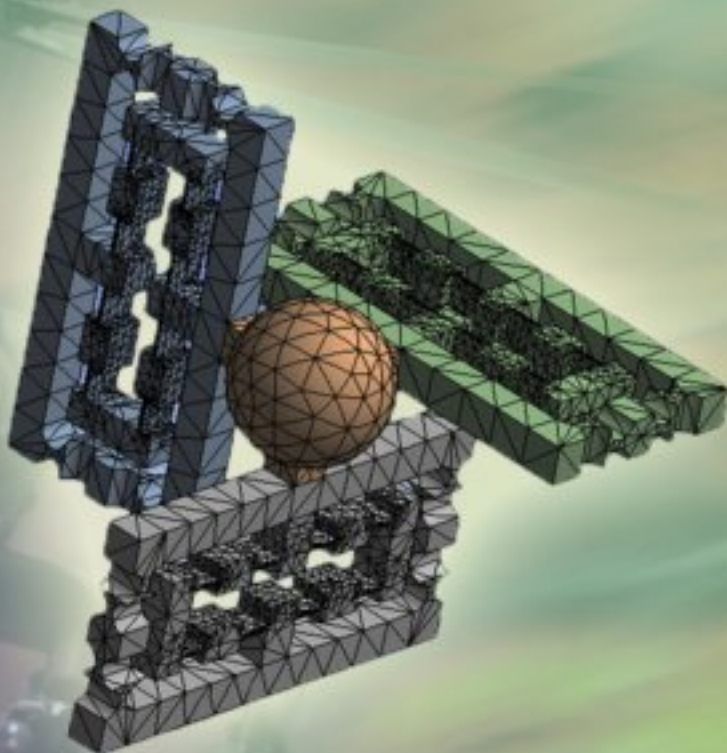
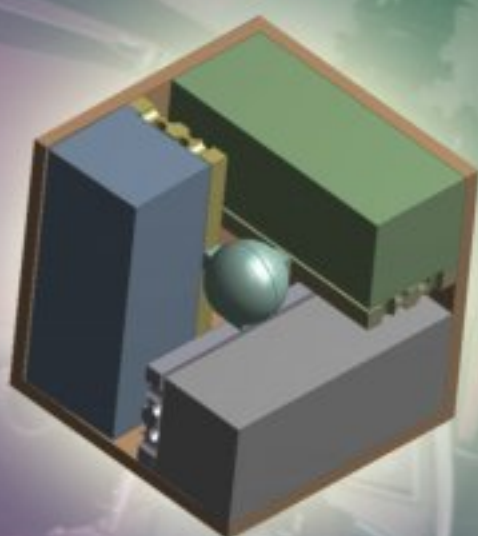


