Efficient and compact voltage converters for the e-mobility sector

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E-mobility is increasing the demand for efficient and compact voltage converters. Credit: Photo Petair – Fotolia.com

The Fraunhofer Institute for Applied Solid State Physics IAF has

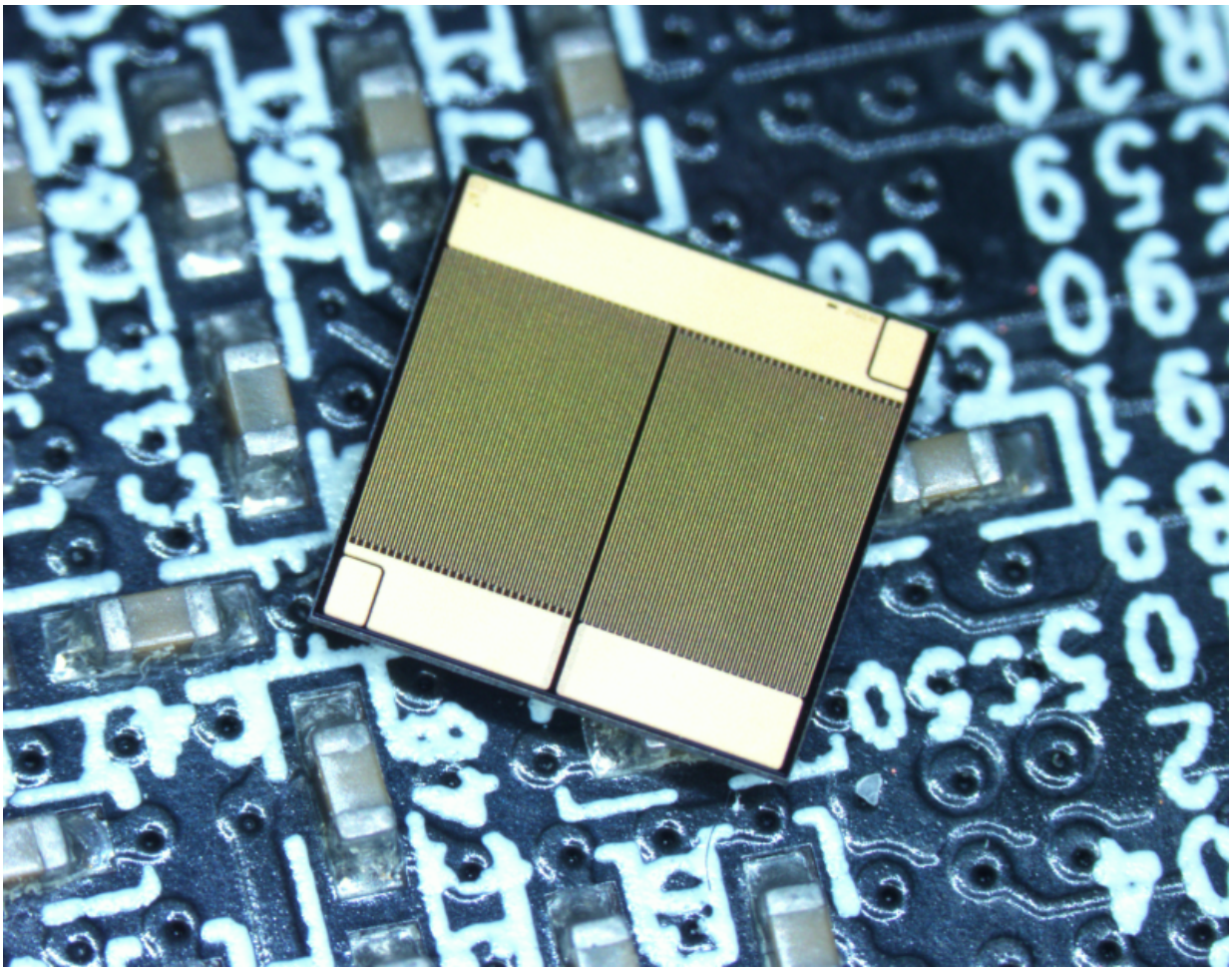
developed the world's first half-bridge circuit for the important 600 volt class in which all the electronic components are monolithically integrated on one chip. Monolithically integrated half bridges are key building blocks of compact voltage converters and significantly increase the efficiency of power electronics devices. This is thanks to the use of the novel semiconductor material gallium nitride (GaN).

