Temperature sensitivity of solar cell efficiency: theories and implications

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This work investigates the physics ruling the temperature sensitivities of photovoltaic devices [1] and highlights some implications for current and emerging technologies. The impact of temperature on the fundamental losses for single junction solar cells is examined and fundamental temperature coefficients are calculated. The importance of the incident spectrum and the bandgap temperature dependence of semiconductors are revealed. The analysis highlights the peculiar temperature behavior expected in the radiative limit of cells made of perovskite compounds such as $CH_3NH_3PbI_{3-x}Cl_x$ and $CsSnI_3$. A graphical illustration is introduced that depicts all the energy transfer mechanisms happening within PV cells. The physical mechanisms ruling the temperature coefficients of different cell parameters (open circuit voltage, short circuit current density, fill factor) are identified and a new expression that relates the temperature sensitivity of open circuit voltage to the External Radiative Efficiency (ERE) of a solar cell is proposed.
Temperature coefficient theories are assessed against measurements made at the University of New South Wales (UNSW, Australia) for a set of crystalline silicon solar cells [2]. The analyses suggest that the relation between the temperature dependence of open circuit voltage and the ERE of photovoltaic devices is relevant. Also, unusual temperature sensitivities of short circuit current and open circuit voltage of cells made of indirect bandgap semiconductors with small collection fractions are highlighted.
Because temperature has a critical impact on the performances of PV devices, this work also introduces original approaches to minimize the temperature-induced losses. The idea is to include the operating conditions in the optimization of the system's parameters in order to maximize the power produced in these conditions rather than in the Standard Test Conditions (STC) [3]. The recent trend of the PV industry towards the creation of products specifically adapted to a given use (climate, type of installation,…) suggests that these original optimizations that take into account the system operating conditions could be implemented in the near future.

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References

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