ISSN 1726-5479

SENSORS & TRANSDUCERS

8^{vol. 119}
/10



Sensors and Transducers Applications

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Contents

Volume 119
Issue 8
August 2010

www.sensorsportal.com

ISSN 1726-5479

Research Articles


Fully Decoupled Compliant Parallel Mechanism: a New Solution for the Design of Multidimensional Accelerometer <i>Zhen Gao and Dan Zhang</i>	1
Optical Temperature Probe Based on the Fluorescence Decay Time of Tris-(dibenzoylmethane) mono (5-amino-1,10-phenanthroline)-europium(III) <i>Hung T. Lam, Leah Tolosa, Govind Rao</i>	14
Applications of InAs Hall Effect Sensors <i>H. Bourbaba, C. Benachaiba, S. Kadri, A. Saidane</i>	22
A Simple Model for Complex Fabrication of MEMS based Pressure Sensor: A Challenging Approach <i>Himani Sharma, P. A. Alvi and J. Akhtar</i>	30
Acoustic Temperature Transducer <i>Tariq M. Younes, Mohammad A. K. Alia, Shebel Al-Sabbah</i>	46
Theoretical Performance of GaAs Solar Cell, with Band Gap Gradient Layer on the Back Region <i>Hassane Benslimane, Hemmani Abderahman, and Helmaoui Abderrachid</i>	58
Design of Simple Instrumentation System for the Quality Analysis of Milk (Casein Analysis) <i>V. G. Sangam, M. Sandesh., S. Krishna., S. Mahadevanna</i>	65
Development of a Portable Water Quality Analyzer <i>Germán Comina, Martin Nissfolk, José Luis Solís</i>	72
A Modified Technique of Active Power Measurement for Industrial Frequency Applications <i>Satish Chandra Bera and Dhritinandan Kole</i>	82
New Organic Solvent Free Three-Component Waterproof Epoxy-Polyamine Systems <i>C. M. Lacnjevac, S. Zlatković, S. Cakić, J. Stamenković, M. B. Rajkovic, G. Nikolić and S. Jelic</i>	91
Measurement Equation is to be Extensively Used: What One May Expect from Dynamic Measurements <i>Kristina Abramchuk, George Abramchuk</i>	104
Preparation and study the Electrical, Structural and Gas Sensing Properties of ZnO Thick Film Resistor <i>M. K. Deore, V. B. Gaikwad, N. K. Pawar, S. D. Shinde, D. D. Kajale, G. H. Jain</i>	117
Amperometric Glucose Biosensor based on Immobilization of Glucose Oxidase in Polyethylenimine and Poly (carbamoylsuphonate) Polymer Matrix <i>U. B. Trivedi, D. Lakshminarayana, I. L. Kothari, N. G. Patel, H. N. Kapse, P. B. Patel, C. J. Panchal</i>	129
Development of Bio-analyzer for the Determination of Urinary Chloride <i>R. Vasumathi, P. Neelamegam</i>	142

Identification and Speed Control of PMDC Motor using Time Moments <i>Prasanta Sarkar, Sagarika Pal, Swadhin Sambit Das</i>	151
Parameter Estimation and Speed Control of PMDC Servo Motor Using Method of Time Moments <i>Prasanta Sarkar, Sagarika Pal, Swadhin Sambit Das</i>	162
Determination of the Region of Stabilizing Controller Parameters of Polytopic Polynomials <i>I. Thirunavukkarasu, V. I. George, Mukund Kumar Menon, S. Shanmuga Priya</i>	174
Identification of Natural Ventilation Parameters in a Greenhouse with Continuous Roof Vents, using a PSO and GAs <i>Abdelhafid Hasni, Belkacem Draoui, Mahieddine Latfaoui and Thierry Boulard</i>	182
Dynamic Modeling of Step Climbing Wheeled Robot <i>Srijan Bhattacharya, Neeta Sahay, Sagarika Pal, Subrata Chattopadhyay</i>	193
ECG Signal Denoising and QRS Complex Detection by Wavelet Transform Based Thresholding <i>Swati Banerjee, Dr. Madhuchhanda Mitra</i>	207
Admittance, Conductance, Reactance and Susceptance of New Natural Fabric Grewia Tilifolia <i>V. V. Ramana C. H., Jayaramudu J., Jeevan Prasad Reddy D., Madhusudhana Rao K. and Varadarajulu A.</i>	215
Role of Catecholamine in Tumor Angiogenesis Linked to Capacitance Relaxation Phenomenon <i>Guangyue Shi, Guanjie Sui, Jianxia Jiang, T. K. Basak</i>	223

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- RASQOFT: Resource allocation, services, QoS and fault tolerance in sensor networks
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- SEMOSN: Security and monitoring of sensor networks
- SECSN: Sensor circuits and sensor devices
- RIWISN: Radio issues in wireless sensor networks
- SAPSN: Software, applications and programming of sensor networks
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- DISN: Deployments and implementations of sensor networks
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Theoretical Performance of GaAs Solar Cell, with Band Gap Gradient Layer on the Back Region

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Received: 17 June 2010 / Accepted: 17 August 2010 / Published: 31 August 2010

Abstract: GaAs solar cell with graded band gap layer in the back region is analyzed as a function of the electric field created by band gap gradient and the base thickness. Studies are reported at AM 1.5, and unity solar concentration. The optimum thickness of the base region is determined. The performance of the cell strongly depends on the electric field. Comparison with the GaAs cell including high-low junction at the back surface show that the use of back surface field created by graded band gap improve the performance of the GaAs conventional cell. *Copyright © 2010 IFSA.*

Keywords: Graded band gap, GaAs solar cell, Back surface field.

