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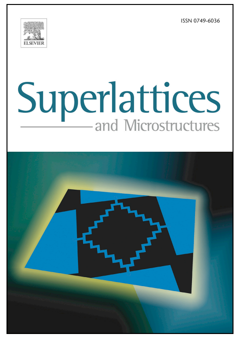

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PII: S0749-6036(18)31226-6

DOI: 10.1016/j.spmi.2018.06.052

Reference: YSPMI 5787

To appear in: *Superlattices and Microstructures*

Received Date: 8 June 2018

Accepted Date: 24 June 2018

Please cite this article as: I. Moeini, M. Ahmadpour, A. Mosavi, N. Alharbi, N.E. Gorji, Modeling the detection efficiency in photodetectors with temperature-dependent mobility and carrier lifetime, *Superlattices and Microstructures* (2018), doi: 10.1016/j.spmi.2018.06.052.

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Modeling the detection efficiency in photodetectors with temperature-dependent mobility and carrier lifetime

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Abstract

We proposed a modeling procedure to calculate the impact of temperature on the detection efficiency in photodetectors based on CdTe materials. Temperature increase impacts on the electrical properties of the materials such as carrier mobility and carrier recombination lifetime. This impact which can be effective in some cases has been normally ignored in the modeling approaches presented in the literature. Here we show that increasing the temperature from 190K to 300K not reduces the mobility of both electrons and holes but also significantly reduces the carrier lifetime. The result will impact on electric-field within the depletion width of the device, drift and diffusion lengths which are used to calculate the carrier collection or detection efficiency of photodetectors. We have collected the temperature-dependency of carrier mobility and lifetime from the experimental reports in literature and showed that detection efficiency of photodetectors is temperature dependent not only by kT constant in the conventional equations but also by temperature-dependency of carrier mobility and lifetime. A practical conclusion of this modeling is to measure both mobility and lifetime after every temperature processing of the semiconductor devices. The model can be further extended to be applied to other optoelectronic devices such as LEDs and Solar cells or humidity sensors.

Keywords: Modeling, solar cells, perovskite, defect generation, time-dependent.

1. Introduction

Device characteristics of photodetectors especially of CdTe materials have been well developed by Kosyachenko's group in Chernivtsi National University in Ukraine [1, 2, 3]. Nevertheless, the routine modeling approaches do not take into account the temperature-dependency of materials parameters. As an example, detection efficiency of CdTe based photodetectors might change under temperature variation even for 190-300K. This hasn't been investigated yet though it might be very effective and realistic to be considered even for a normal operation conditions of the device. A photodetector is made of two Schottky diodes (or a p-n junction and a Schottky barrier) on both sides of the CdTe thickness as shown in Fig. 1. The photogenerated carriers in a photodetector (e.g. X or γ rays) must be collected under a strong electric field within the depletion width of the device before they recombine and are lost as phonons. Therefore, a huge bias is applied to the device (i.e. -400V) is applied to the device which strengthen the electric field in the device junctions and collects the carriers by drift or otherwise by diffusion currents. The depletion width exists in both p-n junction and Schottky barriers as shown in Fig. 1. However, the former could be normally stronger in drift current as a dominant

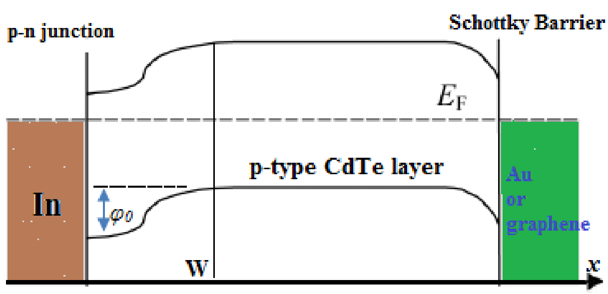

Figure 1: The energy band diagram of the semi-insulating photodetector based on CdTe materials with In and Au graphene contacts. Photodetector is a simple structure made of a p-n junction and a Schottky barrier and the current conduction runs by drift and diffusion currents in depletion width or out of it, respectively.

carrier collection component. Noticeably, both this drift and diffusion current components have the electron/hole mobility, diffusion coefficient or carrier lifetime parameters in their equations as will be discussed later. The experimental literature [4**?**] show that these parameters are not constant during the device operation or especially under stress conditions thus one cannot take them constant for entire modeling process. More than this, both mobility and diffusion coefficient are connected via Einstein law. Graphene electrode in this structure is a promising electrode for a better reliability and performance.

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