Thickness Designs for Micro-Thermoelectric Generators Using Three Dimensional PDE Coefficient-Comsol Multiphysics 4.2a Analysis

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Abstract

Predicting the optimum thickness and gap size between n-type and p-type legs of micro thermoelectric devices are the major challenges in designing micro thermo electric generators. Current research has shown that the thickness of both electrode and thermoelectric layers can be calculated using 3-D Finite Element Methods [1-6]. However, determination of the optimum gap size remains a major challenge. To solve this problem we have used PDE Coefficient form in COMSOL Multiphysics 4.2a to incorporate thermal conductivity (K), electrical conductivity (σ) and Seebeck coefficient (α) matrices of thermoelectric materials into 3.D modeling. The thermoelectric materials evaluated with this approach are n-type and p-type SiGe in [7, 8]. COMSOL was then used to design micro thermoelectric generators and analyze voltage, current, and power, as a function of copper thickness (tCu), SiGe thickness (tSiGe), and gap size (tgap). The schematic diagram showing the geometry of our design is given in Figure 1. In the first design, the (tcu) and width (w) of both copper (Cu) and SiGe were fixed at 50 microns as the (tSiGe) varied from 10 to 200 microns. In the second design, the tSiGe was fixed at 10 microns while the (tcu) varied from 10 to 200 microns. In the third design, the (tgap) was varied from 0.1 to 100 microns and at the same time, the thermoelectric power was analyzed as it crosses (tCu), (w), and (tgap). The voltage and current through n-type and p-type SiGe were first analyzed as a function of temperature gradient between 100 K and 500 K. The voltage and current were then used to calculate power as a function of tSiGe; the results are depicted in Figures 2a and 2b. These results showed that as tSiGe decreased from 200 to 10 microns, the power output increased from 0.011 to 0.19 watts. However; the 0.19 watts analyzed across 10 microns of SiGe layers, decreased to 0.0008 watts when crossed the diffusion barrier between tCu/tSiGe layers (Figure 3a). In additional when (tCu) increased from 10 to 200 microns, the power continued to decrease from 0.0008 to 0.00033 watts as shown in Figure 3a. On the other hand, when (tCu) was decreased from 150 to 10 microns, the power crossing the (tgap) decreased from 0.0008 to zero watts (Figure 3a and 3b). The power crossing the gap increased from zero to 0.0008 watts when the (tgap) was decreased from 100 to 0.1 microns. Therefore, in order to obtain maximum power output, the copper electrode portion joining the n-type and p-type legs should be thicker (approximately 150 microns), while copper electrode layered with SiGe should be thinner, (approximately 10 microns). The maximum output power (0.0008 watts) crossing between the micro thermoelectric legs is achieved when the gap size separating the n-type and p-type is less than 0.1 microns.

Reference

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Figures used in the abstract

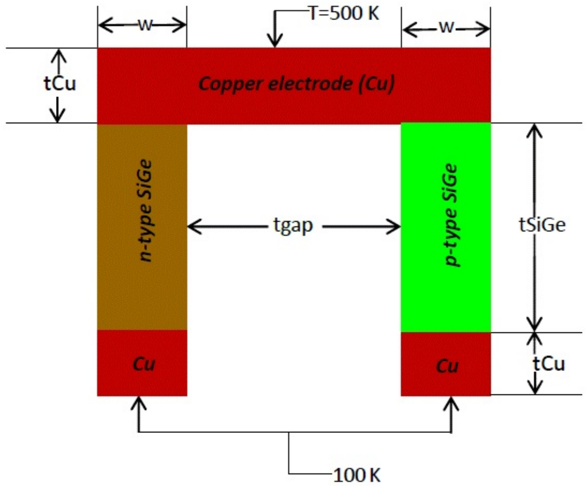

Figure 1: Schematic diagram showing 1-dimension geometrical configuration of the designed micro thermoelectric generator.

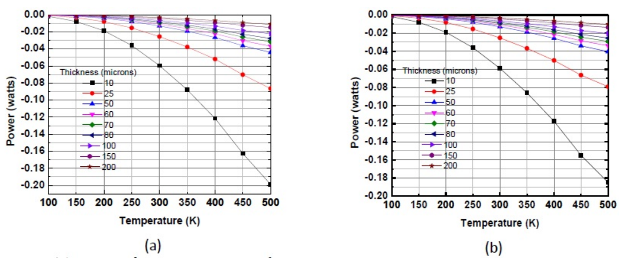

Figure 2: (a). Curve showing variation of power versus temperature as the thickness of n-Type SiGe is varied from 10 to 200 microns; (b). Curve showing variation of power versus temperature as the thickness of p-Type SiGe is varied from 10 to 200 microns.

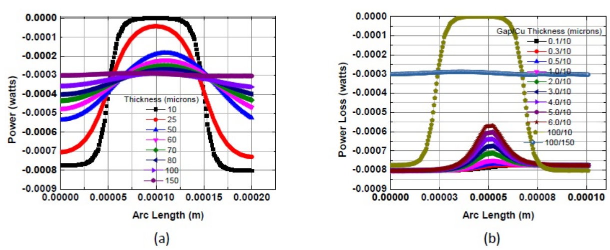

Figure 3: (a). Curve showing variation of power as the thickness of copper electrode is varied from 10 to 150 microns; (b).Curve showing power loss across the n-Type and p-Type junction as the gap is increased from 0.1 to 100 microns.