A-4-I26-011

IUMRS-International Conference on Electronic Materials (IUMRS-ICEM 2012)
23rd (Sun.) to 28th (Fri.) September, 2012 at Pacifico Yokohama, Yokohama, Japan

Self-cooling on power MOSFET using copper plating single-crystalline silicon wafers

H. Nakatsugawa*, Y. Okamoto[1)], T. Kawahara[2)] and S. Yamaguchi[2)]
*Yokohama National University, [1)] National Defense Academy, [2)] Chubu University

The self-cooling device has been developed by combining the commercial n-channel power MOSFET and the copper plating single-crystalline silicon wafers in order to improve heat removal or cooling for power devices. The time dependence of the temperature distribution in the self-cooling device is measured to estimate both the conventional thermal conduction and the Peltier heat flux. This strongly indicates that the copper plating silicon wafer is one of the candidate materials for use in self-cooling devices.

Silicon semiconductor power devices that include metal oxide semiconductor field effect transistors (MOSFETs), insulated Gate bipolar transistors (IGBTs) and central processing units (CPUs) are used in a daily life to give us modern life in the present time. When we use the electrical equipment incorporating these devices, the improvement of heat removal or cooling is one of the most important issues because they will not function correctly if they are operated at temperatures above 423K. The cooling system of the self-cooling device proposed by Yamaguchi *et al.*[1-3)] applies both the thermal conduction and the Peltier heat flux. Table 1 summarizes the results of the measurements using the infrared thermography. The average temperature on the water cooled heatsink does not change drastically. This means that the thermal resistance of the water cooled heatsink remains constant for any time. In contrast, the average temperature of the upper side on the power MOSFET is cooled down 0.3℃ in the self-cooling device (2). This fact indicates that the copper plating silicon wafer is candidate materials for use in the self-cooling device which removes the heat generation on the semiconductor power devices by using both the thermal conduction and the Peltier heat flux.

Table 1. Experimental results of the cooling systems in the current of 20A.

Cooling system	Conventional thermal conduction	Thermal conduction and Peltier heat by using the self-cooling device (1)	Thermal conduction and Peltier heat by using the self-cooling device (2)
a: Average temperature of the upper side on the MOSFET (℃)	21.0±0.3	21.2±0.3	20.7±0.5
b: Average temperature of the bottom side on the MOSFET (℃)	18.3±0.8	19.0±0.8	19.1±0.8
c: Average temperature on the water cooled heatsink (℃)	17.5±0.9	17.3±0.9	17.6±1.0
Voltage between the Drain and the Source of the MOSFET V_{DS} (mV)	31.9±0.3	61.8±0.6	51.4±0.5
Joule heat from the MOSFET (mW)	638	638	638
Joule heat from the n-type silicon (mW)	—	43	43
Peltier heat from the n-type silicon STI (mW), where I=20(A)	—	555 (S=95(μV/K), where T=292(K))	347 (S=59(μV/K), where T=294(K))

References

1) S.Yamaguchi, ULVAC **52**, 14-17 (2007).
2) H.Nakatsugawa *et al.*, J.Electronic.Materials. **38**, 1387-1391 (2009).
3) S.Fukuda *et al.*, Jpn.J.Appl.Phys. **50**, 031301 (2011).

Keywords: self-cooling device, power MOSFET, silicon wafer, electrical resistivity, Seebeck coefficient, thermal conductivity, Joule heat, Peltier heat, infrared thermography

Corresponding author*: naka@ynu.ac.jp