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Current status of thermionic conversion of solar energy

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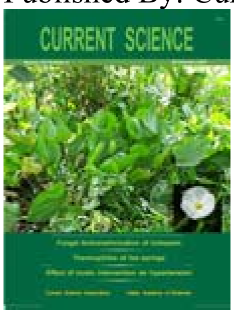

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Recent advances in science and technology of materials fabrication, engineering of work functions, and micrometer gap machining between emitter and collector are making thermionic conversion/converter (TEC) of solar energy an emerging technology. As the converter is the lightest of all devices with highest direct power conversion density (per unit area of the converting surface), it has, potential for substituting photovoltaic technology to a large extent and for deployment in space as a power source. This article summarizes the current efforts/technologies in the field, and discusses their inherent merits and demerits towards realizing the goal of achieving high conversion efficiency and simulation of performance evaluation of a solar TEC. We also discuss the use of both metals and nanomaterials, critical roles of work functions of both emitter and collector, collector temperature, absorptivity and emissivity of the surfaces, radiation losses, and use of both metals and nanomaterials in the efficiency of conversion of solar energy. We further deal with the role of correcting thermionic emission current density equation in the simulation of solar TEC performance. We discuss briefly the possible methods of space-charge control in future in a solar TEC.

Keywords: Emission, solar energy, thermionic conversion, work function.

TAPPING the thermal technology of solar energy is the main focus of researchers compared to other sources of energy generation such as nuclear reactors, combustion of fossil fuel and nuclear energy, because of its renewable nature. In harnessing this energy, researchers have been probing several efficient converters that could give desirable efficiency with less toxic impact on the environment. Therefore, thermionic energy converter (TEC) with unmatchable features of eco-friendly, immovable parts, flexibility and noiseless nature has the potential to convert solar energy to electrical energy through recent advancements of nanoengineering.

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Also, TEC is easy to maintain and has higher efficiency potential close to the Carnot engine, even though there exist limiting factors such as work function of the materials, space charge build-up in the gap between emitter and collector of the TEC, heat loss, as well as physical and chemical factors. Specifically, the heat loss factor can be minimized to achieve optimum performance that is in tandem with the performance of the Carnot engine[1,2]. In recent time, TECs have been modelled as standalone systems with efficiencies >50% and also as combined-cycle systems with efficiencies >60% (ref. 3).

Evolution of thermionic energy conversion technology

The earlier idea of converting heat to electrical energy via thermionic energy was first conceived by Schlichter in 1915 (ref. 4), which later led to scientific collaboration between the then USSR, and USA in the 1950s to set up a thermionic energy converter that would power spacecraft[4,5]. Thereafter, a team of researchers in USA launched a thermionic nuclear fuel element (TFE) that worked at a high temperature for 12,500 h. The invention of Mark III reactor helped USA develop a TEC with an efficiency of 7–11%, and power output of 150 W at elevated temperature[6]. However, the technology faced harsh failure due to undying interest in the photovoltaic technology in the United States at that time. The heat source for a TEC is the major problem. So far, developmental work has focused on TEC systems using heat from a nuclear reactor aboard a spacecraft. The systems recorded efficiencies from 12% to 15% when operating at 600°–1200°C. Interest in the use of TEC for space programmes died down after 1973, except for a vapour thermionic energy converter (VTEC) with a circulating liquid metal source[7] that was built as topping engine for a fusion power plant with 47% efficiency and operating temperature of 1370 K (ref. 7). Consequently, TEC has existed as co-generator with steam turbine Rankine and Sterling engines for solar electricty[8]. In addition, high temperature at the emitter surface is needed to achieve high current density. Solar energy can be concentrated via suitable devices

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