Proceedings of the 4th International Conference on Materials Chemistry and Environmental Engineering
DOI: 10.54254/2755-2721/56/20240650

Research on the current applications of IGBTs in power electronics

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Abstract: Based on the large demand for IGBT components in the 21st century, it is necessary to study the strengths and weaknesses of the IGBT industry. And as one of the irreplaceable and important industrial components in the future, it is necessary to find out the direction of the IGBT industry's future enhancement and the parts that need to be enhanced for its development. Therefore, this study focuses on the future demand and development of IGBT in the economic industry, and determines the future development of IGBT components according to the demand. IGBT has a wide range of applications in the field of power electronics. As a widely used electronic component, this paper compares the advantages and disadvantages of IGBT originals to other originals to get the advantages of IGBT and, at the same time, analyzes the problems encountered by the IGBT industry in modern development and how to optimize the development of the IGBT industry in the future. This paper will be mainly used in the IGBT industry using a comparative analysis approach to the relevant research and, finally, will summarize the advantages of the IGBT that cannot be replaced and put forward the changes that are required by the IGBT industry now as well as the development of the industry in the future.

Keywords: IGBT, Industry Future, Power Electronics, Industry Now Developing.

1. Introduction

In the field of IGBTs, the basic design of electronic components and the basic operating principles of IGBTs have been almost completely researched, but at the same time, the industries in which IGBTs can be utilized have not yet been fully explored, and in certain industry-specific areas, the special parameter design of IGBTs that require attention requires certain research, and in terms of economics, few studies can be found. Studies that consider the development of the IGBT industry are rarely found. The main purpose of this study is to explore the difficulties that the overall IGBT industry needs to face in its future development as well as the specific needs of the industry and to propose possible solutions. Longitudinal comparisons, as well as changes in relevant data, are mainly used to react to the conclusions of the study as well as the problems identified. It is hoped that after this study, the future direction of the IGBT industry as well as the difficulties that need to be focused on can be found.

IGBT in the field of power electronics has a wide range of application scenarios, but in the process, a lot of problems have arisen, so we need to seek innovation and breakthroughs in IGBT components as well as industry from the future of the components themselves as well as the future of the manufacturing industry.

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In the first part, the basic principle of IGBT electronic components is briefly introduced; its basic role and the value of its application in the field of power electronics are explained; what problems are solved using IGBT; what original necessary components are replaced; and what improvements are made compared with those before the application of IGBT. In the second part, it introduces the common problems encountered by power electronic systems using IGBTs and the common shortcomings in their application, finds out the most important points that need to be solved in the application of IGBTs in the field of power electronics, and puts forward how to improve the technology as well as the ways to enhance it. In the third part, we look for problems from the economic point of view of the development of the whole IGBT industry, find the shortcomings and defects of the industry's development, find the necessary economic elements for the future use of IGBTs in the field of power electronics, and look for the bottlenecks that may be encountered by the development of the IGBT industry in the future, as well as the solutions to them.

Citing the case of a well-known power electronics-related enterprise, we analyze the current situation and prospects of IGBTs based on the enterprise's business, and come up with a more suitable development direction for IGBTs.

2. Strengths and weaknesses of IGBTs

In general, an IGBT can be regarded as a PNP transistor driven by a MOSFET, or as a semiconductor device consisting of a BJT and a MOS tube, which has the disadvantage of the high input impedance of the MOS tube and the low on-state voltage of the power transistor [1]. This customer service GTR itself has a very large drive current, and MOSFET itself has a very small current-carrying density. Despite these shortcomings, this electronic component is very suitable for application in more than 600V AC systems. In real life, we often see IGBTs in AC motors, frequency converters, and other systems. It can be said that the IGBT in the field of inverters has irreplaceable inherent advantages [2-4].

The principle of operation of the IGBT is simply similar to the BJT and MOS tubes, IGBT is through the constant opening and closing of the gate terminal for the circuit to open and close to achieve its purpose, that is, in the gate port of the IGBT plus a positive voltage when the transmitter will keep the circuit at the beginning of the state, if the voltage at the gate port is less than or equal to zero, the components will be cut off for the circuit[1].

IGBT advantages are, IGBT both BJT and MOS tube advantages; has a greater value for the circuit of the voltage and current response [1]; IGBT itself has a very high input impedance and very low on-resistance; through the IGBT components can be achieved by using a low voltage to switch the purpose of the high-current; IGBT does not exist in the input current and the low input loss; the gate circuit is simple to construct, has a low cost, is easy to gate drive mass production, and meets the requirements. in the circuit can be applied by applying a positive voltage to turn on the circuit, and by applying a zero voltage or negative voltage to turn off the circuit; its own high current density, so that it can have a smaller size; compared with the BJT and MOS tubes, the IGBT has a higher power gain; compared with the BJT has a higher switching speed; Due to its bipolar nature, it is highly conductive and extremely safe [5].

The disadvantages of IGBT are that the switching speed of IGBT is slower than that of MOS tubes; other components are needed to assist in the processing of AC waveforms; it is more difficult to block higher reverse voltages; it is more expensive compared to BJTs and MOS tubes; there are still some latching problems in some cases; and the shutdown time is longer compared to that of PMOS tubes [1].

