a driving-vision from the 1970s and to discuss a solution for a potentially "ubiquitous" thin film SiGe-on-sapphire structure for CMOS technology. This proposed structure and other various variances could revolutionize the information/communication technologies – insuring the survival of silicon technology – from both the technical and economic aspects.

The discussion will attempt to demonstrate that the pursuit of development of these new materials and novel structures and their integration, for example, of SiGe devices onto very low-loss microwave substrates, sapphire and/or silicon oxide is going to be important to the evolution of electronics over the next 15 years. The key roles of the materials issues and the need for materials breakthroughs, as was the case 35 years ago, are a pre-requisite in the continued viability of silicon scaling at the atomic and nanometer scale, and will be emphasized. The science and engineering for the required silicon scaling (< 50nm) in the 2010–2015 time scale will have to meet challenges in an environment that, if dominated as today by short-term commercial considerations, will be very different from that which characterized the Cold War period. During the latter, initially, defense-oriented markets, were driven almost totally by performance and not by cost. The discussion will therefore consider the case of the intensely short-term industry driven need for instant profitability.

Forecasting the future trends in microelectronics is an extremely risky business. However, it is appropriate in this instance to be reminded with an 1834 quote from Lord Melbourne (William Lamb, Second Viscount Melbourne): "What all the wise promised has not happened, and what all the 'damned fools' said would happen has come to pass".