SWOT Analysis of the Technology Design Ecosystem

3rd NANO-TEC Workshop took place in Lausanne, Switzerland on May 30–31, 2012

The project NANO-TEC ("ECOSYSTEMS TECHNOLOGY and DESIGN for NANOELECTRONICS") organizes a series of workshops in order to establish a joint Design-Technology Community for Nanoelectronics in Europe. During the 1st NANO-TEC workshop in January 2011 the requirements for future 'Beyond CMOS' devices have been identified. These devices have been benchmarked during the 2nd workshop in October 2011. The objective of the 3rd workshop in May 2012 was to conduct an analysis on the strength, weaknesses, opportunities and threats (SWOT analysis) of the benchmarked devices. This analysis took into account the technology and design aspects, but also application perspectives. The target outcome of the workshop was a number of exploitation scenarios for selected number of 'Beyond CMOS' devices. As the detailed documentation of the workshop is currently set up, this article gives only a short overview on the workshop. Additionally it provides a report of the panel session, which took place at the end of the workshop.

Workshop Overview

As both previous workshops, also the 3rd workshop comprises several sessions with plenary presentations followed by a discussion on 'Beyond CMOS: from Technology to Applications'. Each session addressed a SWOT analysis of the specific 'Beyond CMOS' device technology, including the required scientific and technical capabilities, application perspective, and infrastructural considerations and gave a clue on possible exploitation scenarios for these devices. The following presentations have been performed:

As final part of the workshop programme, Livio Baldi (Micron Semiconductors, Italia) chaired a panel entitled "Beyond CMOS: from Technology to Applications". The panelists were the professors Wolfgang Rosenstiel (edacentrum and University of Tübingen, Germany), Paolo Lugli (Technical University of Munich, Germany), Giovanni de Micheli (École Politechnique Fédérale de Lausanne, Switzerland) and Sandip Tiwari (Cornell University, Ithaca, N.Y., USA).

In the beginning, Livio introduced the discussion reminding that it took 50 years and a few hundred

Goran Wendin, Chalmers University of Technology, Gothenburg
Solid-state Quantum Computing

Prof. Dr. Sense Jan van der Molen, Leiden University
Molecular Electronics

Dr. Heike Riel, IBM Zurich
Nanowires

Prof. Dr. Charles Gould, University of Wuerzburg
Spintronics

Prof. Dr. Max Lemme, KTH Royal Institute of Technology, Stockholm
Graphene

Dr. Michael Gaitan, NIST, Gaithensburg, MD, U.S.A.
MEMS

Dr. Julie Grollier, CNRS-Thales, Palaiseau
Neuromorphic Computing

Panel Discussion, Chair: Dr. Livio Baldi, Micron Technology Inc., Milan
"Beyond CMOS: from Technology to Applications"

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www.fp7-nanotec.eu

More information on the workshop can be found at https://www.fp7-nanotec.eu/show/events).

Abbildung 3.31: More than 50 participants joined the 3rd NANO-TEC-Workshop in Lausanne

Abbildung 3.32: Livio Baldi, Micron Technology Inc., Milan

billion dollars to go from a few transistors to the present complexity and that despite this effort design is still a limiting factor in CMOS integration density. With this background and looking at the new beyond CMOS technologies he formulated several questions to be answered by the panelists and during the discussion:

- What can a new (beyond CMOS) technology do to improve the situation of CMOS and who is going to pay for it?
- Which types of applications will be the drivers for 'Beyond CMOS'?
- Will they all compete for the same killing application, or will they share the market?
- Will design challenges be different for different applications?
- Can design tools be the discriminating factor for the success of one specific technology?
- Present design tools are a huge legacy: what can trigger the investment needed for new tools?

Afterwards the panelists took the opportunity to give their point of view on the situation.

Prof. Dr. Sandip Tiwari, Cornell University, Ithaca, N.Y.
Sandip was first stating, that design as a limitation in CMOS integration density is a self-inflicted wound. This is because of the steadily growing complexity met only by the introduction of hierarchy and because of the growing number of constraints (i. e. due to energy consumption). As these aspects have not been considered during the creation of the CMOS design process itself a now "creeky infrastructure" has been developed which is hardly able to cover today's CMOS design problems. Therefore Sandip demands for a stronger foundation of the design at system level, in order to be able to stand the design challenges using new technologies.