3. The Future of IGBT Components

In the field of electric power, IGBT is widely used in the control of current and voltage because of its own switching control function through the voltage to control the circuit shutdown, and in the field of renewable energy, IGBT also has an irreplaceable role. IGBT is often used as an important device in the energy conversion circuit, especially in the fields of wind energy and solar energy, and finally in the field of specialized power electronics. Finally, in the specialized power electronics field, IGBTs are

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usually used in a series of power electronic devices such as frequency converters, UPS, inverters, etc., which can effectively improve the efficiency of power equipment.

The future development trend of IGBT is mainly manifested in the production of IGBT components for the high-end market. In addition, as the overall market for IGBT gradually matures, the trend for IGBT components themselves to be high-end is also becoming more and more obvious. In the future, the industry is expected to continue in high-performance, highly integrated, high-power density, and other directions. With a series of advances in science and technology, IGBT new technology continues to emerge [6]. As semiconductor materials such as SiC and GaN are gradually used in the manufacturing process of components, IGBTs will have higher performance and lower energy loss with the support of new materials, which is conducive to expanding the use of new market environments [7]. For the overall ecological environment of the earth's impact, with the application of IGBT in the field of new energy, environmental protection and other areas will become more and more extensive in the future, the future of the IGBT industry will pay more attention to the protection of the ecological environment and sustainable development, in order to better carry out the earth's carbon cycle and a series of energy-saving and emission reduction measures. In summary, with the continuous development of IGBT technology and the gradual expansion of market demand in the future, the industry will have a very broad market prospects and the future, such as new high-performance IGBT products will inevitably continue to set off another wave of power electronics technology update and iteration, and with good ecological environment and sustainable development [8].

4. The current situation of the overall IGBT manufacturing industry

4.1. Opportunities and Shortcomings

IGBT components can now claim the second-largest market share in the approximately $25 billion global power device market, and growth is strong. According to the latest market research researches, the global IGBT market reached $38 billion in 2020, and the figure is expected to reach $63 billion by 2027. At present, China is the world's largest IGBT market and one of the important IGBT production bases, IGBT core manufacturers are mainly concentrated in Germany, Japan and the United States and other countries and regions, including Infineon, Hitachi, Fuji Electric, etc. The downstream market of IGBTs includes electric power, photovoltaic energy, power electronics and other industries [9].

The development of the IGBT industry is accompanied by many problems. The first is the heat dissipation problem brought about by the increase in power density. With the increase in power density requirements for equipment power, the heat dissipation problem of IGBT components itself becomes more and more important. Excessive operating temperatures can lead to a reduction in the reliability of the IGBT module, resulting in thermal fatigue and failure of the module. Then there is the design of circuit driving and protection circuits, with the improvement of IGBT performance, the design requirements for driving and protection circuits are also becoming more and more demanding, while the driving circuit can accurately control the switching action of the IGBT, it is also necessary to avoid problems such as electromagnetic interference caused by too fast switching speeds. The last issue to pay attention to is the performance requirements for emerging applications, such as smart grid, renewable energy integration and other directions, these new areas put forward higher requirements for the performance of the IGBT, they may have a higher switching frequency, greater current capacity, and other needs [9,10].

4.2. The future of the IGBT industry

In order to respond to future market demands in the IGBT industry, we need to develop more efficient cooling systems, improve the thermal design structure of IGBTs, use better heat transfer materials, and continually optimize heat sink design. In order to cope with the demand for higher voltage carrying capacity, in terms of materials, companies need to continue to delve into the physical and material properties of emerging IGBTs to find a solution that meets voltage withstand requirements without sacrificing its own performance. For the applicability of IGBTs, companies need to design and test

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IGBTs for more stringent environmental adaptability, and need to develop new testing and verification methods to ensure their performance and reliability under various conditions, which includes the development of research into new environmental adaptability test methods, as well as the latest fault simulation and diagnostic methods. In terms of enterprise cooperation, there is a need to better understand the needs and upcoming challenges of customers and related industries through exchanges and cooperation with users and experts in the application field, so that enterprises can provide products that meet the needs [7,10].

5. Conclusion

A series of discussions have shown that IGBT components combine the advantages of BJTs and MOS tubes with higher power gains and smaller chip sizes. In the development of the IGBT industry, today's IGBT occupies the second largest share of the world semiconductor market, with more than 90% share in medical equipment, smart car manufacturing, etc. However, with the development of IGBT-related industries, the IGBT industry will need to make a future in the miniaturization of the components, heat dissipation problems of the IGBT components, as well as the service life of the IGBT itself. A series of exploration and enhancement, attention to the use of new materials in the future design and cooperation with the relevant laboratory development and research, in terms of government policy, the policy of comprehensive support and scientific and technological innovation funding support is also a necessary initiative, this paper believe that under the premise of optimization of the components of the IGBT itself, as well as the industry's internal scientific research and other professional manufacturing materials and industrial innovation, IGBT industry in the future will retain today's market share in the case of better meet people's production needs, solid components in the power electronics industry production core position. At the same time, there are still some shortcomings in the research. For example, in the output value of IGBTs, when looking for information, I did not find the latest industrial development in 2023, and in the research's data performance, the text lacks some relevant charts and tables for vertical and horizontal comparison. Charts can be better for the strengths and weaknesses of IGBTs to make the appropriate analysis and description of the IG more intuitive. The overall development of the IGBT industry is visualized; these areas still need to be optimized in order to research the characteristics of the future development of the IGBT industry, but also lack a certain amount of research for the relevant IGBT demand for enterprise surveys. Such surveys can be better at finding the direction of the future development of the IGBT components as well as the pain points that exist now.

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