"THE CAR INDUSTRY IS THE TECHNOLOGY DRIVER."

Electronic circuits with components made of silicon semiconductors are widely used in electrical appliances. The energy consumption of these components could be reduced if the silicon were replaced by a new class of semiconductors – so-called wide bandgap (WBG) semiconductors. The international Power Electronic Conversion Technology Annex (PECTA) expert group is working toward this goal. Roland Brüniger chairs this expert group on behalf of the Swiss Federal Office of Energy. In this interview, Brüniger explains the potential and areas of application of WBG semiconductors.

Roland Brüniger (at the lectern) chairs the PECTA working group, which is dedicated to the promotion of energy-efficient WBG technology.
Photo: Peter Bennich, Swedish Energy Agency

A technical report about the results of several research projects in the field of electricity, which are financially supported by the Swiss Federal Office of Energy in the international IEA 4E PECTA program. The report has been published in the technical magazine eTrends (issue December 2023).

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Roland Brüniger. Photo: Stefan Bisang

Mr. Brüniger, the International Energy Agency (IEA) in Paris is the first port of call for monitoring and analyzing global energy consumption. What role does the IEA play in energy research? And what is the significance of the PECTA expert group, which operates under the umbrella of the IEA?

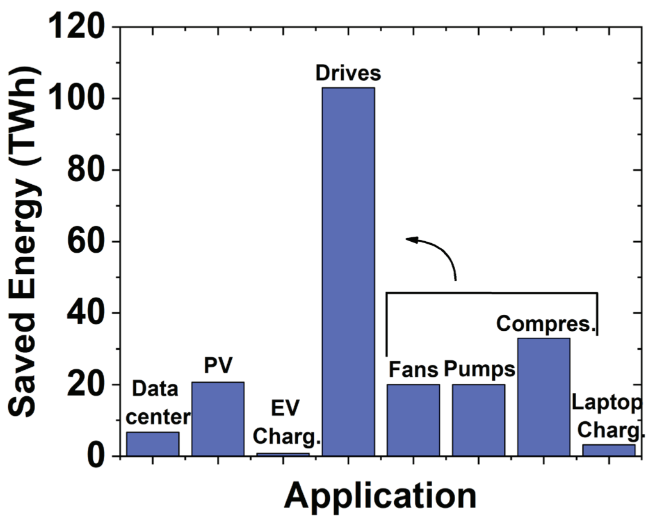
Roland Brüniger: Many countries around the world are conducting research in the field of energy in order to enable the transition to a sustainable energy supply. The IEA supports international exchange between researchers. Around 40 Technology Collaboration Programmes (TCP) serve this purpose, in which experts from several countries exchange ideas on a topic. One of these programs, "Energy Efficient End-Use Equipment," or 4E TCP for short, deals with the energy efficiency of end devices. In order to further advance work in this important area, Switzerland initiated the PECTA working group within the 4E TCP in 2019 together with Denmark, Austria and Sweden. The working group is dedicated to energy efficiency in the field of power electronics. These are components that are used to control and convert electrical energy.

PECTA focuses on a group of semiconductor materials that are more energy-efficient than classic silicon, which is mostly used in power electronics components today. The novel semiconductors are grouped under the term "wide-bandgap semiconductors " (WBG). These WBG semiconductors – especially silicon carbide (SiC) and gallium nitride (GaN) – have enormous potential to perform electronic switching operations with much lower electrical losses. In addition, the components can be built smaller and lighter with the same performance, which in turn reduces the need for raw materials. The PECTA working group promotes the international exchange of information on WBG research, raises awareness among political decision-makers of the possibilities of this new technology and supports wide-ranging measures to accelerate the introduction of WGB technology into the market.

