Journal of ELECTRONIC MATERIALS, Vol. 42, No. 11, 2013
DOI: 10.1007/s11664-013-2647-3

Numerical Simulation of Spatial and Spectral Crosstalk in Two-Color MWIR/LWIR HgCdTe Infrared Detector Arrays

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The sequential two-color $Hg_{1-x}Cd_xTe$ architecture has emerged as a key technology in the development of third-generation infrared detectors. Due to the expense required to manufacture these devices, it is imperative to create numerical models which can predict the electrical and optical behavior of the technology as well as evaluate design concepts prior to exhaustive development. We have developed a three-dimensional simulation model which fully accounts for the optical phenomena that become increasingly important in small pixels and uses a drift–diffusion approach to determine the electrical behavior of the device. In particular, we employ a finite-difference time-domain method to solve Maxwell's equations and a finite-element method to evaluate the solutions of the coupled Poisson and carrier continuity equations. We apply our simulation model to simulate the dynamic resistance and current density versus voltage characteristics of this detector architecture. The quantum efficiency is then determined for both spectral bands while observing the effects of variable pixel pitch and detector geometry. Finally, we use a spatially finite Gaussian beam to analyze the crosstalk and perform a simulated spot scan.

Key words: Infrared detectors, mercury cadmium telluride, numerical simulation, two color, photovoltaic detectors, crosstalk

INTRODUCTION

The mercury cadmium telluride ($Hg_{1-x}Cd_xTe$) alloy is the most well-developed material system for fabrication of infrared (IR) detectors, having a wide range of civilian and military applications. $Hg_{1-x}Cd_xTe$ has an electronic bandgap that can be tuned from the short-wavelength IR out to the very-long-wavelength IR. In addition, sophisticated growth and processing techniques have been developed, enabling the creation of large-format focal-plane arrays (FPAs). The most widely manufactured FPAs are second generation, consisting of two-dimensional arrays of single-color photovoltaic detector pixels sensing in the mid-wavelength infrared (MWIR) or long-wavelength infrared (LWIR). In recent years, however, interest has shifted towards the creation of more complex detectors capable of higher sensitivity, increased operating temperature, and detection in multiple spectral regions.

In many situations, it is technologically advantageous to detect and differentiate multiple spectral bands within a single pixel in an array. Such two-color detectors offer the benefits of increased detection range and have the ability to demarcate between an object and its background.[1] Two methods have been developed for dual-color sensing. Simultaneous detectors typically contain multiple electrical contacts per unit cell and are grounded through the substrate on which the detector is grown. Photosignal is extracted directly from one of the contacts, while the second contact, common to both spectral bands, provides the sum of the two photocurrents.[2] While this architecture provides the benefit of real-time imaging, the geometry of the pixel reduces the optical fill factor and reduces the

(Received February 1, 2013; accepted May 23, 2013;