The 2002 International Technology Roadmap for Semiconductors (ITRS)

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Introduction

The semiconductor industry has continued to prosper and to foster the growth of multiple industries since the early ‘70s. Compared with other industries, the semiconductor industry has enjoyed a unique factor leading to its success: “Decreases in device feature size have provided improved functionality at a reduced cost.” Historically, device linear features have decreased at the rate of about 70% every three years, while in recent years this has accelerated to a 2-year cycle. Cost per function has simultaneously decreased at an average rate of about 25–30%/year/function. Silicon technology continues to play a major role in sustaining the semiconductor industry growth. How long will the industry be able to sustain this growth?

The past

The Semiconductor Industry Association (SIA) in ’92 coordinated the production of what was originally the *National Technology Roadmap for Semiconductors* (NTRS). This document of requirements and possible solutions was subsequently generated in ‘94 and ‘97. The NTRS provided a 15-year outlook for the major trends of the semiconductor industry, offering a reference document for all semiconductor manufacturers. It also provided guidance for suppliers of equipment, materials and software as well as providing clear targets for researchers in the outer years.

The semiconductor industry became a global industry in the ‘90s, as many semiconductor suppliers established regional manufacturing or assembly facilities around the world. Similarly, suppliers to the semiconductor industry established worldwide operations. Alliances, joint ventures, and many forms of cooperation were established among semiconductor manufacturers as well as among equipment, materials, and software suppliers.

The above considerations led to the realization that a document providing guidance for the whole industry would benefit by inputs from all regions of the world with leadership activities in semiconductors.

The present

This realization led to the creation of the *International Technology Roadmap for Semiconductors* (ITRS). The invitation to cooperate on the ITRS was extended by the SIA at the World Semiconductor Council in April ‘98. The offer was enthusiastically accepted by the trade organizations of Europe (EECA), Korea (KSIA), Japan (EIAJ), and Taiwan (TSIA). Initial collaboration of these five organizations produced the ITRS ‘98 Update, a major revision of the ‘97 NTRS tables. In ‘99, the five regions jointly produced a new edition of the semiconductor industry roadmap—*ITRS ’99* followed by the ‘00 ITRS Update. The ‘01 edition was published last year with the ‘02 ITRS Update in progress.

As reported in previous ITRS versions, the number and difficulty of the technical challenges to be overcome continue to increase as technology moves forward. The red areas signifying: “No solutions yet” are in most cases shown within a 5-year reach. Traditional scaling, the basis of the semiconductor industry the last 30 years, is beginning to show the fundamental limits of the materials constituting the building blocks of planar CMOS. However, new materials can be introduced in the basic CMOS structure to replace and/or augment existing ones to further extend device scaling. Since assimilation of new materials into the modified CMOS process gives the device physicist and circuit designer improved electrical performance, similar to historical trends, the new regime has often been identified as “Equivalent Scaling.” It is expected that new materials will provide a viable solution to extending the limit of planar CMOS for the next 5–10 years.

The future

Despite new materials, it will be challenging to maintain a rate of improvement in electrical performance of about 2× every two years in high-performance components by relying exclusively on technology improvements. Innovation in techniques used in circuit and system design will be essential to maintain the historical trends in performance improvement. To achieve this result, it is expected that integration of multiple silicon technologies on the same chip and closer integration of package and silicon technology is necessary. This emerging product category is identified as Performance System-on-a-Chip (P-SoC).

Cost-effective solutions will require an assessment of the silicon technology complexity that can be afforded for a given cost. Specifically, given a system cost target, what technology complexity can be afforded? This product category is identified as Cost-effective System-on-a-Chip (C-SoC). This chapter was expanded to comprehend “System Drivers.”

As the ITRS looks 10–15 years in the future, it becomes evident that most known technological capabilities will be approaching or reaching their limits. To provide the Computer, Communication, Consumer, and other electronics industries with continuously more efficient building blocks, it is necessary to investigate new devices that may provide a more cost-effective alternative to planar CMOS. Preparation for this potential transition includes identifying early candidates and testing their feasibility as noted in the ‘01 ITRS and developed in the ‘02 ITRS Update.

Conclusions

Planar CMOS silicon gate technology resulted from investigations initiated in the ‘50s. These early studies did not lead to the semiconductor industry, as we know it today, until the late ‘60s. It is difficult for any company to support the escalating R&D investments required to evolve technology from Traditional Scaling to Equivalent Scaling, and investigate and develop new devices usable beyond CMOS limits. Contributors to the ITRS agree many R&D needs should be in the shared “pre-competitive domain.”

ITRS documents provided up-to-date references of requirements, potential solutions, and timing for the semiconductor industry. This was accomplished by providing a forum for international discussion, cooperation, and agreement among leading silicon semiconductor manufacturers and equipment, materials, and software suppliers, as well as researchers in university and government labs. It is hoped the ITRS documents, through cooperative efforts among various ITRS participants, will help the R&D investments to be more uniformly shared by the whole industry.

Finally, integration of multiple functions (e.g., voice, data, video etc.) continues to be driven by the Internet. It is necessary to integrate multiple hardware and software technologies to provide the best cost-performance solutions to users. Not all functions are realized using only silicon technology. This became apparent the last few years as non-silicon semiconductor devices and optical devices showed unprecedented growth. To better synchronize the availability of these technologies and further reduce the cost of overall solutions to users, it appears beneficial if silicon and non-silicon semiconductor roadmaps were more closely aligned.