Emerging Nanoelectronics – Upstream Research In FP7 To Prepare For Complements To CMOS Technology

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This communication highlights key messages that came out of a consultation meeting held on 16 December 2004 in Brussels. We invite comments and reactions from the large interdisciplinary research community working at finding new ways to implement the processing of information in the next 10-20 years.
The main results expected from the meeting were to highlight

- The rationale for advanced R&D in **non-CMOS technologies** concentrating on devices with features at or below 10nm and the related architectures;
- The link between research on **materials and devices** in this context;
- **Implementation aspects** of a research programme, including the roles of universities, research centres and industrial companies, the positioning in the context of planned European Technology Initiatives, collaborative industrial research, curiosity-based research, funding instruments, dissemination of results to the general public and international cooperation.

The following consensus among the participants emerged.

- Industrial R&D will pursue shrinking the features of CMOS circuits according to "Moore's law" to reach levels of about 10 nm in the years 2015-2020; CMOS technology will remain the main choice for IST hardware in that time frame. While the end of Moore's law has been wrongly predicted for some time, an end or slowdown is now increasingly likely. In addition, shrinking may not continue to bring benefits to the same extent that the industry has been used to in terms of cost, performance, power dissipation and weight. It is hence crucial to promote now the investigation of **alternative technologies** for information processing and storage if such alternatives are to be ready for production in 2015-2020.
- Besides the shrinking of CMOS logic and memory devices to increase performance and reduce costs (the "More Moore" line of R&D), an important parallel line of research concerns the development of **value-added functions** complementing the basic logic and memory functions, and their embedding with logic and memory to form complex System-on-Chip (SoC) or System-in-Package (SiP) solutions. This "**More than Moore**" development line is important to develop high added-value components in Europe in close co-operation with system integrating companies. These components will include sophisticated sensing, actuating and packaging functions and will require that a diverse set of options be developed in upstream research.
- Progress in emerging nanoelectronics is hence crucial for the long-term future of the nanoelectronics – nanosystems industries. This research requires vision-driven initiatives to pursue **multidisciplinary and co-operative programmes combining aspects of materials, devices, architectures and initial elements of manufacturability**. As this research is long-term, a strong participation of academic and research organisations is expected, and their work should aim at experimental demonstrations at a realistic scale, up to a point where decisions for further

industrial R&D can be taken. The role of industry in terms of providing guidance and assessment is also important in such projects. The **topics of research** are expected to be largely based on those reported in the "**Emerging Research Devices (ERD)" section of the ITRS** roadmap, and possibly on new approaches that show the prospect of being competitive with CMOS developments.

- As correctly pointed out in the ITRS ERD document, research on materials for new active devices is increasingly important to develop new devices. In particular, **"bottom-up" growth of materials may bring superior quality than "top-down" carving** for components with 10 nm dimensions, and may allow the fabrication of new structures. The development of materials for nanoelectronics and of instrumentation for fabrication and characterisation should be closely linked with the development of devices, as the two are intrinsically linked.
- In addition to focused vision-based research on concepts that have already been proposed, curiosity-driven research should be supported to invent and demonstrate first proof-of-concept of new ideas to implement logic, memory, circuits, or architectures for information processing. It is important that such topics related to **upstream technology research** be included in the scope curiosity-driven research programmes, besides those concerning pure science.
- The very nature of research on emerging nanoelectronics is to explore new options and that it is therefore important to look for breakthrough concepts. In the selection of research topics, priorities will need to be made for example through the **test of basic validity criteria against boundary conditions**. However, as none of the new "post-CMOS" concepts has reached sufficient maturity yet, it is important to generate and nurture substantial numbers of new ideas and not to kill creativity too early with conservative conditions.