Voltage converters are in high demand. Used in mains adapters and chargers for smartphones, laptops and low-voltage household appliances, they can be found everywhere, and – due to our habit of plugging in more and more electrical devices to the mains power supply – they are becoming increasingly widespread. The energy transition and e-mobility are also increasing the demand for reliable and, above all, efficient and compact voltage converters of all kinds. Half-bridge circuits are the centerpiece of many voltage converters. Fraunhofer IAF has now produced and demonstrated the world's first monolithically integrated GaN half bridge for the important 600 volt class. In power electronics components, this is the standard volt class for grid-connected electrical devices, ranging from tablets and washing machines to e-bikes and electric cars.

Monolithic integration involves combining several components on a single GaN chip, enabling extremely small, powerful systems to be created. Besides being very compact, monolithically integrated half-bridge circuits have significantly better electronic properties. For example, the switching frequency can be improved by a factor of around 10 in comparison with conventional voltage converters. "A switching frequency of up to 3 MHz allows us to achieve a much greater power density. This is very important in areas such as e-mobility, where many converters which are as efficient as possible have to be fitted in very little space," says Richard Reiner, research associate at Fraunhofer IAF in the Power Electronics business unit. Monolithically integrated half bridges are more compact, are easier to assemble and improve reliability.

High-performance on-board chargers for electric cars

The German government has set itself the target of putting one million electric cars on the country's roads by 2020. Covering long distances without generating any emissions requires not only powerful batteries but also the development of lightweight electric cars which generate as little energy as possible. This can only be accomplished using electronic components based on semiconductor materials such as gallium nitride (GaN), which in contrast to silicon carbide (SiC) can be grown as epitaxial layer on cost-effective, large area silicon substrates. When used to produce electronic components for electric vehicles, GaN enables higher power densities to be achieved more energy efficiently. The aim of car manufacturers and users is to develop extremely efficient on-board chargers for electric vehicles which take up as little space as possible.



Fraunhofer IAF's monolithically integrated half-bridge circuit. Credit: Photo Fraunhofer IAF

Their compact design minimizes negative influences such as line impedances, improving the electrical switching characteristics. The integration of additional sensor technology, such as a thermal monitoring system, improves operation even further. "This innovative approach brings a new level of power density, efficiency, robustness, functionality and reliability to e-mobility," explains Dr. Patrick Waltereit, deputy head of the Power Electronics business unit at Fraunhofer IAF.

Fraunhofer IAF is presenting its monolithically integrated half-bridge circuit at PCIM Europe in Nuremberg (hall 7, booth 237) from May 16–18, 2017.

Design of the monolithically integrated half-bridge circuit

Fraunhofer IAF's half-bridge circuit comprises two GaN high electron mobility transistors (HEMT) and two integrated freewheeling diodes. The HEMTs have a breakdown voltage of more than 600 volts and an on-state resistance of 120 mΩ. A folded chip layout enables the DC link capacitance to be tightly connected between the supply voltage and ground. This design creates an optimized power path and allows for clean, stable switching at high frequencies. The operation of this circuit was demonstrated at the WiPDA 2016 in a down converter from 400 to 200 volts at a switching frequency of 3 MHz.

Even more complex circuits, such as a monolithically integrated multilevel inverter, have already been produced using this GaN-on-Si technology. In this topology, ten GaN power devices are placed on one chip with an area of 2 x 3 mm2. Each switch has a breakdown voltage of 400 volts in off state and a resistance of 350 mΩ in on state. Compared with conventional converters, multilevel inverters generate less noise during DC/AC conversion. This means that they require smaller output filters. Monolithic integration therefore not only reduces costs, but also makes voltage converters more compact and lightweight. This converter was demonstrated in inverters operating at the mains voltage level used in the USA (120 volts).

Provided by Fraunhofer Institute for Applied Solid State Physics IAF