Thermoelectric Properties of Single-Crystalline and Dense Sintered SiC

Shinji Fukuda[1], Tomohisa Kato[2], Yoichi Okamoto[3], Hiroshi Nakatsugawa[4], Hiroyuki Kitagawa[5], Satarou Yamaguchi[1],

[1]*Department of Electrial Engineering, Chubu University, Kasugai, Japan*

[2]*National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan*

[3]*National Defense Academy, Yokosuka, Japan*

[4]*Graduate school of Engineering, Yokohama National University, Yokohama, Japan*

[5]*Department of Materials Science, Shimane University, Matsue, Japan*

E-mail: TE07803@isc.chubu.ac.jp

Silicon semiconductor devices are used everywhere to give us modern life in the present time. Cooling is very important to keep the performance of highly integrated Si devices and power devices such as metal oxide semiconductor field effect transistor (MOSFET) and insulated gate bipolar transistor (IGBT). Yamaguchi *et al*. have proposed a new scheme to cool down the devices by its own current named "self-cooling device", in which the cooling process uses both Peltier effect and thermal conduction. In the proposed scheme, it is required that Peltier materials have high thermal conductivity, high Seebeck coefficient and low electrical resistivity. These requirements are different from the conventional Peltier materials' such as Bismuth-Telluride alloys. Silicon carbide SiC has high Seebeck coefficient but has low figure of merit *Z* because it has high thermal conductivity. Because of this, SiC is one of the candidate materials for self-cooling devices. We report the transport parameters of single-crystalline and dense sintered SiCs.

The samples were three single-crystalline SiCs (SC) and six sintered SiCs (ST). SCs were hexagonal structures (α-type) and doped with nitrogen. STs were α-type and cubic structures (β-type). All STs are n-type. The relative densities of STs are 99% of the density of the single-crystalline SiC. We measured the electrical resistivities, the Seebeck coefficients and the thermal conductivities from 300 K to 400 K. Electrical resistivities were measured by the four-probe method. The Seebeck coefficients were estimated to make the temperature differences of 4 – 5 K. The thermal conductivities were measured by the steady-state method.

For both SC and ST samples the Seebeck coefficients decrease along the decrease of electrical resistivities. The Seebeck coefficients of α-typed STs are around 350 μV/K and their electrical resistivities are higher than 10^{-1} Ωm. Therefore, the power factors are very small shown by Fig.1. The Seebeck coefficients of β-typed STs are 120 μV/K and their electrical resistivities are around 10^{-4} Ωm. The Seebeck coefficient and the electrical resistivity are 370 μV/K and 10^{-4} Ωm respectively for α-typed SC. The power factor of the SC is higher than those of β-typed STs. The thermal conductivities of STs are 190 to 240 W/Km.

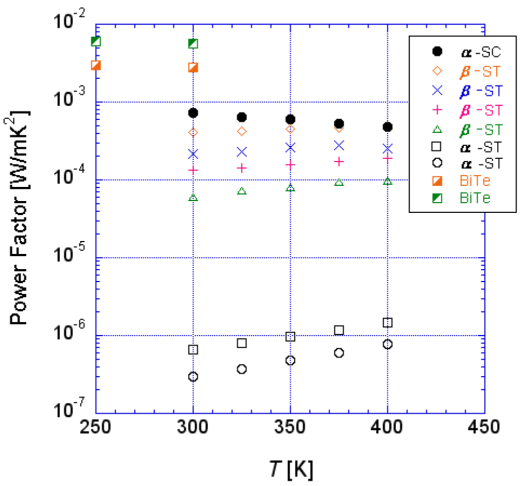

Fig.1 Temperature dependence of power factors in single-crystalline(SC) and sintered(ST) SiCs.