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Direct photoelectric conversion of the focused solar radiation on the base of low-temperature plasma

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A model of the direct photoelectric conversion of concentrated solar radiation in a plasma ignited in a heat pipe filled with a mixture of sodium vapor and krypton is developed. The model considers the non-homogeneous distribution of the alkali atom density in the heat-pipe volume and the thermionic effect of a cathode. The model treats a hot plasma core in a local thermal equilibrium (LTE) state and takes into account non-equilibrium layers near the converter walls. The model is employed to calculate an open-circuit voltage, a plasma resistance, a short-circuit current, an energy flux of positive ions directed toward the cathode, and a conversion efficiency of the solar radiation. We found within the framework of a two-temperature model that the reduction of the electron temperature by 20% compared with the LTE plasma temperature took place at the outer boundary of the ionization layer near the cathode. This non-isothermal model predicts a rather high value (approximately 33%) for the conversion efficiency for a 300x solar radiation concentration ratio. We analyzed the impact of chemical reactions on the plasma conductivity in the external cooling loop region. Two possible explanations for an abnormal high conductivity in an oversaturated vapor of alkali metals are considered. First, the reduce of the effective ionization potential takes place because of the high concentration of alkali metal molecules. Second, a high concentration of micro drop components in the vapor may serve as an additional source of free electrons through the thermal emission effect. The increase of the ambipolar electric field strength in the near-anode region due to non-equilibrium shape of electron energy distribution function (EEDF) is considered. Thus, the formation of the non-equilibrium EEDF in the photo plasma may play a significant role in the problem of attainment of maximal possible values of the converter efficiency.

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