Investigating Hot Carrier Effects in GaAs P-N Diodes under Pulsed Laser Irradiation

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The Shockley-Queisser theory states that photons with energy below the forbidden energy bandgap of a semiconductor do not contribute to the net photoresponse of a solar cell, while photons with energy higher than the bandgap participate in the formation of photoresponse [1]. However, recent investigations have revealed that photons with energy lower than the bandgap can induce a photovoltage across a p-n junction known as the hot carrier photovoltage, which exhibits an opposite polarity as compared to the classical photovoltage [2]. Our calculations have shown that up to 10% of the total absorbed solar light in GaAs falls within the below bandgap range, and this proportion strongly depends on carrier concentration and thickness of the top layer [3]. This research sheds light on the intricate interplay between the sub-bandgap photon absorption and its potential impact on solar cell performance, offering new insights for the design and optimization of photovoltaic devices.

This investigation examines photoresponse of LPE-grown GaAs p-n diodes to pulsed laser irradiation of varying wavelengths, specifically 0.532 μm, 1.064 μm, and 1.342 μm. The obtained results yield significant observations. First, the 1.342 μm photons (h□ = 0.92 eV) predominantly contribute to the hot carrier current, displaying limited capacity to induce substantial classical generation-based photoresponse. Second, the influence of 1.064 μm photons (1.16 eV) leads to a prevailing hot carrier photoresponse that surpasses the classical photocurrent generated via the two-photon absorption. The heating effect arises due to the 0.9 eV excess energy remaining after generating the standard electron-hole pair, and contributes additionally to carrier heating via the intraband absorption. Third, in contrast to predictions based on classical theory, laser illumination with a 0.532 μm wavelength (h□ = 2.32 eV, surpassing the bandgap) still exhibits a discernible hot carrier photoresponse which is likely caused by the 0.9 eV excess energy remaining after the classical single photon interband absorption. Overall, this study highlights significant role of the hot carrier effect and emphasizes its consideration when evaluating efficiency of solar cell. These findings challenge the conventional understanding derived from classical theory.

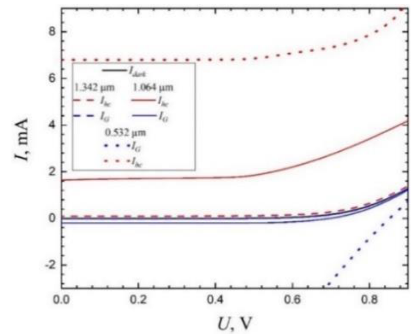

Fig.1. *I-V* characteristics of GaAs p-n junction under laser illumination of 0.4 MW/cm^2 intensity and corresponding wavelength: 0.532 μm (dotted lines), 1.064 μm (solid lines) and 1.342 μm (dashed lines). Red lines refer to the hot carrier photocurrent, blue lines denote classical generation-caused photocurrent.

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