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The Maximums of the Power Factor of Thermoelectrics

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INTRODUCTION & AIM

An important characteristic of thermoelectric material, power factor ($PF \equiv \sigma S^2$, σ – specific electrical conductivity, S – Seebeck coefficient) often has extreme values depending on the temperature (T), composition, concentration of charge carriers (n), Fermi energy etc. [1-7]. In this paper, PF – T dependence is considered. In some cases, it has a minimum, in others - a maximum, and in some cases - both. This is demonstrated in Figs (1,2) based on literary and our data. For practical purposes, it is of interest to determine the maxima of this thermoelectric characteristic, which is included in the expression of the figure of merit $ZT \equiv \sigma S^2 T/k$ (k – thermal conductivity).

Below, a mathematical approach to the issue will be made. In particular, it turned out that despite the presence of several variable quantities in the formulas used, no need to use the Lagrange multiplier method - the usual calculation can be applied.

METHOD

To determine $(PF)_{max}$, the Lagrange multiplier method should have been used and the function f (T, m*, μ_W) = f (T, S_r) = f (T, S) should have been considered (m* - effective mass, μ_W – weighted mobility, S_r - reduced Seebeck coefficient). But when making the additional condition, the T's are truncated and $(PF)_{max}$ is calculated more easily.

RESULTS & DISCUSSION

To compile an expression for S, formulas known from the literature [8] relating T, m*, and concentration of charge carriers (n) the following expression can be obtained:

$$f(S) \sim \left\{ \frac{\left[e^{(S_r-2)}-0.17\right]^{2/3}}{S_r\left[1+e^{-5(S_r-S_r^{-1})}\right]} + \frac{1}{1+e^{5(S_r-S_r^{-1})}} \right\}.$$

Using the equations from [8,9] we get: $\mu \cong \left(\frac{m^*}{m_0}\right)^{-3/2} \mu_W$,

$$\frac{m^*}{m_0} \sim \left(\frac{n^{2/3}}{T}\right) \left\{ \frac{3\left[e^{(S_r-2)}-0.17\right]^{2/3}}{1+e^{-5(S_r-S_r^{-1})}} + \frac{S_r}{1+e^{5(S_r-S_r^{-1})}} \right\}, \quad \mu_W \sim \left\{ \frac{e^{(S_r-2)}}{1+e^{-5(S_r-1)}} + \frac{\frac{3}{\pi^2}S_r}{1+e^{5(S_r-1)}} \right\}$$

(μ, - drift mobility, m_0 – electron rest mass). Using these expressions we will get: $PF \sim AT^{3/2}$, where

$$A = \left\{ \frac{\left[e^{(S_r-2)}-0.17\right]^{2/3}}{1+e^{-5(S_r-S_r^{-1})}} + \frac{S_r}{1+e^{5(S_r-S_r^{-1})}} \right\} \left\{ \frac{e^{(S_r-2)}}{1+e^{-5(S_r-1)}} + \frac{\frac{3}{\pi^2}S_r}{1+e^{5(S_r-1)}} \right\} \left\{ \frac{\left[e^{(S_r-2)}-0.17\right]^{2/3}}{1+e^{-5(S_r-S_r^{-1})}} + \frac{S_r}{1+e^{5(S_r-S_r^{-1})}} \right\}^2.$$

The empirical result is: $(PF)_{max} \cong 1.42 \cdot 10^{-8} A_{max} T^{3/2}$.

CONCLUSION

The maximum values of thermoelectric parameter of materials - power factor is estimated. Based on the formulas known from the literature, which interconnect the thermoelectric parameters, the function of the mentioned factor is obtained and its maximum was estimated. The obtained data can be used to analyze the experimental data of those works in which, for some reason, the maxima of the specified thermoelectric parameter is not given.

FUTURE WORK / REFERENCES

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