1. Introduction

Attempt to improve the performance of solar cells has been the aim of several papers. Further improvements of the device performance require an accurate knowledge about the electronic and optical loss.

The attention of researchers has been directed towards the development of graded band gap AlGaAs solar cells with high efficiency since long [1- 4]. Konagai and al studied p-p-n graded band gap solar cell, this interesting proposal looking at the improvement of the spectral response of the GaAs cell. Studies have been conducted to increase efficiency through the establishment of the built-in field in the emitter or base to improve spectral response [1]. A graded band gap has been used to decrease the dark current of GaAs solar cell [5]. In this work, the n/p-GaAs solar cell with band-gap gradient at the back surface is theoretically analyzed. Some Authors demonstrate that heterojunction back surface field significantly improves the performance of the n/p cell [7, 8]. Gale and al showed experimentally that

heterojunction back surface field improves the open circuit voltage in GaAs solar cells. Demoulin et al. suggested that this improvement is due to lower recombination velocity of heterojunction BSF. They derived a theoretical expression for the effective back surface velocity, S_{pp}^+ , it was used to calculate V_{oc} for heterojunction back surface field. In this paper we report on a similar study using GaAs solar cell with (BSF) created by AlGaAs graded band gap semiconductor over one suns, the temperature equal to 300 K, and under AM1.5 spectral conditions. The results of this study are presented in Section 4.

2. Analysis

In this part, spectra of collection efficiency are calculated by solving continuity equations. The configuration treated is shown in Fig. 1.

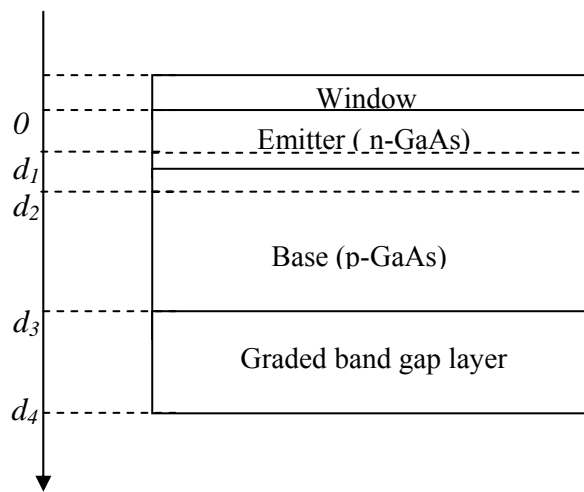


Fig. 1. A schematic diagram of the structure of GaAs cell with band gap gradient in the back region.

2.1. The Holes Current in the n Region

The continuity equation for excess hole in the n region:

$$D_p \frac{d^2 \Delta p}{dx^2} - \frac{\Delta p}{\tau_p} + g_1(\lambda, x) = 0, \quad (1)$$

$$g_1(\lambda, x) = I_0 \alpha(\lambda) \exp(-\alpha(\lambda)x),$$

where Δp is the excess hole concentration, D_p the diffusion constant for holes, τ_p the holes lifetime and I_0 is the Incident photon flux at surface. The general solution of equation (1) is easily found,

$$\Delta p = A \exp\left(\frac{x}{L_p}\right) + B \exp\left(-\frac{x}{L_p}\right) + \frac{Q_0}{D_p} \exp(-\alpha(\lambda)x), \quad (2)$$

$$\text{With } L_p^2 = D_p \tau_p, \text{ and } Q_0 = -\frac{\alpha(\lambda)I_0}{\alpha(\lambda)^2 - L_p^2}$$

