Evaluation of Efficiency Factors of Commercial Thermoelectric Materials Using COMSOL Multiphysics® Software

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Introduction: Many challenges have been raised about the applicability and reliability of the dimensionless figure of merit (ZT) in estimating the efficiency factor (Φ) of different thermoelectric (TE) materials. To avoid these challenges, we have developed special program using Comsol Multiphysics to compute Φ of TE materials without using conventional ZT parameters. The obtained Φ in eight TE materials are within the range as those reported in the literature between 0.091 μWcm^{-2}K^{-2} ≤ Φ ≥ 0.001 μWcm^{-2}K^{-2}. This work has shown that Comsol Multiphysics is a powerful tool for analysis of TE materials and can be used to predict Φ without using conventional ZT.
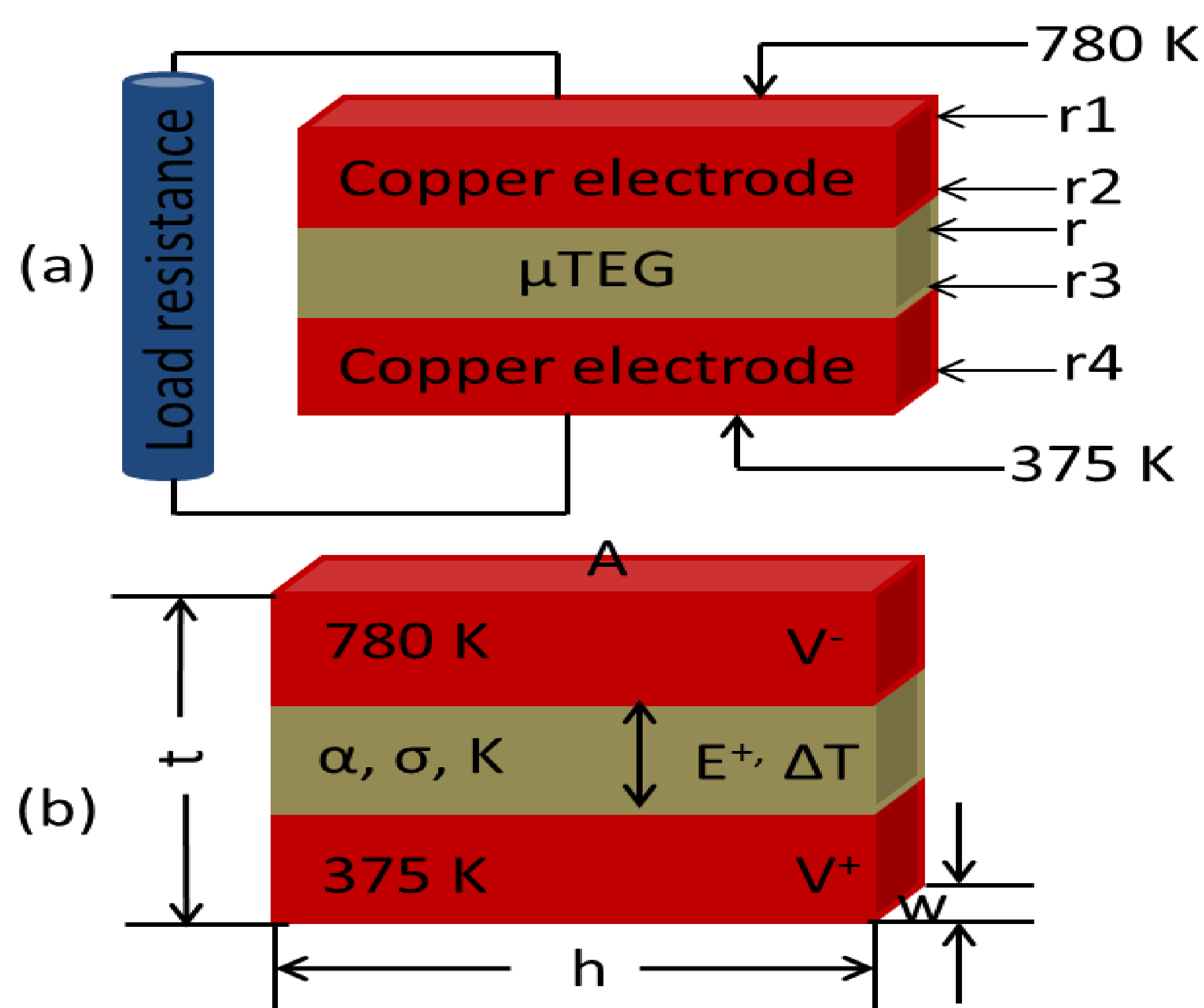

Figure 1. (a) Single leg model, (b) parameters used for simulation.

