

Hot Carrier Photocurrent as a Candidate for an Intrinsic Loss in a Single Junction Solar Cell

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Abstract : The advancement in improving the efficiency of conventional solar cells toward the Shockley-Queisser limit seems to be slowing down or reaching a point of saturation. The challenges hindering the reduction of this efficiency gap can be categorized into extrinsic and intrinsic losses, with the former being theoretically avoidable. Among the five intrinsic losses, two — the below-E_g loss (resulting from non-absorption of photons with energy below the semiconductor bandgap) and thermalization loss — contribute to approximately 55% of the overall lost fraction of solar radiation at energy bandgap values corresponding to silicon and gallium arsenide. Efforts to minimize the disparity between theoretically predicted and experimentally achieved efficiencies in solar cells necessitate the integration of innovative physical concepts. Hot carriers (HC) present a contemporary approach to addressing this challenge. The significance of hot carriers in photovoltaics is not fully understood. Although their excessive energy is thought to indirectly impact a cell's performance through thermalization loss — where the excess energy heats the lattice, leading to efficiency loss — evidence suggests the presence of hot carriers in solar cells. Despite their exceptionally brief lifespan, tangible benefits arise from their existence. The study highlights direct experimental evidence of hot carrier effect induced by both below- and above-bandgap radiation in a single-junction solar cell. Photocurrent flowing across silicon and GaAs p-n junctions is analyzed. The photoresponse consists, on the whole, of three components caused by electron-hole pair generation, hot carriers, and lattice heating. The last two components counteract the conventional electron-hole generation-caused current required for successful solar cell operation. Also, a model of the temperature coefficient of the voltage change of the current-voltage characteristic is used to obtain the hot carrier temperature. The distribution of cold and hot carriers is analyzed with regard to the potential barrier height of the p-n junction. These discoveries contribute to a better understanding of hot carrier phenomena in photovoltaic devices and are likely to prompt a reevaluation of intrinsic losses in solar cells.

Keywords : solar cell, hot carriers, intrinsic losses, efficiency, photocurrent

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