Structural Dependent Temperature Distribution in Silicon Nanosheet Thermoelectronics

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Introduction: Thermoelectric (TE) devices generate electrical potential when they have temperature difference. Silicon is one of the materials applied to TE devices. However, most of the studies about TE silicon devices have focused on 1D structure, like Si nanowire, not on 2D. In this study, silicon nanosheet TE device was considered, and we simulated the temperature distribution to estimate TE effect.

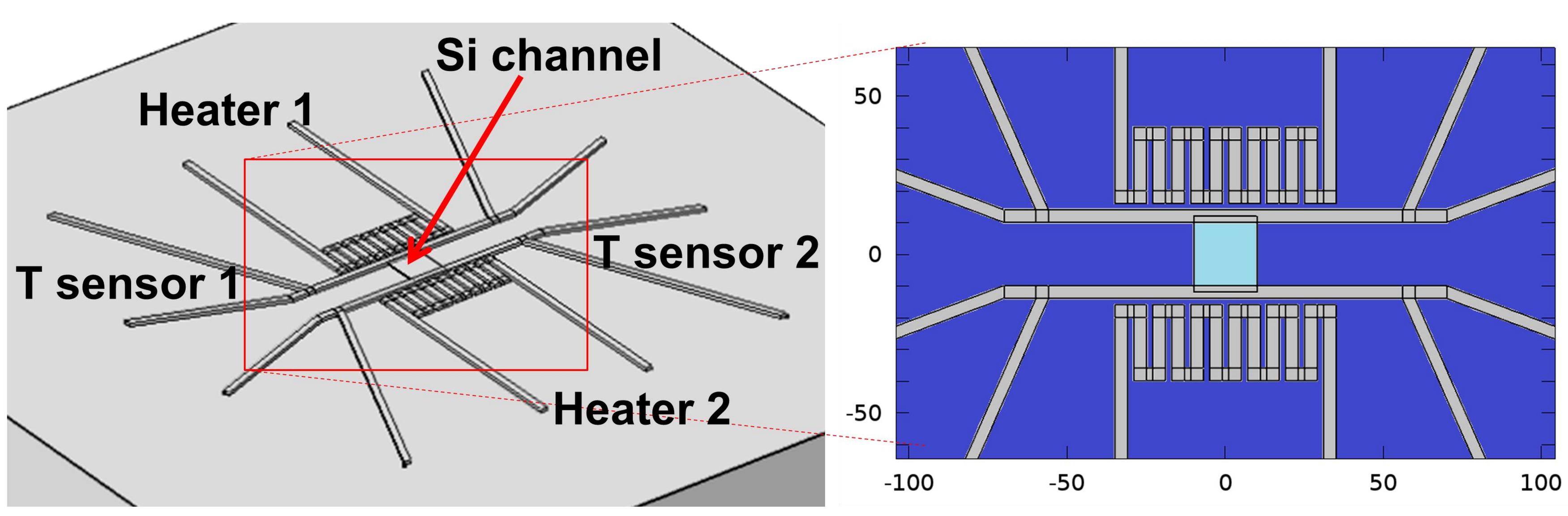

Figure 1. Scheme of device for simulation

Computational Methods: Silicon nanosheet was connected two T sensors, and two heaters were on SiO_2/Si substrate next to channel. Then, 10mA current was applied to the one of heaters, and this generated heat and heat difference on the nanosheet.

The various geometric conditions was considered to know the structural dependent temperature distribution. Also, the existence of silicon bulk substrate and cooled metal chuck was taken into account. And, the current value was swept, 0mA to 70mA with 10mA step.

