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Semiconductor technology & processing

Marc Heyns on the post-CMOS era

“The seeds that will grow into the leading semiconductor technology of the future have already been planted!”

Marc Heyns, imec fellow & expert in Beyond CMOS and More Moore

The search for the chip technologies of tomorrow follows various complex paths along which long-term trends and innovations alternate with one another. With a playing field as far-reaching as this, the possibilities are endless. What we need to do is focus our research on high-risk, high-gain projects, or, to put it another way, ‘risky, but promising’ projects, because that is where imec is able to make the most difference. If we can prove sufficient gain, then a technology can suddenly mature very quickly. Of course, there are also risks attached to this approach, but in the end, we want to encourage scientists to take a leap. Because if they can do that, then the chance of achieving breakthroughs is all the greater. There has never been so much room for creativity in semiconductor technology development as now.

In times when making increasingly small circuits was still straightforward, it was just a matter of doing it. But now there are many more opportunities for innovation and development – just think of spin waves, quantum computing, 2D-materials, topological materials or phononics. It is on this very creativity that we need to build further. We are entering a new era of exploration, propelled forward by far-reaching developments in CMOS-technology and an exponential growth of discoveries in physics, with a host of new materials and concepts that leave the field wide open...

Application, application, application

In this era of unprecedented possibilities, we are also looking at research differently. Where previously technology itself was still the driving force, now applications lead to the most inventions. New discoveries come along as a solution for a specific problem or to make a product that can improve our everyday lives. This trend has been around for a long time. Transistors, for instance, became more popular than vacuum tubes for radios because among other things they enabled a new application: the portable radio. This application-focused way of thinking can be seen in all areas and is growing stronger all the time. Even device scaling has adapted to the application: many 'smart' applications need in fact ultra-low power technologies. The coming years we expect to see many innovations in this area.

A dead-end, or...?

Despite being pronounced dead wrongly on many occasions, scaling still remains the dominant trend in the semiconductor industry. Every nanometer still counts and that is not likely to change soon. Imec aims to push Moore's Law to the extreme by scaling down logic devices to the 5nm technology node and far lower. Our innovations cover e.g. scaled FinFETs and gate-all-around Si nanowire FETs, and we exploit design-technology co-optimization to enable a high performance. Or, alternatively, 3D integration allows us to stack components vertically thereby winning real estate on the chip. An alternative to the classical 3D stacking approach is sequential stacking which involves the vertical integration of sequentially processed device layers (or tiers) with isolation and interconnect layers in between. Yet, scaling is more than just cramming as many transistors as possible onto a given surface area. It is also about adding functionalities. (Sequential) 3D integration, for one, allows us to combine different technologies. Consider the integration of optical elements, sensors or batteries on chip for Internet of Things and other 'smart' applications, for instance.

More recently, another trend has emerged: hybrid scaling or heterogeneous integration. The fundamental difference with traditional device scaling is that hybrid scaling features no preferred device architecture that makes up a system. Instead, multiple device technologies are applied to create different subsystems of a system-on-chip, depending on their function in the system. For example, magnetoresistive random access memory (MRAM) could be used for embedded cache memory, aggressively scaled FinFETs for the highest performance CPU cores, and spin logic devices for ultra-low-power functions. In the context of future hybrid scaling, the vertical nanowire field effect transistor (FET) has the potential to become an important player as well. It is, for example, a promising technology for enabling highly dense static random access memory (SRAM) cells.

From vacuum tube to quantum computer

The big surprise of 2017 is for me undoubtedly the huge leap forward made by quantum computing. Although this is still a relatively experimental technology, researchers have reported great progress within the space of a year. I have high expectations for the imec program on quantum computing for which we can undoubtedly take the lead in these innovations thanks to the extensive expertise available. Imec has arguably the world's most sophisticated platform for advanced CMOS processing, a platform currently used to screen options for 5 nm technology and beyond. At that scale, we have already built up experience with managing quantum effects, so it is a unique basis to start engineering a quantum computer.