With respect to the possible drivers for 'Beyond CMOS', Sandip mentioned ultra-low power Microsystems, machines with learning or inference capabilities and effective education platforms. Sandip agreed that design challenges will be different for different applications although he also sees common aspects. As Apple now is successful with good design Sandip is convinced that design tools can be the discriminating factor for the success of one specific technology because a design tool is the codification of a design process and its mathematical translation which itself makes the difference. Additionally Sandip named the energy challenge and the application challenge due to the changing society as triggers of the investment in new tools that could break the huge legacy of present design tools.

Finally, like in the previous NANO-TEC workshop, Sandip demands for a new open infrastructure that brings people and things together. He characterizes this as an international-national scale problem that crosses frontiers of many disciplines, that needs a cooperative effort with much thinking at its start and long project duration under a unified leadership.

Prof. Dr. Wolfgang Rosenstiel, edacentrum and University of Tübingen
Wolfgang introduced his position with a characterization of design stating that every circuit being designed today, starts with a computational model at a high level of abstraction, then goes through a sequence of synthesis and optimization transformations, followed by rigorous digital simulation and prototyping, as well as formal and semi-formal verification, before it is finally manufactured via advanced lithographical and chemical processes.

In order to be able to design efficiently, an automation process (Electronic Design Automation) has been established. This came out of one of the earliest interdisciplinary collaborations: Computer scientists and engineers in EDA collaborated successfully with the electrical engineers to derive various levels of circuit models, physicists and chemists worked together to find manufacturing models, theoretical computer scientists conducted various kinds of complexity analyses while applied mathematics and optimization experts improvised highly scalable simulation and synthesis algorithms and while application domain specialists to develop intellectual property (IP) libraries, etc.

In the end, according to Wolfgang a design process turned out. Thus, to bring an application to a chip implementation, what design is, one has to find algorithms, implement them in a computational

Abbildung 3.33: Sandip Tiwari, Cornell University, Ithaca, N.Y.

Abbildung 3.34: Wolfgang Rosenstiel, edacentrum and University of Tübingen

model using a language coming to an architecture consisting of functional blocks containing logic gates implemented by circuits build out of devices that are made of materials in a certain structure following the laws of physics and chemistry. As this design process between application and device is well established in its middle, difficulties are to be found at the top between system and application and at the bottom between circuit and device.

To overcome those difficulties Wolfgang agreed to Diederik Verkest from IMEC who, during the second NANO-TEC workshop, proposed a certain property of a device to be the solution: This is called "Systemability", which is defined as "ability to economically design and manufacture reliable systems from the interaction of devices fabricated in a given technology." And this gap is due to the different communities of technology and design.

To be able to design future applications using new technologies Wolfgang demands for models and abstractions at all levels of the design process as a key issue and additionally for …

- …powerful new, physically aware, system-level design science and methodologies at the top of the design process to increase the productivity of designers, otherwise efficient use cannot be made of advanced devices and materials.
- … robust optimization methodologies in the middle of the design process to provide guaranteed performance of integrated systems composed of devices whose characteristics are highly variable, that operate in several different physical domains, and that have uncertain reliability.
- … a revamped, systematic, and greatly improved interface to manufacturing (Design for manufacturing) at the back end (and throughout the flow) to support the design of high-yield systems that obtain maximum utilization of a technology and to assure that we can produce products using new technologies.

Wolfgang agreed to Sandip, that design challenges will be different for applications which differ from each other. As each application has its own specific requirements it is clear, that this leads to different design optimization criteria. While there are criteria like real-time, energy efficiency, productivity, reliability and robustness, safety and security it is mandatory, that these are of different importance for different applications.

According to Wolfgang, design tools will definitely be the discriminating factor for the success of one specific technology, because of the difficulties mentioned before, which have to be overcome by design tools. Furthermore Wolfgang stated that the need for a new technology (i. e. when CMOS reaches barriers) will trigger the need for appropriate new tools and methods. Hence, a design methodology and tools for a specific technology will pave its way to success.

Prof. Dr. Paolo Lugli, Technical University of Munich

In the beginning of his statement Paolo asked, if the presented structures and devices, which are definitely different from CMOS, can really be designed and how they can be pushed forward.

In particular he mentioned graphene, where the main problem of contacting has not been really solved yet. Starting from that Paolo demands that in many cases, the solution for an overwhelming problem is to rethink a whole technology including the way things are approached. In this manner a contact could not be a contact the way it is understood in CMOS and that therefore there is a strong need in new design tools and methods. As, according to Paolo, design starts from the physics and the chemistry, the nanostructures need to be modeled to get an idea how they work. If you want to create an architecture of those nanostructures and devices it is the same. Paolo repeated the need to rethink things, which will be a very creative process which cannot be done by one person. Finally he emphasizes his view, that none of the presented nanostructures will make it alone, they all will be a certain addition to CMOS.

