Asymmetry Induced Terminal Voltage Improvement in Mg2Si-based Thermoelectric Unicouple

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Abstract

Thermoelectric power generation has been envisioned as a clean energy alternative to conventional thermal to electric power generation for decades due to its noiseless and low-cost operation. However, a typical thermoelectric generator suffers from low device efficiency, so it has been a constant endeavor for thermoelectric researchers' community to consider alternate thermoelectric materials and geometries to increase the power efficiency of the thermoelements. In this work, we propose the incorporation of asymmetry in Mg2Si-based thermoelectric unicouple element primarily to enhance the efficiency of thermoelectric generator. Asymmetrical shape of thermoelectric leg helps in two-ways, a) harnessing the Thomson effect, which depends on the temperature gradient in the leg and temperature variation of Seebeck coefficient of the material as the operating temperature range, and is generally neglected in conventional rectangular thermoelements, b) reducing the overall electrical resistance of the device. Mg2Si-based alloys are promising medium range thermoelectric materials and selected for the current application due to their larger variation in Seebeck coefficient with temperature as compared to conventional Bi2Te3 based thermoelectrics. We have carried out finite element simulations on 2D- axisymmetric and 3D geometries of the Mg2Si-based thermoelectric unicouple using the dedicated Thermoelectric module of COMSOL Multiphysics® for a theoretical analysis of temperature profile, internal resistance and heat flux in the presence of asymmetry, and the impact on power generation efficiency. Temperature dependent material properties like Seebeck coefficient, thermal conductivity and electrical conductivity of Mg2Si-based alloys (p-type Mg2Si0.6Ge0.4: Ga-0.8% and n-type Mg2Si0.3Sn0.7) have been taken from literature [1, 2]. We have explored various geometries and shapes of thermoelectric legs including tapered p- or n-leg with different tapering factors, different thicknesses of p- or n-leg within a unicouple, hourglass shaped leg and a combination of above etc (Figure 1), and carried out a comparative analysis for the optimal shape considering the material properties and temperature range in consideration [3, 4]. It has been found that increasing the tapering factor or thickness of a p-leg increases the output terminal voltage (Figure 2) and hence efficiency of the thermoelectric unicouple module depending upon the load resistance and dimensions of the device. Furthermore, an optimization study can be carried out to find an optimum geometry and load resistance for the operating temperature range. Hence, we have demonstrated the inclusion of asymmetry as a potential way to enhance the efficiency of thermoelectric unicouple.

Acknowledgements: This work was supported in part by IIT Bombay IRCC seed grant and partly by ARCI-Center for Automotive Energy and Materials, IIT Madras Research Park, Chennai.

Reference

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Figures used in the abstract

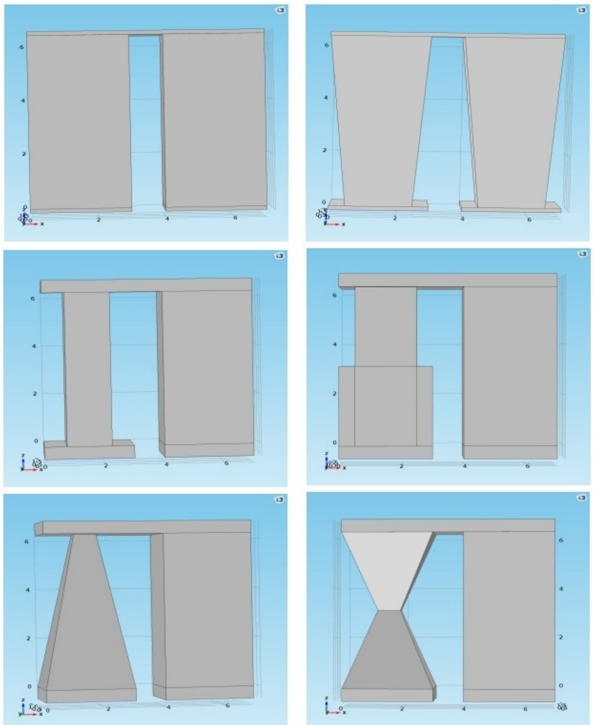

Figure 1: a) Rectangular Module, b) Both legs Tapered Downwards with Tapering Factor 0.5, c) P-leg Reduced Width by Factor of 0.5, d) P-leg Half Wrapped with Alumina, e) Pyramidal Shaped p- leg, f) P-leg Hourglass with Tapering Factor 0.25.

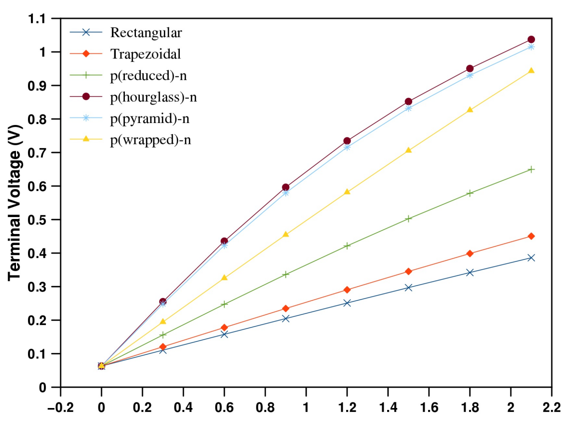

Figure 2: Terminal Voltage of Different Shaped pn Unicouple as a Function of Input Current.