Key Power Device Technologies Catering to Sustainable Growth of Power Electronics

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Summary
Power devices, through their manifold revolution till date and through manifestation of their various designs, have become an essential part of every aspect of our lives. Amongst other things power devices enable power conversion and motion control in consumer goods, industrial equipment and transportation traction control efficient and climate friendly through the application of power electronics. The growth of power electronics, centering on inverter technology as its core concept, and further evolution of power devices, as key component to essential for the power electronics’ growth, are expected extend far into the future sustainably as the demand for energy saving and alternate energy sources increase rapidly. Highlighting these progresses, several evolutionary changes and breakthroughs have been achieved in the areas of power semiconductor device technologies. Fig. 1 shows the milestones of progresses made in the inverter technology, representing the growth of power electronics, and the major power device technologies that supported it.

More specifically, introduction of various power device technologies such as the power module concept in mid 1970s, the epoch making devices like IGBT in mid 1980s, the Intelligent Power Module (IPM) in late 1980s and also the highly advanced version of IGBT – named as CSTBT- in late 1990s have contributed extraordinarily in downsizing and improving performance of inverter systems. Through our R&D efforts, it has been also demonstrated that an even larger scale of inverter size reduction and performance improvement can be achieved by using Silicon Carbide based power devices. Mitsubishi, among other companies, is also actively involved in developing SiC device technologies to fulfill the future needs and leading research works in this area.

In this paper, the trends related to key power device and module technologies which are essential for maintaining a sustainable growth of power electronics application are explained in detail. This study includes discussion related to past and state-of-the-art IGBT chip technologies manifested till date and its future trend in line the description given in Fig. 2.

Along with the evolution of various power chip technologies, the packaging technology for realizing actual device components have gone through various changes and the trend continues toward achieving higher power density longer life, compact size and more user friendliness.
Fig. 3 summarizes trends related power module packaging for different power handling categories based on Mitsubishi’s designs.

In the content of the paper, some examples of state-of-the-art power module technologies are introduced and discussed to provide a proper view of how and where the latest IGBT chip designs are practically utilized and what level of performances such technologies exhibits in real applications.

Fig. 4 Major trends related to power device technologies.

In the final part of the paper, overall technological trends related to power devices is discussed. Fig. 4 shows an outline of the discussion in this respect emphasizing three major categories of trends for sustainable technological growth in the future. In the power chip category, the 6th Generation IGBT and Diode technologies are the state-of-the-art technologies and concept studies are taking place to realize the next generation chip concepts using silicon and silicon carbide as semiconductor materials.

The second category relates to integration. In the future, power modules expected to be integrated with more of peripheral system functions within its housing following the forerunner IPM architecture to achieve higher power density, more efficient and reliable performances in actual application. Mitsubishi, among others, are actively involved in this area and working on various technologies including advanced HVIC and ASIC processes and circuitry related items to realize such goals in the near future.

The third category exhibits the key trends related to power module packaging technologies. At Mitsubishi, we are aiming for higher power density and higher reliability using our leading backbones of transfer molding process and case-type assembly techniques. Cutting-edge solutions such as technologies for better thermal conductivity, higher operating temperature capability, newer chip-to-electrode bonding method and structure for high-level integration are being developed. All these state-of-the-art technologies and future trends are motivated and catered to maintain a sustainable growth of power electronics applications and contribute extensively in the global effort to counter climate change.

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References