Prof. Dr. Giovanni de Micheli, École Polytechnique Fédérale de Lausanne

Giovanni opened his statement promising that, to be realistic, CMOS will be "here to stay as a business", because CMOS is so large, and so many efforts have been spent on it that it cannot be left. But, Giovanni added, certainly there will be space for new things,

Abbildung 3.35: Paolo Lugli, Technical University of Munich

Abbildung 3.36: Giovanni de Micheli, École Polytechnique Fédérale de Lausanne

Abbildung 3.37: Parque Guell in Barcelona

Please mark your calendar, the final dissemination event of NANO-TEC, the 4th workshop "Summary of recommendations for the Technology-Design Ecosystem in Nanoeletronics" will take place on November 6–7, 2012 in Barcelona, Spain.

if they are really at the leading edge, regarding i. e. low power, high speed or reliability. Also an integrated combination of sensing and computing could be of interest, in short, according to Giovanni, the dimensions of nanostructures offer tremendous opportunities.

From the business point of view Giovanni predicted a hybridization of technologies that means that some of the new technologies will come together with CMOS, in order to improve certain aspects. He mentioned first examples like 3D and monolithic 3D integration, the mixing of processes. But although the industry could take advantages of the new technologies it will be a huge task to integrate them. To Giovanni it will be of particular interest to see the combination of classical CMOS with some kind of memristor or grapheme device that would lead to a tightly integrated structure, offering lots of opportunities.

Furthermore Giovanni addressed point tools as they will be needed to build a system in future. But he made clear, that the EDA-Industry (a small 4 Billion $ market with no real new investments in new areas) driven by three large companies will not push design tools for new technologies. To Giovanni, the critical part is in the backend, where downscaling CMOS already causes enough challenges, while design for new technologies is even harder and needs to have something new. But to his opinion, this will driven only by (new) companies who will come with a new technology together with its design tools. Finally Giovanni send a message to the young generation: electronics is still an extremely vibrant field, interesting and fascinating, with lots of challenges and problems to be solved and that nobody should believe people saying it flattens out.

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Discussion

In the following discussion several topics were addressed. Heike Riel from IBM asked, if there will be a solution to design the variability into the whole system without loosing its small size. Sandip answered, this will most certainly happen, if design tools will be available to adopt gates accordingly. If systems have to be designed 100 % correctly, Giovanni added, variability has to be considered in design especially at the physical level, because a system may be locally incorrect.

On a question from Mart Graef from TU Delft how the design community could be involved in the discussion on new technology, Giovanni answered that this would only happen because of the need for a specific application which will involve the design community automatically. Wolfgang added that the NANO-TEC project is a good start, but specifically simulation and modeling has to be implemented in order to make design people be able to do their exercises for building circuits. In this context Paolo proposed the universities to work on design for 'Beyond CMOS' technologies while its educational aspects would create a new kind of young people.

Sandip expressed that companies will not do design for the new technologies by their own because they have to bring products to the market. Therefore, the only way will be to bring all kinds of people together in order to make decisions how the things shall be done and then people would work on it.

On another question from the audience how young people can be attracted, Paolo and Sandip agreed, that the fascination of technologies will do that while Giovanni stated that the curiosity about applications will drive the young, because everybody likes to know what inside an iPhone is. To him the young could be attracted by telling them that "you can change things".

In the end, the vivid discussion certainly did not turn out the solution how the new technologies will be designed into future application, but it showed a common sense in which an open minded and new kind of thinking will be the path to be taken. (Pp)

World Wide Wahn – der neue Webauftritt des edacentrum

Entwurfsautomatisierung für die Internetseite

Wir befinden uns im Jahre 2012 n.Chr. Das ganze World Wide Web ist von Bewohnern des Siliziumtales besetzt… Das ganze WWW? Nein! Ein von unbeugsamen Niedersachsen bevölkertes Anwesen hört nicht auf, den eindringenden „Social-Networks" Widerstand zu leisten.

So oder so ähnlich ließe sich die Situation am edacentrum in den letzten Monaten beschreiben. Dem ganzen „Hype" rund um Facebook & Co zum Trotz hatte sich die unerschütterliche Gruppe junger, dynamischer edacentrum-Mitarbeiter aufgemacht, um mit verfügbaren Entwurfswerkzeugen der vermeintlich neuesten Generation dem Internetauftritt des edacentrum einen zeitgemäßen Anstrich zu geben.

Der Projektplan stand, alle Lieferanten waren einbezogen und sämtliche Materiallager gut gefüllt und