# §8. Fundamental Study on Cryogenic Characteristics of SiC Power Device and Its Application to AC/DC Converter

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The large capacity and high current ratings are required for the power supply system to energize SMES coil or nuclear fusion reactor coil in the future. It is the important issue to construct such a power supply system with high efficiency AC/DC converters, as its operational loss should be lowered for minimizing the total loss. SiC-based power electronics device is a promising one to be applied to high current AC/DC converter as its switching element. SiC-based power electronics device has some excellent electrical characteristics, compared with conventional Si-based power electronics device, namely high withstanding voltage, low on-state resistance, high operational temperature, etc. The on-state resistance of power electronics device is an essential parameter related to the operational loss in the device itself. The low on-state resistance of SiC-based power electronics device is the desirable characteristics to reduce the conductive loss, which is the main part of the operational loss in device. The advantages of SiC-based power electronics device are discussed for its application to AC/DC converter, and the conductive characteristics is mainly studied with aim of forward voltage investigation. Based on some experimental results, the fundamental evaluation on forward voltage of SiC-based Schottky Barrier Diode (SBD) is estimated in comparison with that of conventional Si-based SBD.

To compare the conductive characteristics of Si-based SBD with that of SiC-based SBD, a conventional Si-based SBD is examined on its forward voltage in room temperature and in liquid nitrogen temperature. A typical Si-based SBD (6CWQ10FN) has the rating voltage of 100 V and the forward rating current of 7 A. In room temperature, the built-in voltage of the Si-based SBD is about 0.3 V and the forward voltage increases up to about 0.65 V according to the current. The forward voltage has the trend to be saturated in current range 3 A to 5 A, therefore it means that, in higher temperature, on-state resistance of Si-based SBD becomes smaller than that in room temperature. To examine the conductive characteristics in lower temperature, the forward voltage of Si-based SBD is measured in liquid nitrogen temperature. The built-in voltage of Si-based SBD in liquid nitrogen temperature is more than twice of that in room temperature. Following built-in voltage, the forward voltage is almost linearly increased without any saturation in the range up to 5 A. The gradient of forward voltage vs. current is on-state resistance of Si-based SBD, which shows constant in liquid nitrogen temperature. As the result, with cooling down the operational temperature, the forward voltage of Si-based SBD is increased.

As same as Si-based SBD, the conductive characteristics of SiC-based SBD is examined on its forward voltage in room temperature and in liquid nitrogen temperature. The SiC-based SBD (SDP06S60) has the rating voltage of 600 V and the forward rating current of 6 A. In room temperature, the built-in voltage of the SiC-based SBD is about 0.85 V and the forward voltage increases up to about 1.45 V with proportional to the current. The forward voltage has the trend to be linearly increased in measured current range of 0.5 A to 5 A. As mentioned in former section, it is also important to examine the conductive characteristics of power electronics device in cryogenic temperature, therefore the forward voltage of SiC-based SBD is measured in liquid nitrogen temperature. The built-in voltage of SiC-based SBD in liquid nitrogen temperature is increased to about 1.2 V. The forward voltage following built-in voltage has almost the same trend in both temperature of room and liquid nitrogen. The gradient of forward voltage vs. current is on-state resistance of SiC-based SBD, which shows same and constant in room and liquid nitrogen temperature. As the result, although the built-in voltage is increased, the conductive characteristics of SiC-based SBD is almost same on on-state resistance in room and cryogenic temperature.

SiC-based power electronics device, which is now under development, is an advanced power device with excellent electrical characteristics. To examine the conductive characteristics of SiC-based device, SiC-based Schottky Barrier Diode (SBD) is investigated experimentally on its forward voltage. The forward voltage of SiC-based SBD is measured in cryogenic and room temperature. To compare with conventional Si-based SBD, the forward voltage of Si-based SBD is also measured in the same condition. The difference between SiC-based and Si-based SBD is studied on temperature dependence of forward voltage. It is found that the temperature coefficient of forward voltage is negative in Si-based SBD and positive in SiC-based SBD. The positive temperature coefficient of forward voltage in SiC-based SBD is desirable to keep current sharing in parallel connected devices for high current operation. The large capacity AC/DC converter is required to be low operational loss system for high efficiency. To reduce the operational loss, it is necessary to decrease forward voltage and on-state resistance of switching device used in AC/DC converter. SiC-based power electronics device has the possibility to satisfy such requirement for advanced conductive characteristics. Further development and investigation for the attractive SiC-based power electronics device are expected.