高効率熱電変換
Highly Thermoelectric Conversion Efficiency

テクノ プロ R&D[1], °掛本博文 [1]
TechnoPro Inc. R&D company [1], Hirofumi Kakemoto
E-mail: hiro2014ka@gmail.com

[INTORDUCTION] To realize sustainable development goal, sustainable clean energy should be created using energy harvesting systems. Thermoelectric (TE) has studied in metallic, semiconducting, nitride, and oxide materials, and TE materials are fabricated TE device for the energy harvesting from waste heat. [1,2] It is possible to increase the high TE conversion efficiency (η) up to 12% with dimensionless figure of merit (ZT)~1.7 with thermal difference (dT) up to ~150K. [3,4]

In this presentation, above mentioned η from waste heat around 200°C will be presented.

[EXPERIMENTAL] The *P*- and *N*-type one-leg devices (their process was reported in ref. 3, 4) were examined to consider its TE properties, and estimate efficiency as shown in calculation.

[CALCULATION] EMF (V) was calculated as follows, $V=(e/q_D)\{q_D L(1+\exp(-q_D L)+2\exp(-2q_D L)-2\}$, where e, q_D and L are charge, Debye length, and sample length, respectively. TE conversion: total efficiency ($\eta_{tot}=\eta_C\eta_m$) was estimated from η of Carnot cycle: $\eta_C= dT/T_{hot}$, and η of material: η_m: expressed by ZT and $dT=T_{hot}-T_{cold}$ as follows, $\eta_m=[(1+ZT)^{0.5}-1]/[(1+ZT)^{0.5}+T_{cold}/T_{hot}]$. As shown in **Fig.1**(d), total η_{tot} was estimated.[1]

[RESULTS] **Figure 1** (a) shows waste heat distribution from room temperature to 800°C. Below 200°C, waste heat is potentially increased. (It should have a target for TE generation at around 200 °C, up to dT~ 150K) [2]

Currently, the huge electromotive force (EMF) values of TE materials were compared with space charge (SC) theory. Their EMF values, however, no conduction was expected.

Therefore, a high Seebeck coefficient ($S=V/dT$), with a favorable electrical conductivity (σ): as shown in **Fig.1** (b), S and σ are up to 8,000μV/K, and 12 S/cm at 500K, respectively, could be realized, such as, in their multi-layered $S/\sigma/S$ structure. [3,4] As shown in **Fig.1**(c), eventually, $ZT=(S^2\sigma T)/\kappa$ is estimated as 1.7 with κ_2~22W/mK at 500K: with dT=10K.

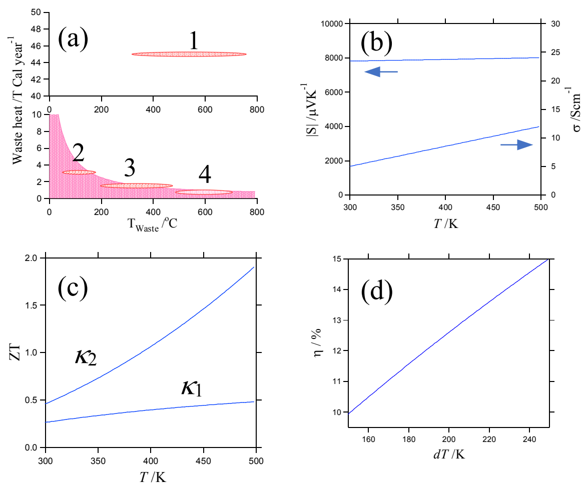

Fig. 1 TE generation from waste heat as recycle energy by using TE device, (a) The waste heat distribution (upper: 1 automobile, lower: 2 transfer-substation, 3 iron and steel furnace, 4 incineration plant), (b) S and σ versus T, (c) ZT versus T as a function of κ, and (d) η_{tot} versus dT.

Figure 1 (d) shows the total efficiency of TE conversion: η_{tot} was estimated from ZT at 500K (1.7) and dT~200K, η_{tot} was estimated as ~12%.

The estimated η_{tot} versus dT is possible to be expected TE conversion from waste heat as shown in **Fig.1**(a). Here, as shown in **Fig.1** (d), the recycle energy from waste heat is possible to be generated by TE device. It is close to coefficient of performance (COP). It is revealed to be possible to be performed high η_{tot} from waste heat around 200°C.

[SUMMARY]

The obtained results are summarized, as follows: A huge Seebeck coefficient (S) would be explained by SC theory, and huge S with favorable electrical conductivity (σ), and thermal conductivity ($\kappa_{1,2}$) by multi-layered $S/\sigma/S$ structure. ZT in above values, and η_{tot} are estimated with dT~200K of waste heat. It is revealed to generate TE transition around 500K and possibly dT~200K with above optimized parameters of TE materials.

Reference [1] M. Sakata et al., *Thermoelectric Energy Conversion*, *Theory and Applications*, Shokabo (2005) [in Japanese]. [2] H. Koumoto, Science & Technology Trend, Sept. p.20 (2008) [in Japanese]. [3] H. Kakemoto, ACS Appl Elec. Mater. **1**, pp.2476–2482 (2019). [4] H. Kakemoto, to be submitted.