Computational Methods: The following equations were used to insert TE parameters in Partial Differential Equation (PDE).

$$\nabla \cdot (-c\nabla u) = f \quad \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$c = \begin{pmatrix} \lambda + \sigma\alpha^2 & \sigma\alpha T \\ \sigma\alpha & \sigma \end{pmatrix} \quad \dots\dots\dots\dots\dots (2)$$

$$f = \begin{pmatrix} \sigma((\nabla V)^2 + \alpha\nabla T\nabla V) \\ 0 \end{pmatrix} \quad \dots\dots\dots\dots (3)$$
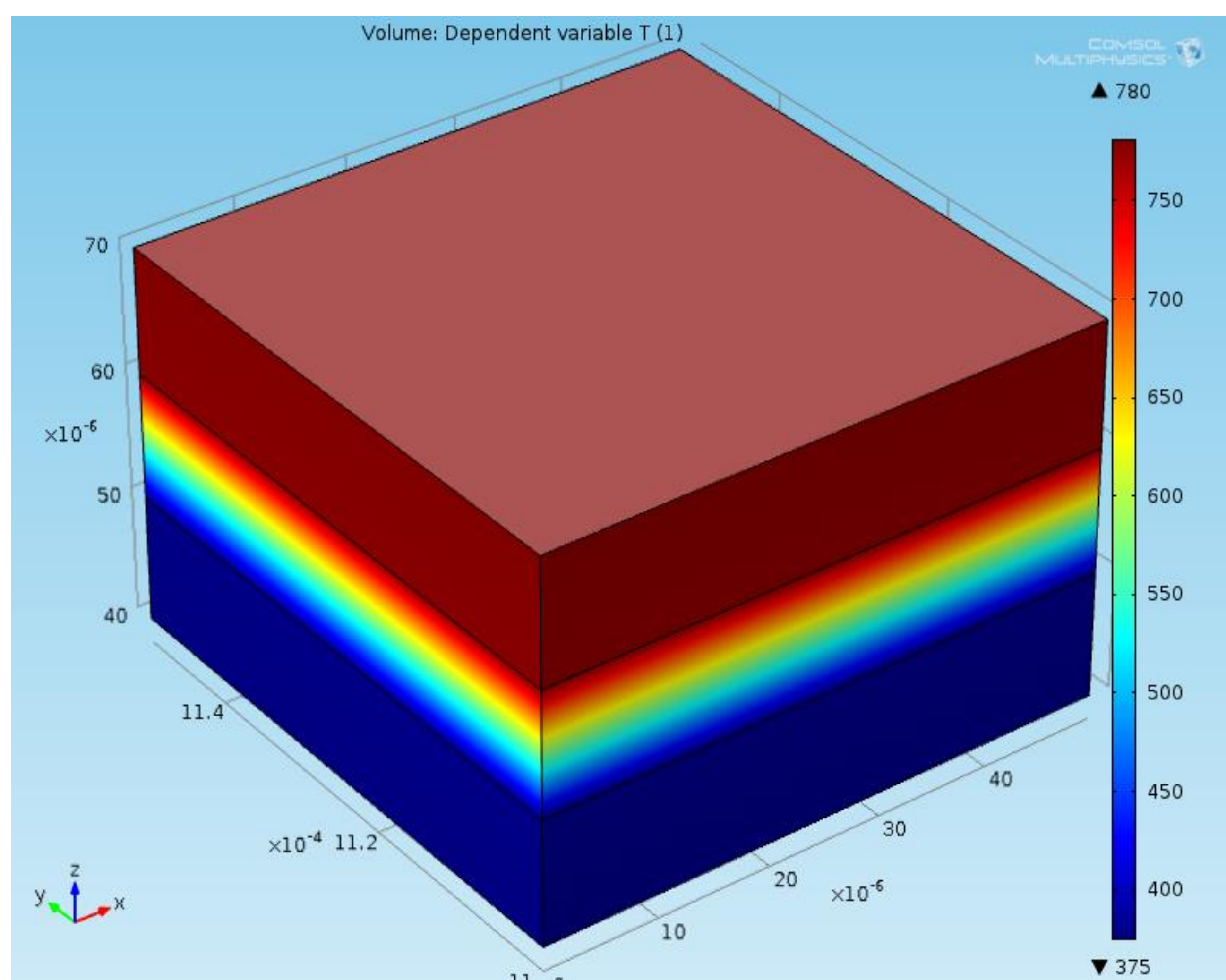