The short circuit current j_{sc} is given by

$$J_{sc} = -eD_p \left. \frac{d\Delta p}{dx} \right|_{x=d_1}$$

3.2. The Electrons Current in the p Region

3.2.1. p-GaAs Layer

Without the electric field in the p-GaAs, the continuity equation is expressed by

$$D_n \frac{d^2 \Delta n_1}{dx^2} - \frac{\Delta n_1}{\tau_n} + g_2(\lambda, x) = 0, \quad (3)$$

$$g_2(\lambda, x) = I_2 \alpha(\lambda) \exp(-\alpha(\lambda)x), \text{ where } I_2 = I_0 \exp(-\alpha d_2)$$

and Δn_1 is the excess electrons concentration in p-GaAs layer. D_n is the diffusion constant for electrons and τ_n the electrons lifetime. The general solution of equation (3) is given by

$$\Delta n_1 = C_1 \exp\left(\frac{x}{L_n}\right) + C_2 \exp\left(-\frac{x}{L_n}\right) + \frac{Q_1}{D_n} \exp(-\alpha(\lambda)x), \quad (4)$$

$$\text{where } Q_1 = -\frac{\alpha(\lambda)I_2}{\alpha(\lambda)^2 - L_n^2}$$

3.2.2. p-AlGaAs Graded Band Gap Layer

The continuity equation for excess electrons in the Graded-band-gap layer is

$$D_n \frac{d^2 n_2}{dx^2} + \mu_n E \frac{dn_2}{dx} - \frac{\Delta n_2}{\tau_n} + g_3(x, \lambda) = 0, \quad (5)$$

The electric field is given by

$$E = \frac{Eg_{d_4} - Eg_{d_3}}{d_4 - d_3}$$

where Δn_2 is the excess electrons concentration in the graded band gap layer, and $g_3(x, \lambda)$ is given by [3]. The general solution of equation (5) is easily found:

$$\Delta n_2 = C_3 \exp(X_1 x) + C_4 \exp(X_2 x) + \frac{1}{X_1 - X_2} (Q_3(x) \exp(X_1 x) + Q_4(x) \exp(X_2 x))$$

$$X_1, X_2 = -\frac{q}{2kT} E \pm \left[\left(\frac{q}{2kT} E \right)^2 + \frac{1}{L_n^2} \right]^{1/2},$$

where

$$Q_3(x) = -\frac{1}{D_n} \int_0^x \exp(-X_1 x) g_3(x, \lambda) dx \quad \text{and} \quad Q_4(x) = \frac{1}{D_n} \int_0^x \exp(-X_2 x) g_3(x, \lambda) dx$$

The constants C_1, C_2, C_3 and C_4 can be determined from the following boundary conditions

$$\left\{ \begin{array}{ll} \Delta n_1(x) = 0 & x = d_2 \\ D_n \frac{d\Delta n_1}{dx} = D_n \frac{d\Delta n_2}{dx} + \mu_e E n_2 & x = d_3 \\ \Delta n_1 = \Delta n_2 \exp\left(-\frac{\Delta E_C}{kT}\right) & x = d_3 \\ D_n \frac{d\Delta n_2}{dx} + \mu_n E \Delta n_2 = S_n n_2 & x = d_4 \end{array} \right.$$

The short circuit current densities into the p-n junction are then determined by the minority gradient at the junction

$$J_{scn} = eD_n \left. \frac{d\Delta n_1}{dx} \right|_{x=d_2}$$

The generation current in space charge region j_{dr} is given by [9]. The total photocurrent at a given wavelength is:

$$J_{ph} = J_{scn} + J_{scp} + J_{dr}$$

The total current of such a device under illumination is simply a summation of the dark current (J_d) and the photocurrent (J_{ph}), given as

$$J = J_{ph} - J_d$$

4. Results

4.1. Photocurrent and Open-circuit Voltage V_{oc}

The photocurrent of n-GaAs / p-GaAs/ p- Al_xGa_{1-x} as solar cell is examined as a function of base thickness p-GaAs, and value of electric field in the graded band gap region. Fig. 2 shows that the photocurrent increase with electric field, and attains a maximum at base thickness between 1.2 and 1.8 μm . At low thickness; graded band gap layer contributed in the total photocurrent. The electric field prevents the charge carriers from recombination at the back side. If base thickness increase, the photons cannot arrive the graded layer, there is no generation of the photocarriers, so the improvement due to the electric field is the same that the high-low junction inclusion at the back of solar cell (BSF). The same variation is observed for open circuit voltage (Fig. 3).

