A thermoelectric cooling/heating knife using Bi_2Te_3-based bulks

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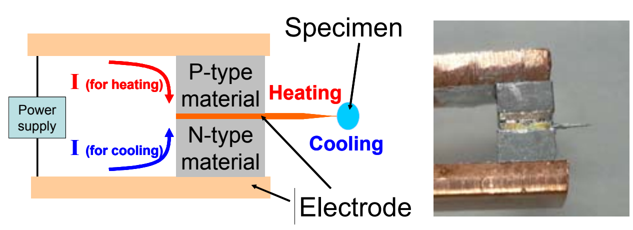
Thermoelectric phenomena (Peltier, Seebeck, and Thomson effects) are well known in terms of the fact that it directly converses electric energy to heat energy or vice versa. Peltier device has widely been used as an electronic cooling or temperature control device, which has called π-type structure. However, the π-type structure has been only used to cool wide area of macro-objects, and difficult to cool small-size objects especially below millimeter. To overcome this problem, we have proposed and fabricated a novel Peltier device, which we call a point-contact-type sandwich-structure (PCS).

As shown in Fig.1, the PCS device has a sharp metallic micro-tip which is located between p-type and n-type thermoelectric materials. The size of the micro-tip can be changed from 100 nm to 500 µm according to the size and the figure of objects. The PCS device can be useful in a wide range of fields such as medical treatment and bioelectronics. We have been aiming at the application of the PCS device in medical engineering especially surgery.



(a) A schematic (b) A photograph

Fig.1 PCS device

More recently, we have fabricated a pen-type Peltier knife as shown in Fig.2, targeting a more practical use for medical engineering. This device uses sintered p-type ($Bi_{0.59}Sb_{1.30}Te_3$) and n-type ($Bi_2Se_{0.37}Te_{2.36}$) bulks, and a surgical knife is sandwiched between those two bulks.

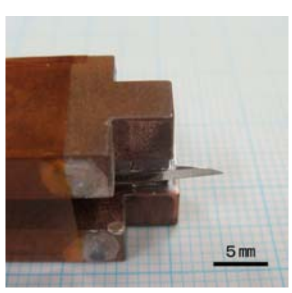


Fig.2 A photograph of the pen-type Peltier knife

The temperature of the knife tip of the Peltier knife device was measured and was plotted in Fig.3. A change of current polarity can easily alter cooling to heating or vice versa. Electrical current in the device was changed 0A to 30A for cooling, and was changed 0A to 20A for heating. For cooling, a minimum temperature of the tip was -12.2℃ at 16A (3.4W), and for heating, a maximum temperature of the tip was 174.7℃ at 20 A (7.6W).

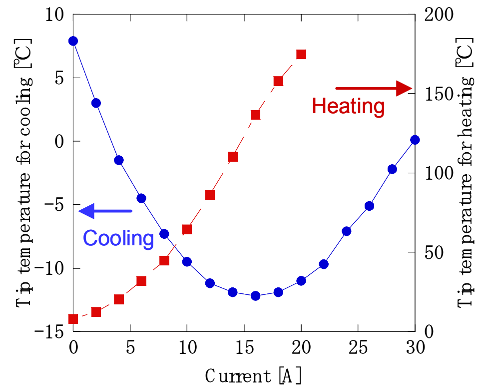


Fig.3 Current dependence of tip temperature

Current dependence of time constant of the Peltier knife device was plotted in Fig.4. In cooling operation, time constant increases with increasing current, and reaches a maximum, then decreases. In heating operation, time constant almost remains to be about 5 seconds. This difference in the trends of time constant is considered to be due to the different role of Joule heat in Peltier cooling and heating.

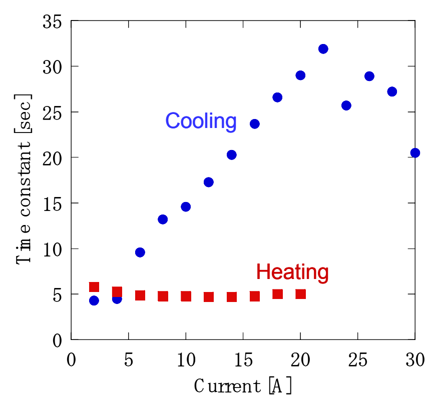


Fig.4 Current dependence of time constant

Switching operation between cooling and heating was performed as shown in Fig.5. The results indicate that the device can quickly switch cooling to heating (or vice versa). For instance, between 180℃ and -20℃, the device operation is changed from heating to cooling in 10 [sec] and from cooling to heating in 13 [sec].

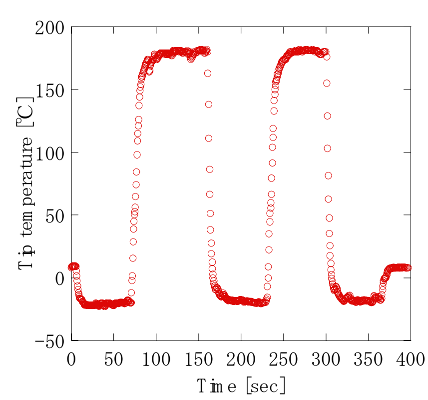


Fig.5 Switching operation between cooling and heating.

After the device is developed, it will contribute to many applications in medical treatment. For example, it may be possible that tissues can be cut from a living body simultaneously during cooling and heating.