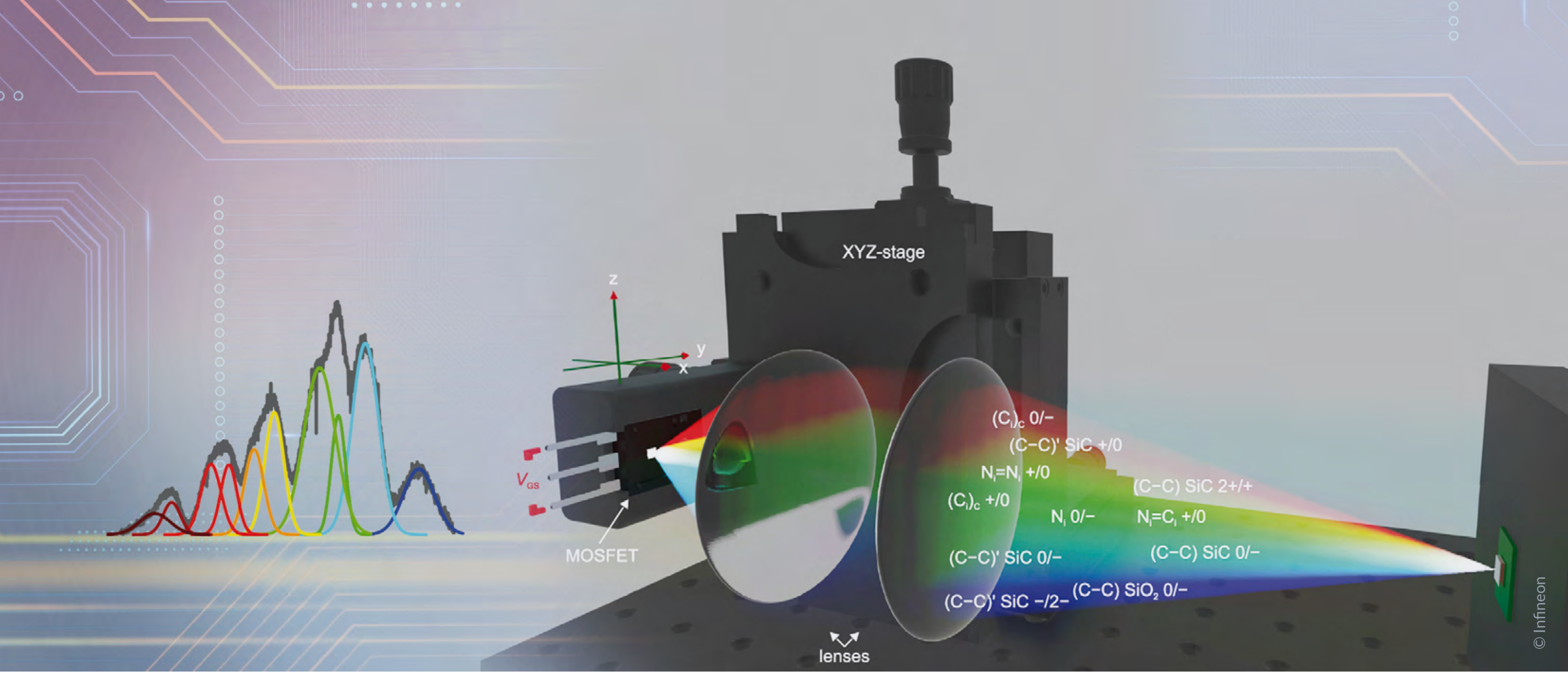

Federal Ministry
Republic of Austria
Labour and Economy

Microelectronics: Ever smaller, ever more efficient

Electronic devices do not get smaller and more efficient on their own. This progress is the result of intensive research, including work conducted by eight CD Laboratories at the Institute for Microelectronics at TU Wien.

Since the establishment of the first CD Laboratory at today's Institute for Microelectronics in 1989, there have been tremendous developments: Today, microelectronic components range from the smallest, highly sensitive sensors in medical technology to inverters for photovoltaic systems, which must withstand very high voltages. To date, eight CD Laboratories at the Institute for Microelectronics have contributed to this development.

The conquest of the third dimension

Then, as now, transistors have been the key components that convert applied current into logical "zeros" and "ones", forming the basis for bits and bytes. Early electronic circuits can be imagined as villages: transistors as houses, connected by roads, i.e. lines that must not be overloaded ("burn out"). Over time, microelectronics conquered the third dimension: skyscrapers and subways were integrated and villages grew into vast metropolises like Manhattan or Tokyo.

But how are all these transistors optimally built, arranged, wired, and switched? The CD Laboratory for Integrated Devices, which was launched in 1989, was already working on computer-based mathematical models and simulation software for silicon enriched (doped) with phosphorus, boron, or arsenic. The behavior of these materials under applied voltage was modeled using a computer program (FORTRAN at the time). The software tools developed in this way proved to be highly successful and sought after, leading to the founding of a spin-off company in 2008 by members of the institute: Global TCAD Solutions. Today, the company has over 40 employees and offices in Taiwan and India and is now a commercial partner of a CD Laboratory.