Figure 2. Temperature distribution in a single leg model.

$$P = [\sigma A(\alpha\nabla T - E)] * V \quad \dots\dots\dots\dots\dots\dots (4)$$

$$\Phi = \Delta P \, (\Delta T)^{-2} * A^{-1} \quad \dots\dots\dots\dots\dots\dots (5)$$

Results: The product of electric currents per meter and voltages per meter were calculated using PDE and the results were reported as power per unit area or (W.m^{-2}). The Φ were calculated using parametric programing in PDE by using special probe to capture change in power (ΔP), ΔT, and area (A), thus (Φ = ΔP*A^{-1}*ΔT^{-2}).
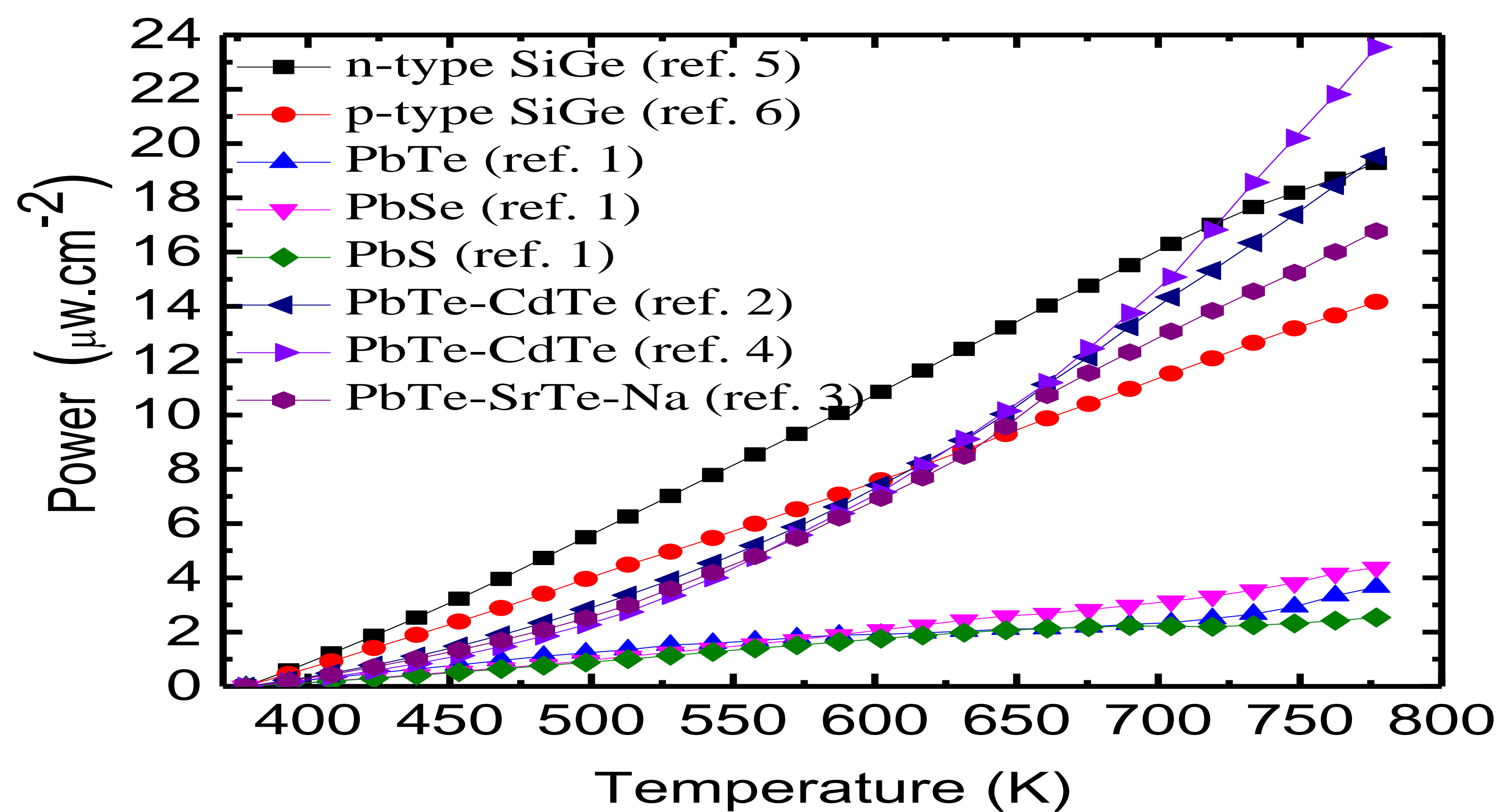

