SiNANO Institute Recommendations

The following major areas of technology are considered to be opportunities of real significance at the European level:

Advancing CMOS

- **New materials** New high k materials/gatestacks are essential for the post 22 nm/HfSiO era. Alternative contacting techniques are required (e.g. Schottky barriers using new materials such as Pt) as conventional approaches start to limit device performance.
  Ge, III-Vs and ultimately graphene (in various states of strain and orientation) are prospective alternative high performance channel materials. Si-Ge multilayer semiconductor structures have potential for new low power memory technology (e.g. tunnelling SRAM) and for active optical components relevant to on-chip/inter-chip communications.
  Thin layers of certain ferroelectric materials exhibit some intriguing dielectric behaviour and could play an important role in future devices and memory applications.
- **SOI platforms** Europe has pre-eminence in this area and this technology is likely to move into mainstream, particularly for low power applications.
- **Multiple-gate** This is rapidly becoming *de rigueur*, allowing much better electrostatic control and enriched functionality, including that of memory.
- **The management of power dissipation** This currently limits processor clock speeds and is an increasingly important driver in CMOS technology. Sub-threshold operation and tunnel FET technology, especially with multiple-gate architectures and Ge channels, are potential solutions.
- **Architecture** Routes will be required for the development of 3D integration, embedded memory, multifunctional devices, and new interconnect regimes (RF, optical).
- **1D/0D structures** These potentially provide for a new generation of innovative devices with integration at the trillion level, but much work is needed to develop a templated self-assembled (bottom up) processes.
- **Nanoscale characterization** Physio-chemical analysis and measurement of the electrical properties at the nanoscale is critical. Development work is needed to enable full 3D imaging and strain measurements at the device level.
- **Modelling and simulation** This is fundamental for advancing all CMOS development. Variability is a key issue to address. Europe has a pre-eminence in this area and with good dialogue between theorists and experimenters this expertise can be a significant differentiator.

The only viable route to achieve significant return on investment in this area is to ensure that all work is undertaken within the framework of effective collaboration between world leading university groups and the European Research Institutes, and generally with steer from a major international processing house. Targeted investment is recommended.

Increased functionality integrated into CMOS

- **Application-driven integrated systems** The integration of sensors, RF components, silicon photonic devices and NEMS with CMOS will yield breakthrough solutions for a wide range of new applications. Specifications will typically include minimal/self-sustaining power and possibly an SOI technology and flexible platforms. Europe has the strength and depth in RF and analogue design to lead in these areas. Medical and environmental applications will provide the greatest opportunities. For example, the utilisation of electronic cooling to access very low temperatures (<100mK) could produce sensors that would revolutionize biological and medical research and also a qbit platform as required in quantum computers.
- **Design** System design is the starting point for new functionalities, and early evaluation is needed to ma**t**ch a CMOS generation with application-specific components. Multi-scale and multi-disciplinary modelling is mandatory in much of this work as co-design of circuits and technology become essential.

Europe has the expertise and provenance to establish, develop and exploit these application-driven areas - yielding highly differentiated intellectual capital of significant value. These are considered to be paramount areas for investment.