Chapter 12

Physics, Modelling, and Optimization Studies of Photon–Enhanced Thermionic Emission–Based Hybrid Energy Conversion System: A Review

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ABSTRACT

The sustainable development of clean and efficient electricity generation techniques accelerated the research for invention of alternative electricity generation methods. In this chapter, the conceptual analysis of newly invented photon-enhanced thermionic emission (PETE) energy conversion process has been presented. It is a promising option for harvesting solar energy in terms of capturing photon as well as thermal energy simultaneously and converting solar energy into electrical energy based on photovoltaic and thermionic emission processes of energy conversion. Thus, the PETE process utilizes photons for PV conversion and heat of radiation for thermionic emission process. The main objective of this chapter is to review and analyze the performance of PETE converters including thermal modeling, choice of materials, and parametric optimization. The appropriate choice of material requirements for cathode and anode of PETE converters is necessary for practical design of PETE converters. The PETE converter may be an efficient future option for electricity generation using solar energy.

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NOMENCLATURE

\( A_0 \): Area (m²)
\( N_C \): Effective density of states in conduction band (# per cm³)
\( c \): Speed of light (m/s)
\( n_{id} \): Diode ideality factor
\( E_g \): Energy band gap of semiconductor (eV)
\( N_V \): Effective density of states in valence band (# per cm³)
\( E_{g, PV} \): Energy band gap of semiconductor material used in solar cell (eV)
\( N_A \): Electron concentration for ionized acceptor (# per cm³)
\( E_{F_p} \): Quasi-Fermi levels for valence band (eV)
\( N_A \): Concentration of p-type acceptor (# per cm³)
\( E_{F_n} \): Quasi-Fermi levels for conduction band (eV)
\( n_{eq} \): Equilibrium electron concentration without photo-excitation (# per cm³)
\( E_F \): Equilibrium Fermi level (eV)
\( n \): Electron concentration with photo-excitation (# per cm³)
\( E_A \): Ionization energy of p-type acceptor (eV)
\( \delta n \): Excess carrier concentration from equilibrium condition (# per cm³)
\( E_C \): Conduction band minimum energy level (eV)
\( P \): Holes concentration with photo-excitation (# per cm³)
\( E_V \): Valence band maximum energy level (eV)
\( p_{eq} \): Equilibrium hole concentration without photo-excitation (# per cm³)
\( E_x \): Exergy (W)
\( P \): Power (W)
\( E_n \): Energy (W)
\( Q \): Energy (W)
\( G \): Solar irradiation (W/m²)
\( R_0 \): Rate of photon emission at equilibrium conditions (# per m² per sec)
\( H \): Cathode height (cm)
\( R \): Rate of photon emission at non-equilibrium conditions (# per m² per sec)
\( H \): Planck constant (J·s)
\( R_r \): Rate of photon-enhanced recombination at non-equilibrium conditions (# per m² per sec)
\( I_r \): Reverse saturation current (A)
\( R_c \): Rate of thermionic emission in cathode (# per m² per sec)
\( I_{rr} \): Irreversibilities (W)
\( R_a \): Rate of reverse thermionic emission from anode (# per m² per sec)
\( I_{ph} \): Photocurrent (A)
\( R_c \): Rate of photon induced electrons (# per m² per sec)
\( I \): Electrical current (A)
\( R \): Resistance (Ω)
\( j \): Current density (A/cm²)
\( S \): Entropy (W/K)
\( K_{RD} \): Richardson Dushman constant (A/cm²K²)
\( sr \): Aspect ratio
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