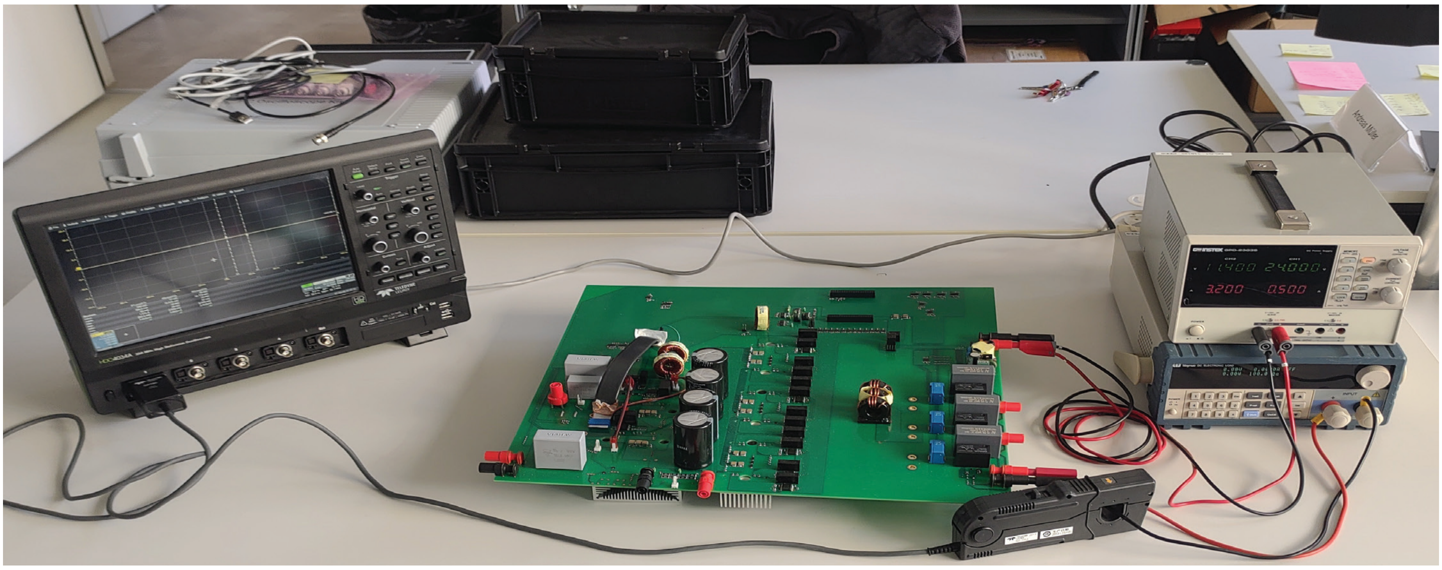
In September 2023, the European Conference on Power Electronics and Applications took place in Aalborg, Denmark with over 1,000 participants. Among other things, the current state of research on WBG semiconductors was presented, and PECTA experts were able to present their work in independent sessions. What is the status of wide-bandgap technology today?

WBG semiconductors are a major topic of research and development. The automotive industry is currently the technology driver in this area. Other industrial sectors are still reacting cautiously to applications of WBG semiconductors. This is mainly because there is still relatively little reliable experience to prove the long-term reliability of these components.

In order for the new technology to become widespread, it is important that its benefits are scientifically documented. Research involving the École Polytechnique Fédérale de Lausanne (EPFL), the results of which were presented in Aalborg, has quantified the power density and efficiency of chargers based on traditional silicon and novel GaN semiconductors,



Estimation of the savings that would be achieved if silicon-based converters were replaced by WBG converters in all electrical appliances worldwide (based on the year 2021). The greatest potential lies dormant in the area of electric motors (including electrically powered heating, ventilation and air conditioning systems). Graphic: FHNW



Test setup of the ZHAW research group led by Prof. Andreas Heinzelmann for measuring the efficiency of DC/DC converters with new wide-bandgap semiconductors in solar inverters for single-family home systems. Photo: ZHAW IEFE

showing that GaN solutions are much more efficient than silicon solutions at higher power and also feature a lower volume. In another collaboration between the Austrian Institute of Technology and the Zurich University of Applied Sciences (ZHAW), also presented in Aalborg, the increase in efficiency of PV converters for single-family homes with new WBG materials is demonstrated with real setups and measurements.

On the one hand, such results serve as a basis for standardization and regulation. On the other hand, they create the basis for the next generation of WBG applications, as PECTA is also keen to share its results with industry.

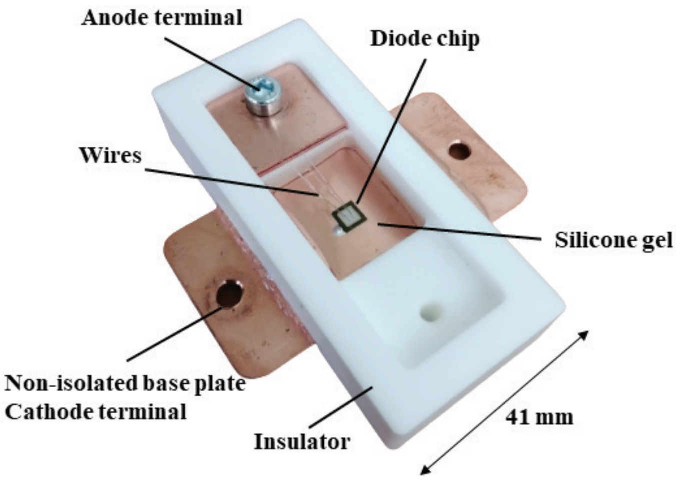
In 2020, an Application Readiness Map (ARM) was presented, which estimates the maturity level of WBG semiconductors for various potential applications. An update was presented at the conference in Aalborg. For which applications are electronic components with WBG semiconductors already used?

GaN semiconductors are already being used in various chargers. However, as mentioned, the main area of application for WBG solutions has so far been the automotive industry. The Tesla 3, which has been available in Europe since 2019, is equipped with WBG converters. The associated reduction in losses and weight is reflected in a greater range. In addition to the extended range, there is an additional reason why WBG applications are becoming increasingly widespread in the automotive sector: Cars are used relatively little in terms of their service life, with a total of only about 3,000 to 6,000 hours over a car's lifetime. In industrial applications, on the other hand, converters are exposed to much higher time constraints and the requirements for durability are correspondingly higher.