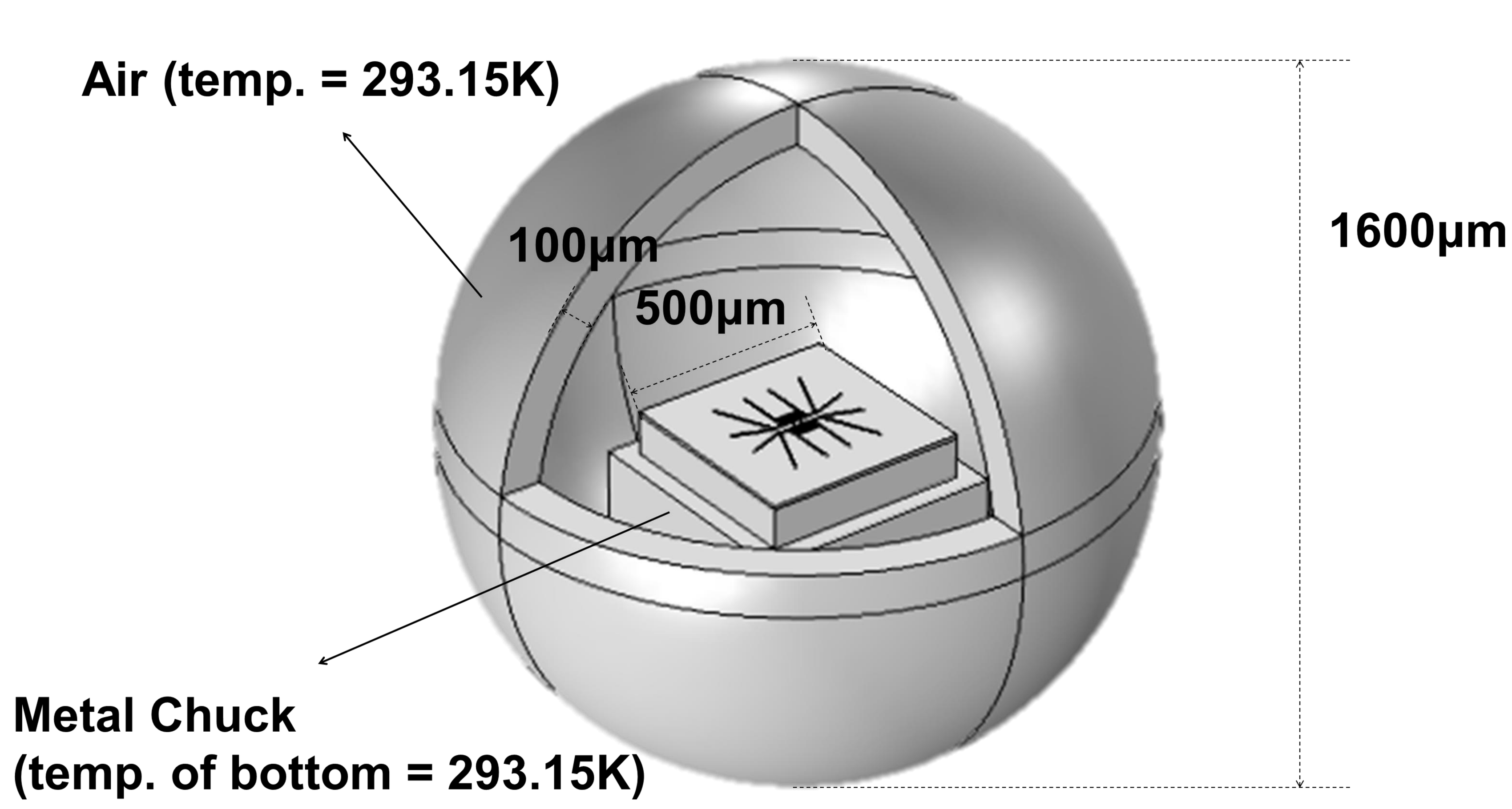

Figure 2. Boundary conditions of simulation

Results: As the current was increased, the temperature of device and the temperature difference between two T sensors were increased. The largest temperature difference was found in the case without bulk silicon. And the thicker SiO_2 layer made the larger temperature difference. Due to the metal chuck, the temperature was relatively low.