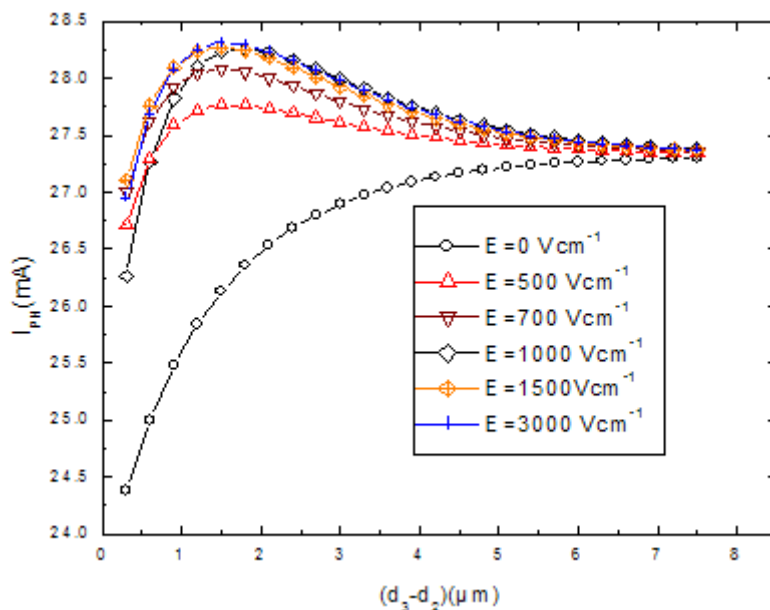


Fig. 2. Plot of photocurrent vs. base thickness (d_3-d_2) for different value of electric field in the back region of the GaAs cell.

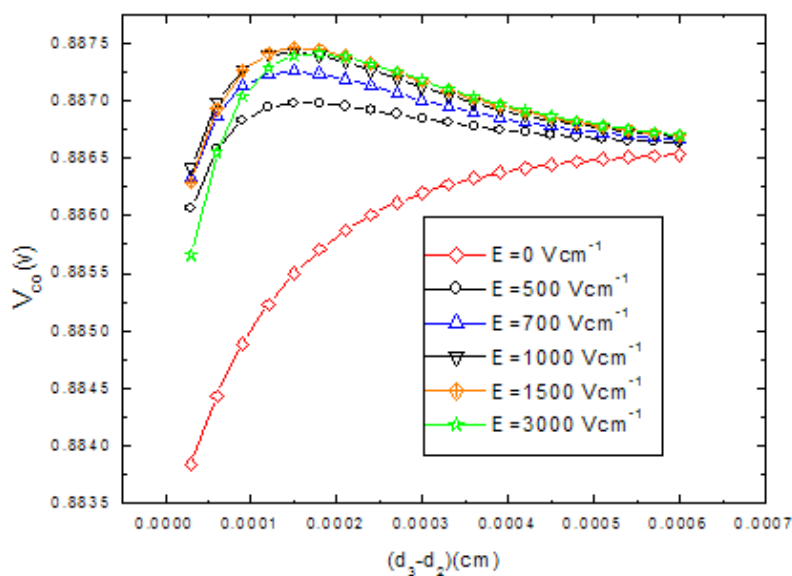


Fig. 3. Plot of open circuit vs. base thickness (d_3-d_2) for different value of electric field in the back region of the GaAs cell.

