Development of thermal diodes using Ag_2Ch (Ch = S, Se, Te)

Tsunehiro Takekuchi

Toyota Technological Institute, 2-12-1 Hisakata, Tempaku, Nagoya 468-8511, Japan

Thermal diode is a new device in which the heat flux strongly depends on the direction of heat flow, and is expected to be one of the key technologies in thermal management. One of the typical thermal diodes is a composite of two solid materials possessing a different temperature dependence of thermal conductivity. The thermal conductivity of one of the constituent materials increases with increasing temperature, while the other decreases. Their performance could be improved by employing materials possessing a significant temperature dependence of thermal conductivity. By employing icosahedral quasicrystals, which possess $\kappa_{900K} / \kappa_{300K}$ ~9, as one of the components, we succeeded in developing thermal diodes possessing a thermal rectification ratio ($TRR = j_{Q\_F} / j_{Q\_B}$) exceeding 2.2.[1] But such a large value of *TRR* required a wide temperature difference, $\Delta T = 600$K, between two connecting heat reservoirs.

In order to make the temperature range of thermal rectification much smaller, we employed in this study a series of compounds obtainable at Ag_2Ch (S, Se, and Te). These silver chalcogenides show a phase transition at around 400 K [2], and the high-temperature phase is characterized by ionic conduction of Ag^+ to realize a very small lattice thermal conductivity as low as 0.6 $Wm^{-1}K^{-1}$. [3-5] We also revealed by measuring the temperature dependence of their thermal conductivity together with electron transport properties that the lattice thermal conductivity of low-temperature phase also possesses very small magnitude presumably because of the anharmonic oscillation of lattice vibration. Notably, the lattice thermal conductivity becomes a several times larger than that both of low-temperature phase and high-temperature phase during the phase transition to make a peak of ~10 K in width in the temperature dependence of thermal conductivity as shown in Fig.1.

The variation of phase transition temperature with varying composition [2] together with the corresponding peak in thermal conductivity allowed us to construct thermal diodes possessing a large value of *TRR* and working with a narrow temperature difference near the boiling temperature of water. We made a thermal diode using Ag_2Se and Ag_2Te, and evaluated its performance by placing it between two heat reservoirs kept at 393K and 407 K. The resulting value of *TRR* = 1.95 were observed for the present thermal diode. Although it was slightly smaller than that achieved for our previous thermal diode consisting of icosahedral quasicrystals, the working temperature range should be advantage for practical applications.

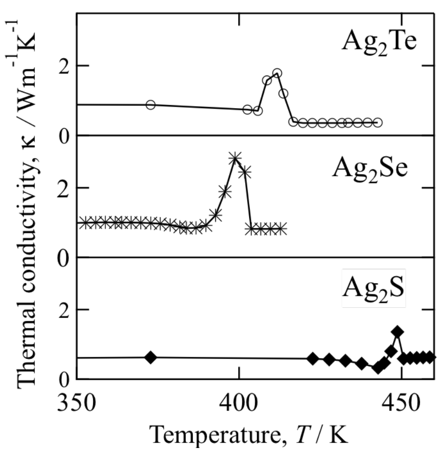

Figure 1 Temperature dependence of thermal conductivity observed for Ag_2Ch (Ch =S, Se, Te).

[1] T. Takeuchi, *Sci. Technol. Adv. Mater.* **15**, 064801 (8pp) (2014).
[2] S. Miyatani, *J. Phys. Soc. Jpn.* **15**, pp. 1586 – 1595 (1960).
[3] Y. Pei *et al.*, *J. Mater. Chem.* **21**, pp.18256-18260 (2011).
[4] D. Jung *et al.*, *Materials Transactions* **53**, pp. 1216-1219 (2012).
[5] J. Capps *et al.*, Philosophical Magazine Letters **90**, pp.677-681 (2010).