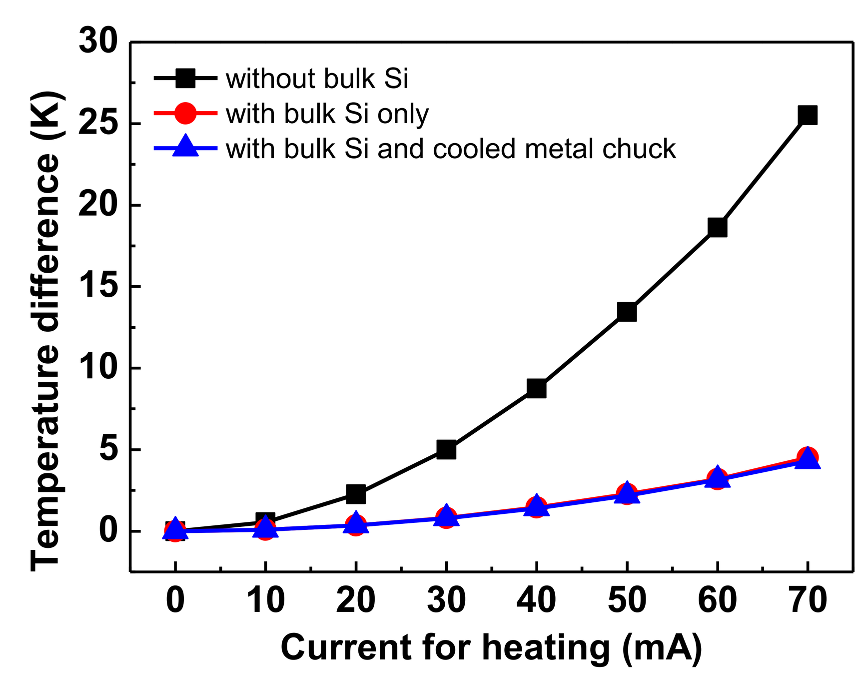

Figure 3. Temperature difference vs. heating current

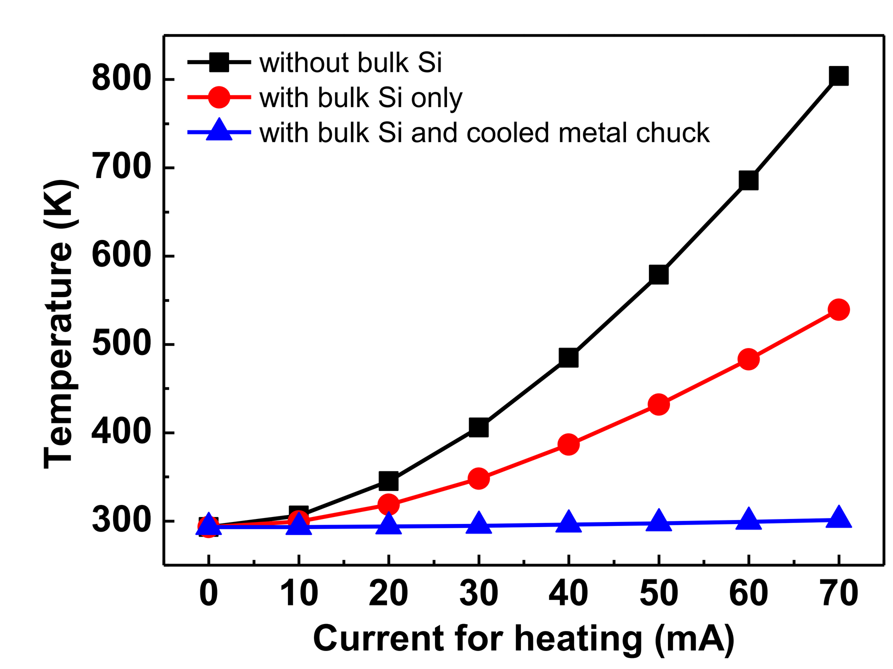

Figure 4. Temperature at the middle of channel vs. heating current

Heating current = 10mA	1μm SiO_2 without bulk	1μm	2μm	10μm	1μm on chuck	1μm on cooled chuck
T sensor 1	378.51	306.64	306.61	306.54	299.3127	293.2441
T sensor 2	407.77	306.68	306.70	307.9497	299.3572	293.2886
Temperature difference	2.93 x 10	4.46 x 10^{-2}	8.19 x 10^{-2}	1.41	4.45 x 10^{-2}	4.45 x 10^{-2}

Table 1. Temperature and temperature difference in various conditions. (unit : K)

Conclusions: The bulk silicon and metal chuck acts as heat sink. And cooling the chuck can help that the unheated side of Si channel stay cold. The thickness of SiO_2 layer is dominant to make temperature difference. Using this result, we will show that Seebeck coefficient can be changed by the geometry of the devices.

References:

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