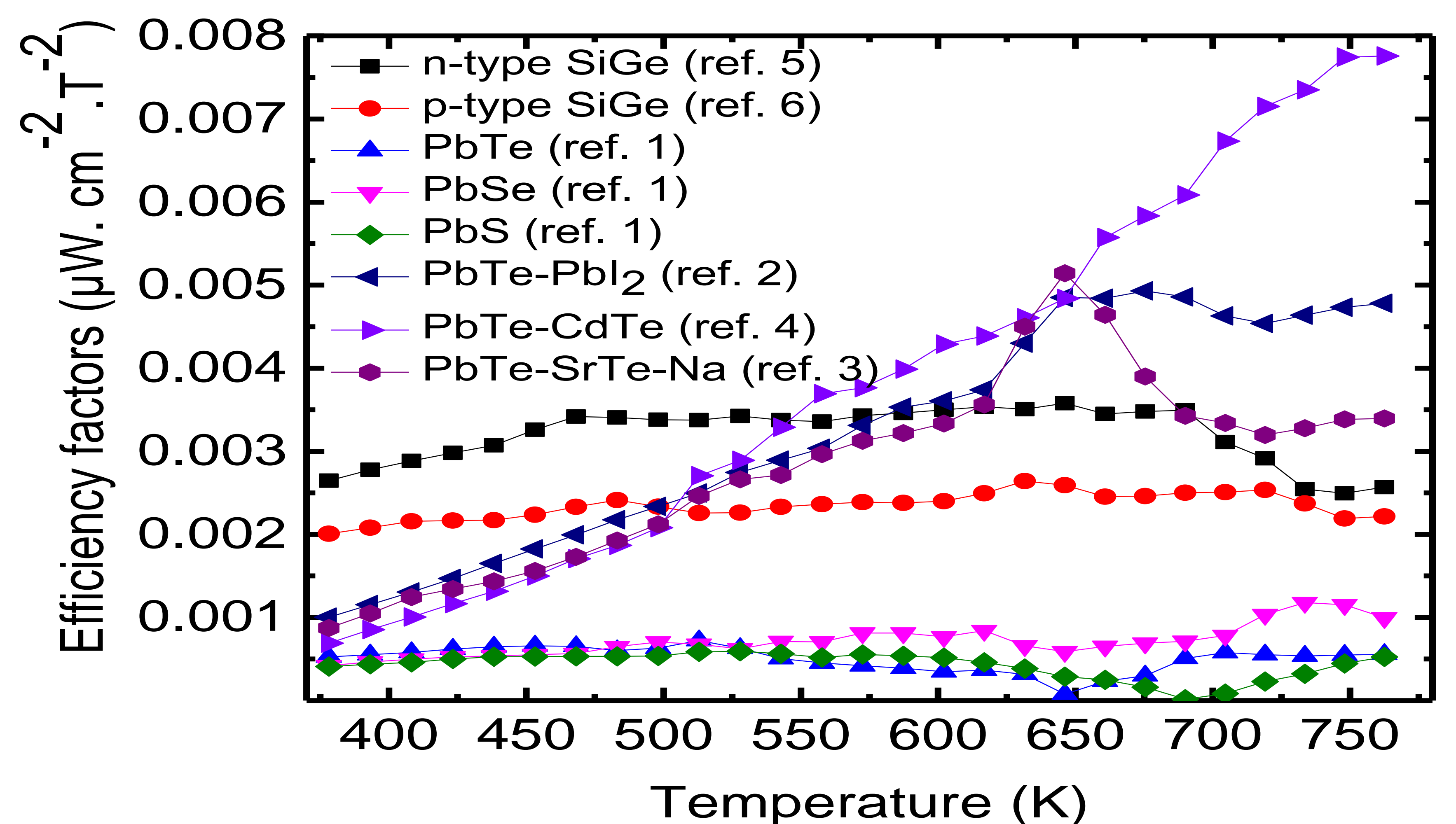**Figure 3**. Power versus temperatures.

Figure 4. Efficiency factors versus temperatures.

Conclusions: We noted that our results are within the range as those reported in the literature, showing that Φ can be from 0.091 μW.cm^{-2}K^{-2} ≤ Φ ≥ 0.001 μW.cm^{-2}K^{-2}. We have also shown that Comsol Multiphysics is a powerful tool for computing Φ of different TE materials without using conventional ZT parameters.

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