4.2. Efficiency

Improvement in efficiency η due to electric field is expected from the above results regarding photocurrent and V_{oc} this is studied by plotting different graphs for the efficiency against base thickness for different value of electric field created by graded band gap in the back region of solar cell. Fig. 4 shows variation of efficiency η with base thickness up to $0.1 \mu\text{m}$ for different value of electric field. It seems most favorable effect of electric field in back region. Fig. 5 shows the efficiency obtained from the present model and the efficiency of n/p GaAs cell heterojunction back surface field. At low base thickness, the electric field created by band gap gradient also increases the efficiency of the cell compared with the cell based on GaAs with heterojunction back surface field (n-GaAs/p-

GaAs/p⁺- Al_{0.3}Ga_{0.7}As). In the case of higher base thickness, the analytical model of (n-GaAs/p-GaAs/p⁺- Al_xGa_{1-x}As) solar cell and the GaAs n/p cell with heterojunction back surface filed shows that the tow model predict a similar efficiency.

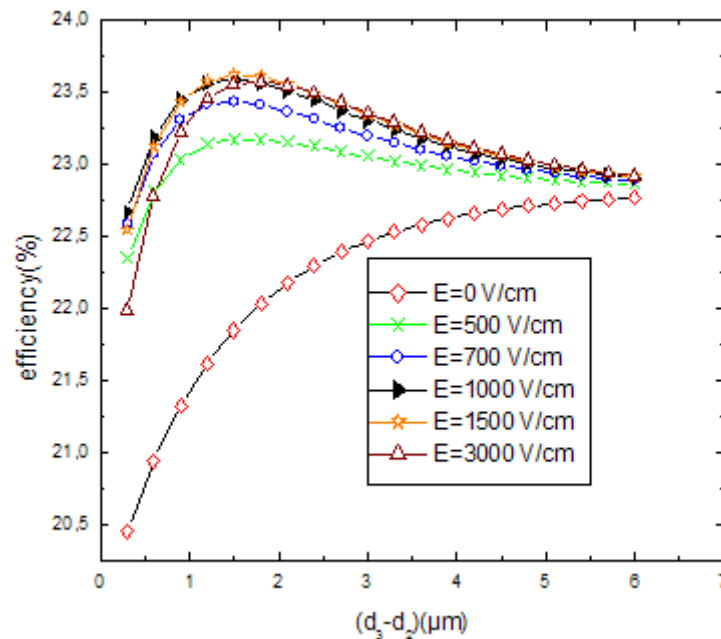


Fig. 4. Plot of efficiency vs. base thickness (d_3-d_2) for different value of electric field in the back region of the GaAs cell.

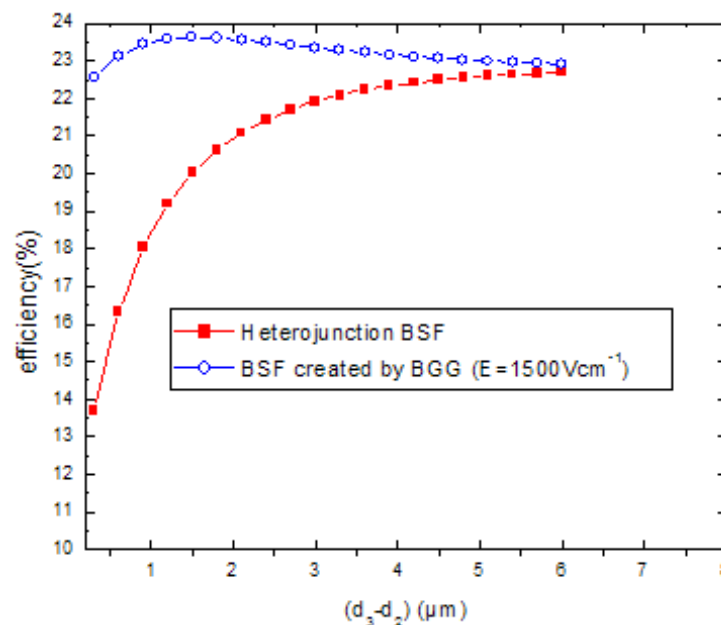


Fig. 5. Comparison of the efficiency of GaAs cell with band gap gradient $Al_xGa_{1-x}As$ in the back region from present model and the efficiency of the GaAs cell with heterojunction BSF ($Al_{0.3}Ga_{0.7}As$).