Quantum computing has quickly become a reality. This does not mean, however, that traditional computing systems will simply disappear. They will continue to exist alongside new computing concepts, such as quantum and neuromorphic computing that will target other application areas. The technology with which you compete is always a moving target. There will always be a market for the current technology, while a new one is in the development process. Just think of vacuum tubes: they continued to exist for ages after solid-state transistors arrived – and when they finally disappeared, they were very sophisticated designs. Quantum computers are also fabricated with specific applications in mind. They will be, therefore, rather an addition then a replacement for existing technologies. Nevertheless, their importance and application domains will continue to grow.

And the winner is...

> *So, will quantum computing be the technology of the future? Although it is undoubtedly a potential candidate-winner, we don't yet know what the ultimate winning technology will be.*

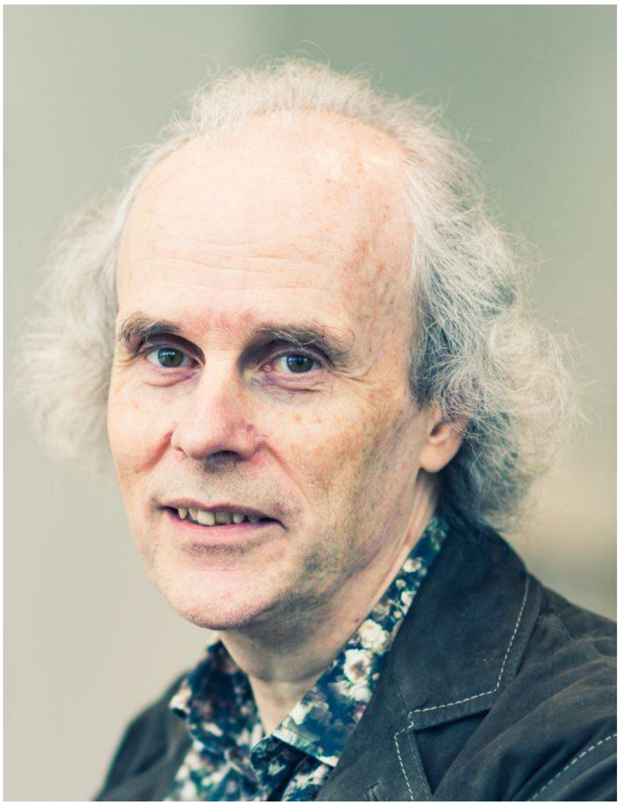
Most likely, multiple technologies in many application domains will shape the future. There are still so many other technologies being developed and new innovations are presenting themselves constantly. Consider the new topological materials that allow the control of quantum effects at room temperature and all of the possible applications that go with them. Imec is also looking actively at new 2D materials. Because of the multitude of applications, more than one winner could surface as future technology. On the other hand, it is equally plausible that the winning technology has already taken its first steps, but that it is still under the radar because it has not yet reached its full potential. One thing is for sure, the seeds that will grow into the leading technology of the future have already been planted!

Imec playing a pioneering role in CSR

With the arrival of each new technology comes increasing pressure from the area of social responsibility. In fact, the technologies that we are developing have a direct impact on our quality of life and on the society around us. Corporate Social Responsibility (CSR) has been a prominent trend in the technology sector over the past years, and will continue to gain importance. Imec is able to take up a pioneering role working closely together with companies to draw up a concrete CSR plan. Imec already places strong emphasis on CSR on all levels. For applications in the area of portable healthcare, for instance, we are examining ways of how we can introduce these devices cheap and effective in places that are hard to access. And, we are working on environmentally friendly alternatives in technology, on green energy, and on many other applications that are aimed at improving people's lives. This is enabling imec to combine the cornerstones of CSR in practical ways: People - Planet - Profit.

Want to know more?

- Read more about quantum computing and heterogeneous sequential-3D integration



Biography Marc Heyns

Marc Heyns received the M.S. degree in Applied Sciences (Electronics) in 1979 and the Ph.D. degree in 1986 from the KU Leuven, Belgium. In January 1986, he joined imec where he became Department Director and Program Director responsible for ultra-clean processing technology, high-κ gate stacks and Ge and III/V CMOS. He became an imec fellow in 2001 and a Professor at the KU Leuven at the Department of Materials Engineering in 2005. His current research interests focus on 'Beyond CMOS', exploring novel materials and concepts for future technologies.