What are the energy savings of using devices based on WBG semiconductors?

A research group led by Renato Minamisawa from the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) has shown that the use of WBG technologies has great potential. If silicon-based converters were replaced by WBG semiconductors in various electrical appliances worldwide in 2021, more than 100 terawatt hours (TWh) of electricity could have been saved worldwide in the field of electric motors alone, which is equivalent to the production of ten nuclear power plants.

The savings potential is even more considerable when looking to the future. The number of photovoltaic systems and charging stations for electric cars will increase massively in the coming years. If energy-efficient WBG converters were installed in these systems, we could save a lot of electricity. The FHNW study further estimates the savings potential and the additional production in 2050 in the field of photovoltaics alone at 270 TWh per year.



MOSFET transistor for high-voltage applications (10 kV) based on the WBG semiconductor SiC, developed by researchers at the FHNW in cooperation with ABB Switzerland. The electronic component was developed as part of the AMPERE project, which was supported by the SFOE. The transistor can be used in the railroad sector or in lighting applications. Photo: FHNW

Semiconductor technology is strongly influenced by technology companies from Silicon Valley, as well as manufacturers from South Korea, China, Taiwan and Japan. How can the PECTA working group, which is supported by European countries, exert its influence in this environment?

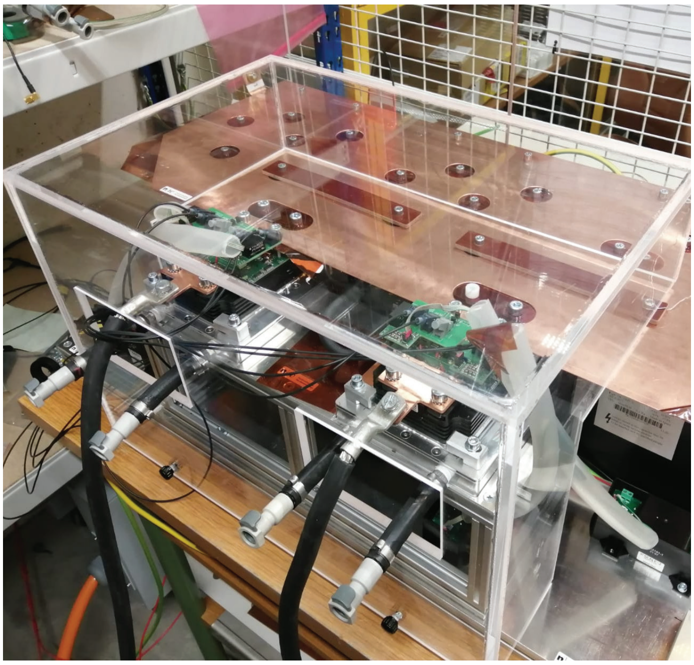
Although PECTA is currently managed by four European countries, the results will of course flow to all 14 member states of 4E. This means that countries such as the USA, Canada, Japan, Korea, China, Australia and New Zealand are always informed of the latest PECTA results. In addition, European industrial companies also have a say in the semiconductor industry. Think of Germany's Infineon. With Hitachi Energy Semiconductors (formerly ABB) in Lenzburg, Switzerland also has an international semiconductor industry. In addition, several international corporations that produce WBG semiconductors, such as the U.S. company Wolfspeed or the Japanese Mitsubishi Electronic Europe B.V., have subsidiaries in Europe. After all, European countries and Switzerland are very active in research and often in exchange with the relevant industry.

The work of PECTA is not linked to the fact that semiconductors are produced in Europe. If PECTA works to create an open-minded climate and conducive framework conditions for the use of WBG semiconductors, this will benefit all WBG applications, regardless of where the devices or the semiconductor components installed in them were produced.

Where do you see a need for further action to open up new areas of application for WBG semiconductors?

In addition to research on improving reliability, which I have already mentioned, one focus is on initiating a circular economy mindset. Power electronics components must be designed from the outset in such a way that they require as few resources as possible for production, have a long service life and can be recycled at the end of their service life with as little waste as possible. A second focus is on charging stations for electric cars. In the future, these will operate bidirectionally, i.e. they will not only enable cars to be charged, but will also feed power from the car battery into the grid. WBG converters will have a large field of application here in the future, so it makes sense to focus on efficiency. And thirdly, we also want to make a contribution to exploiting the high potential of PV inverters.

↗ The eight **scientific contributions** of the PECTA working group at the Power Electronics Conference in September 2023 in Aalborg (Denmark) are available at: https://www.iea-4e.org/pecta/publications/



Prototype of a 6.5 kV converter for railroad applications. It contains WBG modules based on SiC from Hitachi Energy Semiconductors. Photo: FHNW

- **Information** about PECTA can be found at: https://pecta.iea-4e.org/

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- SFOE **technical papers** on research, pilot, demonstration and flagship projects in the field of electricity technologies can be found at www.bfe.admin.ch/ec-strom.

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