5. Discussion

A schematic band diagram is shown in Fig. 1. The GaAs cell is made in the normal way, but the back layer of the cell is made from the graded band gap AlGaAs semiconductors. The electric field created by band gap gradient tends to confine minority carriers (electrons) in the base and graded gap regions and helps to drive them toward the junction. The electric field keeps minority carriers away from the back ohmic contact and increases their chances of being collected, especially when the thickness of the base region is small compared to the effective diffusion length. The electric field prevents the charge carriers from recombination at the back side. Therefore, the short-circuit current density will increase. The open-circuit voltage is also increased due to increased short-circuit current and decreased recombination current at the back contact.

Fig. 2 and 3 show the tradeoff between the open circuit voltage and photocurrent as the base thickness and several values of electric fields. Notice that when the base thickness was low; the open circuit voltage and the photocurrent was increased. The cell efficiency is shown to have a greater dependence on the electric field in the back region Fig. 4. It has been proved that the solar cells incorporating graded composition layers on the back region considerably improve their performance compared to n-p-p⁺ back-surface field heterojunction solar cell.

6. Conclusion

Theoretical analysis studies are reported for the GaAs-AlGaAs graded band gap in the back region at 300 K, AM 1.5, and unity solar concentration, predicts other important feature which is not manifested in uniform semiconductors. This paper shows that the elimination of the bulk and surface recombination losses in the base with electrical field increases the conversion efficiency. An optimized design is obtained by maximizing conversion efficiency. Structure parameters on the GaAs cell with graded band gap gradient of the back region optimized values is investigated to show the behavior of the performance characteristics. The results of the paper show that conversion efficiency is sensitive to those structure parameters which give important to electric field in the back region.

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Guide for Contributors

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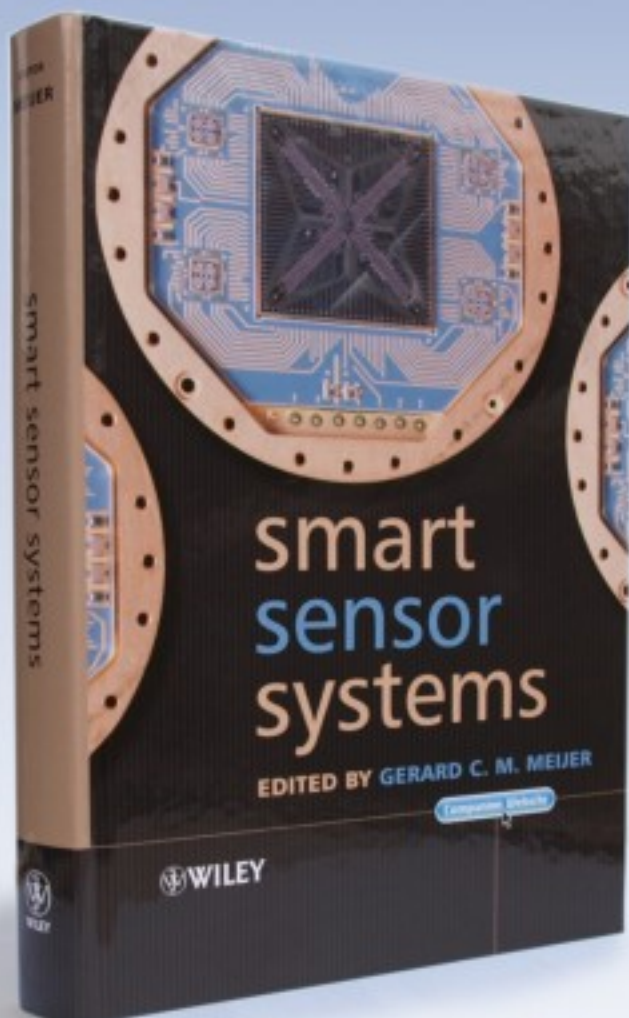
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