The CD Laboratories

1989–2002: CD Laboratory for Integrated Devices 1 and 2 (Siegfried Selberherr)

2003–2009: CD Laboratory for Technology CAD in Microelectronics (Tibor Grasser)

2010–2016: CD Laboratory for Reliability Issues in Microelectronics (Hajdin Ceric)

2015–2022: CD Laboratory for High Performance TCAD (Josef Weinbub)

2018–2025: CD Laboratory for Nonvolatile Magnetoresistive Memory and Logic (Viktor Sverdlov)

2019–2025: CD Laboratory for Single-Defect Spectroscopy in Semiconductor Devices (Michael Waltl)

2022–2029: CD Laboratory for Multi-Scale Process Modeling of Semiconductor Devices and Sensors (Lado Filipovic)

The commercial partners

ams-OSRAM AG, Global TCAD Solutions GmbH, Infineon Technologies Austria AG, Österreichische Industrieholding AG, Silvaco Group, Inc.

Three questions for …

Prof. DI Dr. Tibor Grasser
Head of the Institute of Microelectronics, TU Wien

What do CD Laboratories mean for the Institute of Microelectronics?
Prof. Selberherr's CD Laboratory for Integrated Devices, which ran until 2002, made a decisive contribution to the development of the Institute. With each new CD Laboratory, a new research field for the institute has opened up, enabling efficient communication and providing a broad and comprehensive perspective. Thanks to their long duration, CD Laboratories serve as a stable backbone for this development.

What are the advantages of working with companies?
Collaboration with companies has proven to be very fruitful for our institute: As basic scientists, we explore questions which are yet to be answered. Our long-term commercial partners play a crucial role in identifying these questions and testing our results in real-world applications.

What do you particularly appreciate about the CD Laboratories' funding model?
Die große Zahl der CD-Labors
The large number of CD Laboratories at our institute probably speaks for itself: they offer security and predictability combined with added flexibility and scientific freedom. The evaluation process ensures scientific excellence, making CD Laboratories a testament to the high quality of our scientific research.

Subsequently, the simulation tools were expanded to address an increasing range of challenges: power components, wiring, memory, and sensors – covering an ever-increasing number of materials explored and used.

The combination does the trick

The chemical bonds between atoms in electronic components can be described quantum-mechanically using the Schrödinger equation. However, even the thinnest layers used in today's advanced devices still contain many thousands of atoms – making this equation impossible to solve for such large systems.
A multiscale approach is therefore used: for a few atoms, their movements can still be calculated quantum-mechanically. At the next level, these calculations are abstracted, incorporating measurement results as well. This process continues step by step until an entire device, and ultimately even complex circuits, can be simulated. This combination of calculation and measurement has proven to be very successful in describing the behavior of components, including performance, reliability, and aging, with sufficient accuracy.

No modeling without measuring

Other CD Laboratories are working on the foundations for very powerful and fast electronic measuring devices. These are essential for detecting and localizing randomly occurring individual defects in the atomic structure: If an atom is in the wrong place or an electron "gets lost", this leads to reduced current flow at the same applied voltage. Highly refined voltmeters and ammeters allow us to observe individual electrons and compare the data with theoretical predictions, making it possible for these defects to be identified and localized.

The path to the future

The major trends in microelectronics – miniaturization, differentiation for various applications, and the use of different elements – will continue to be the focus of research in the future. AI and machine learning will also play an increasingly important role.
At the same time, urgent new challenges are emerging, particularly for sustainability in production. Issues such as water and energy consumption, the release of environmental toxins, and recyclability remain critical concerns. Currently, recyclability is often hindered by the wide variety of elements used. While considerable progress has been made, the rapid growth of production has outpaced these advancements. Research is now actively addressing these challenges.

Added value for science

The further development of electronic components relies on three key pillars: very precise measurement of the processes occurring within components, the statistical analysis of large datasets stemming from many such measurements, and calculations based on the physical and quantum mechanical properties of the materials used. The Institute for Microelectronics is one of the few institutes worldwide that integrates all three of these areas of expertise. The holistic approach to the problem minimizes potential risks, such as the risk of modeling being based on measurement errors. With each new CD Laboratory, the Institute has expanded into new research fields, while good integration within the Institute and strong internal collaboration maximizes its impact.

Added value for companies

For the commercial partners, the primary goal is to significantly reduce the time and costs associated with developing new electronic components. This is achieved by leveraging modeling to shorten the development process and to improve the software tools used for such modeling. Specifically, this involves developing new algorithms, for example, based on a deeper understanding of the interface physics between two materials, and adapting them to new technologies such as magnetoresistive memory or physical etching and deposition models. Better products increase competitiveness, and CD Laboratories also raise their profile in the scientific community.