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光子支援効果を用いた熱電子発電器エネルギー変換効率の数値解析
Numerical Analysis of Energy Conversion Efficiency of Thermionic Energy Converter with Photon Enhancement Effect

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1. Introduction

A novel concept of thermionic energy converter with photon enhancement effect is a recently proposed by researchers in Stanford University[1]. The device is based on thermionic emission of photoexcited electrons from a semiconductor emitter. Conventional thermionic energy converter requires high emitter temperature T_E over 1300 K, and even at higher temperature the conversion efficiency from heat to electricity is less than 15%. Therefore, the available emitter material and heat source are restricted. Photo enhanced thermionic emission using a semiconductor emitter has a possibility that a lot of electron emission can be obtained at considerably lower T_E than usual electron emission from metal surface. To design and develop photon enhanced thermionic energy converter operated at low temperature: 500-800 K, the operating conditions, such as bandgap E_g, effective electron affinity χ of semiconductor emitter and T_E, were discussed by numerical analysis.

2. Analysis

The photoexcited emission current density from emitter surface follows the derivation suggested by

$$J_{em} = e\Gamma_{em} = en\langle v\rangle \exp[-\chi / kT_E] \tag{1}$$

where <v> is the average electron velocity perpendicular to the surface. When the surface area for emission equals to the surface area for photon absorption, the flux of photon generation of conduction band electrons Γ_{ph} is equalized with the rate of recombination Γ_{re} and Γ_{em}. In the ideal mode of thermionic energy converter, the maximum output current density equals to J_{em}, and the maximum output power density P_O is estimated by

$$P_O = (E_g + \chi - \phi_C) J_{\mathrm{em}} \tag{2}$$

where ϕ_C is the workfunction of collector. T_E in steady state was calculated from the power balance equation on the emitter[2,3].

3. Results and discussion

Figure 1 shows the calculation result of the conversion efficiency η using a semiconductor as the emitter. η increases with the increase in T_E, and then η reaches the maximum value η_{max} at a certain temperature. Though η_{max} slightly decreases with the decrease in χ, the operating temperature to give η_{max} is reduced much. The effect of surface coating of Cs and introduction of Cs vapor in the space between electrodes on χ and J_{em} will be investigated by experiments.

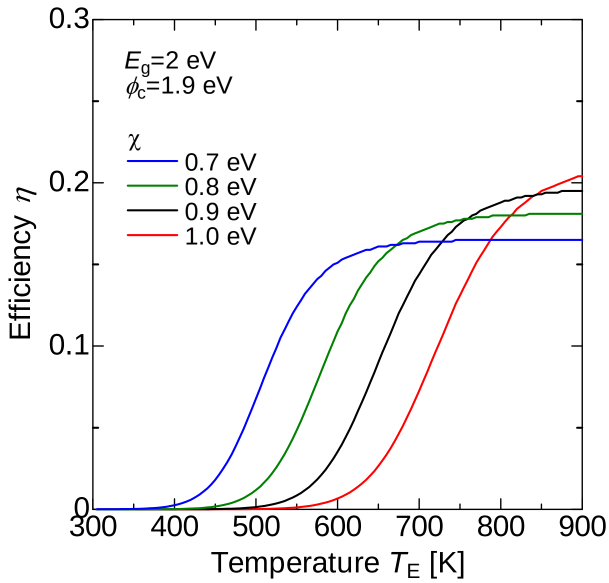

Fig. 1. Calculated conversion efficiency η from heat to electricity as a function of emitter temperature T_E.

References

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