SMALL SYSTEMS, HUGE IMPACT

imec shows how systems-level simulation at a tiny scale can yield enormous benefits by moving dramatic innovations to market, rapidly and reliably.

By ANSYS Advantage staff

Based in Leuven, Belgium, imec is a global hub for advanced micro- and nanoelectronics research. The center brings together its own researchers with academic researchers and industry partners who share an interest in engineering forward-looking solutions in information and communications technology, healthcare, energy and other fields.

With offices in Belgium, the Netherlands, Taiwan, the United States, China, India and Japan, imec employs more than 2,000 people worldwide. At imec’s headquarters, about 500 guest researchers from industry work together with imec researchers on specific research topics. imec teams are engaged in pre-competitive research and development, working to solve shared engineering problems that span many products in a single industry.

As director of heterogeneous integrated microsystems research at imec, Chris Van Hoof leads the research and development of game-changing innovations in miniature components and subsystems, ultra-low-power wearable wireless sensor systems and smart implantable devices. With a Ph.D. in electrical engineering from the University of Leuven, Van Hoof has used or directed the use of ANSYS software “since forever.” Recently, Van Hoof talked to ANSYS Advantage about the critical role of engineering simulation at the microscale, especially the growth of systems-level simulation in this cutting-edge research area.

How does imec’s work differ from most other R&D efforts?
imec’s goal is to stay two or three generations ahead of the technologies that are on the market today. While most engineering teams are trying to improve an existing product or look at the next generation, we are working on advanced technologies that might not be integrated into commercially available products for another 10 years. Our work spans nanoelectronics technologies, technologies for smart systems, semiconductor technologies, healthcare technology and energy technologies, among others. We are trying to bring technologies together in new and unexpected ways. Sometimes our R&D work results in new solutions, but sometimes we disprove a concept, which is equally important. Having worked at imec since 1992, across a range of technology areas, I find it very gratifying to see our early-stage research ultimately have an effect in the world. For example, some of the wearable medical devices we are working on have the potential to help people live much longer, healthier lives. That is exciting to think about.

What are the challenges of engineering product systems at the microscale?
First of all, designing any system can be unpredictable and full of surprises. You might think you know how a collection of separate components will perform when it is brought together in a system, but it’s possible you’re wrong. That’s why it’s critical to verify system-level performance, even at the very early R&D stage. Second, the cost of physical experimentation is very high when working at the microscale. Materials costs are great, and systems can be very complex. For example, a signal-processing device can have hundreds of millions of transistors. Physical modeling would require a

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six-month design loop for a single circuit. We simply don’t have the time or resources to build physical models to verify system performance. Third, often it is simply impossible for us to perform experimental tests — as is the case with medical devices. We can’t ask human subjects to test a theoretical device that’s years from market launch. Fortunately, engineering simulation may help us to overcome part of these challenges. It allows us to test and improve our early-stage systems in a risk-free, rapid and cost-effective manner.

You mentioned the element of surprise when you bring a system together. Can you give an example?

Even the simplest, most straightforward product design can perform unpredictably when you assess how it works as an integrated system. Recently we were developing technologies to support an advanced “electronic nose” that could have a wide range of uses in healthcare, environmental monitoring and food safety applications. For instance, someday you might be able to use your smartphone to conduct a breathalyzer test, manage your allergies by monitoring daily air quality, or detect spoiled or contaminated food so that it can be disposed. This technology is based on a straightforward process — preferential gas absorption — and a simple beam concept. Intuitively, you might think it’s not worth modeling this rudimentary system. However, when we simulated system performance via ANSYS software, the results were surprising. The effect of beam vibration was not at all what we expected. Our ANSYS simulations revealed that the dominant vibration modes were higher-order flexural and not lowest order, nor longitudinal. Full 3-D analysis via ANSYS software enabled us to optimize the device’s performance at higher modes and reduce the unwanted modes of vibration.

What are the drawbacks of failing to work at a systems level?

If you are simulating the performance of only individual components, you are putting the puzzle pieces together but you are by no means arriving at an optimal solution. Let’s say you are trying to improve the life of a power system, and you have an ultimate goal of increasing battery life from three days to seven days. If you are making only local improvements, you are probably not going to get there, because you have not considered the effects of local engineering on every other component. Here’s a real example: Our research team was analyzing performance of a wearable stress monitor. Since three of the top 10 causes of death in the U.S. are linked to stress, this is an important area of focus for research. We wanted not only to extend battery life of the wearable stress monitor to make it more comfortable for the user, but also to increase the accuracy of the physiological data that was collected. When we simulated the system, many of the results were counterintuitive to our basic engineering assumptions. Traditional systems optimization breaks a system down to its building blocks and ensures that the individual blocks meet target specifications that add up to the overall targets and boundary conditions. This approach often works very well, except when you need to push the limits of performance or power consumption. We found out that a radical system redesign was far more effective, so we created a simulation environment for this purpose. We allowed the power consumption of some building blocks to go up (instead of forcing them to go down), and we ended up with far more power savings in total: The power consumption of this wireless microsystem went down from 1 milliWatt to 50 microWatts, thanks to these architectural simulations. We call this approach “consume more to consume less,” and it has helped us to redesign complex wireless microsystems better. They could even be perpetually powered by energy harvesting, which would eliminate periodic battery charging.

How does ANSYS software support your systems-level approach?

imec brings together a very broad range of researchers with diverse competencies — electrical, thermal, mechanical and fluid engineers; chemists, physicists, biologists, medical doctors and others. A growing amount of our work integrates these competencies to focus on how multiple factors impact overall system performance. For example, how does thermal expansion of one component create stresses on other components? How will a simple antenna — which took 10 minutes to design — interact with its surroundings once installed? Obviously, ANSYS software offers strong simulation capabilities in all of these physics. ANSYS also handles variability well, which is important to our medical device investigations, as there is a lot of variability in the human body. Many of our simulations are very complex and numerically large. ANSYS software is designed to handle the problems of size and complexity, and the software performs well.
in a high-performance computing environment. Without ANSYS and engineering simulation, it would take much, much longer for our innovations to make it to market.

**Is product integrity a special concern in your healthcare R&D work?**

Any medical device eventually must go through a very stringent approval process before it is introduced to consumers. For even a simple product like a disposable bandage, there are so many questions to answer. Will the materials be absorbed into the body? How can they be safely disposed as waste? For complex electronic devices, the questions are even more numerous and sophisticated. We are fortunate that we work at a very early stage, where we are removed from the actual consumer by years. Still, ANSYS software helps us to verify a level of product integrity and reliable performance that forms the basis for future development work — conversely, ANSYS tools identify integrity issues so that we can modify our concepts at the earliest possible R&D stage.

**How would you describe your relationship with ANSYS?**

We have been using ANSYS software as long as I can remember, and we have a great partnership with the company. Because imec is pushing the limits of engineering simulation, we work in a collaborative manner with ANSYS that benefits both our organizations. We are in the fortunate position to see new ANSYS capabilities at an early stage, so we provide feedback and help ANSYS to develop and test new products. Just as we are pioneers working up to 10 years ahead of the marketplace, ANSYS is actively engaged in creating innovations that will address emerging engineering challenges. That makes our partnership a very strong one, in which we learn from each other.

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