Simulation of laser beam induced current for HgCdTe photodiodes with leakage current

F. Yin, W. D. Hu, B. Zhang, Z. F. Li, X. N. Hu, X. S. Chen and W. Lu*
National Lab for Infrared Physics, Shanghai Institute of Technical Physics, Chinese Academy of Science, 500 Yu Tian Road, Shanghai, China 200083

Abstract-We report on 2D numerical simulations of laser beam induced current (LBIC) for HgCdTe photovoltaic detector. The effect of junction leakage current on the LBIC signal is investigated, and different leakage paths caused by different reasons in HgCdTe photodiode arrays are taken into account in the simulation. The simulation results are in good agreement with the experiment data. Simulation results suggest that the LBIC can be used to determine the existence of the junction leakage current and investigate the original of the junction leakage current.

I. INTRODUCTION

HgCdTe photovoltaic detectors are widely used in military and aerospace industry, and many studies have been carried out on its performance [1]. It is well known that the leakage current across the junction is easily induced by defects, and can seriously affect the performance of infrared detectors. Because of the high cost of fabricating HgCdTe focal plane arrays, it is important to characterize and identify the underperforming devices.

Laser beam induced current (LBIC) is a non-destructive characterization tool used to identify defects in HgCdTe infrared detector arrays [2], in which a laser beam is scanned through the p-n junction arrays, and the induced current is collected from the remote contacts at both sides of the arrays [3-5]. The LBIC signal reflects the photoelectric properties of the p-n junction arrays.

In this paper, a series of simulations are performed to study the junction leakage current in HgCdTe photodiodes. The effect of different locations of the junction leakage current on LBIC signal is investigated, and further homogeneity study of the junction leakage current in HgCdTe p-n junction arrays is carried out. Simulation results suggest that the original of the junction leakage current can be analyzed by the LBIC signal.

II. SIMULATION MODELS

The two-dimentional simulations are performed using Sentaurus Device [6]. The drift-diffusion model which consists of the Poisson equation, the electron and hole continuity equations and the current transport equation is used, and laser-induced electron-hole item is added to the continuity equations. Fermi-Dirac statistics is adopted for carrier concentration because the degeneracy of states in HgCdTe n-type material. High field saturation model for carrier mobility is taken into account. SRH, Auger and radiative recombination models are included in the carrier generation-recombination process. The simulation structure is shown in Fig. 1. It is a plain n-on-p photodiode with junction depth of 1μm. A Gaussian laser beam with light spot diameter of 1.5μm is stepped across the sample in the horizontal direction. Junction leakage current is simulated by placing a small piece of metal at the interface of the p-n junction, which forms ohmic contact with both sides of the p-n junction.

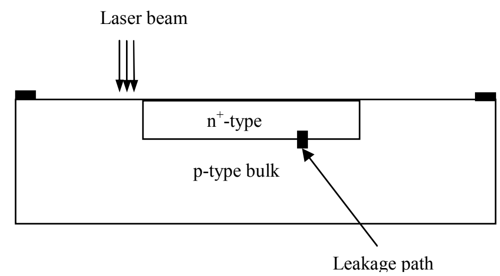

Fig. 1. Cross-sectional structure of simulated HgCdTe photodiode with junction leakage path.

III. RESULT AND DISCUSSION

Fig. 2 shows the effect of different locations of the junction leakage current on the LBIC signal. The LBIC line profile is symmetric when the location of the leakage current is in the n-type center, similar to the case of no leakage current path.

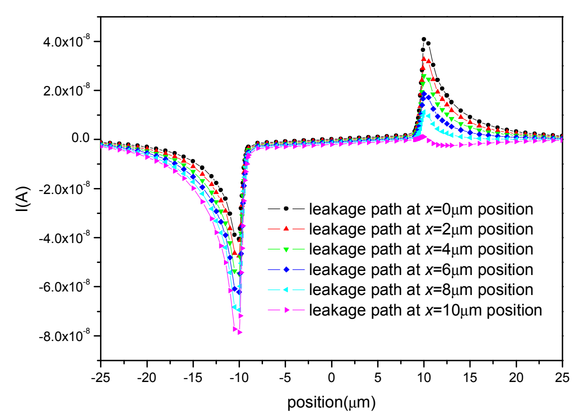

Fig. 2. Simulated LBIC profiles of device with leakage path at different positions.

* Corresponding author: luwei@mail.sitp.ac.cn

978-1-4244-4180-8/09/$25.00 ©2009 IEEE

When the leakage position changes from the center to the right side of the n-type region, the line profiles shift along the y direction. On the left side of the p-n junction, the LBIC signal becomes larger, and the current is smaller at the right side of the p-n junction. When the laser beam illuminates on the left side, most of the photocurrent is collected by the external circuit. When the laser beam is on the right side, most of the photocarriers seek to recombine through the leakage current path, and they have no contribution to the external current, therefore the collected current is smaller.

There are many reasons which can lead to the junction leakage current. First of all, the leakage current in HgCdTe photovoltaic detector arrays caused by the process is considered. Because of the repeatability in p-n junction arrays process, if there is leakage current in one p-n junction, then all the p-n junctions in the arrays will have the same leakage current characteristics.

The LBIC profiles of two p-n junctions with the same leakage current characteristic, as shown Fig. 3(a), are simulated with the leakage paths at positions x = -15.5μm and x = 18.5μm, respectively. The profiles show good repeatability. That is to say, if there is leakage caused by the process, then every p-n junction in the arrays will show the same LBIC profile. Our experimental results shown in Fig. 3(b) appear almost the same as we predict. The measurements have been made on two samples with the same material and device parameters. From the LBIC profiles of the samples, we can conclude that there is a problem in the process when forming sample 2, which leads to the junction leakage current at a particular position in the interface of p-n junction.

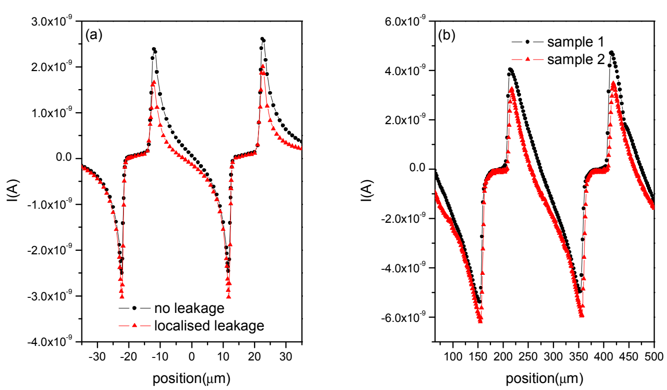

Fig. 3. (a) Simulation results of devices with the same leakage path, and (b) experiment results.

If the leakage current is caused by other factors, then it will be random in different p-n junctions. We simulate the LBIC profiles of two p-n junctions with different leakage current characteristics. The first p-n junction with leakage path at position x = -19.5μm, and the second p-n junction with two leakage paths at positions at x = 13.5μm and x = 17.7μm. Simulation results are illustrated in Fig. 4(a). It is found that the LBIC line profile of each p-n junction appears asymmetric, and the shift of the LBIC profile is unequal. We observe the similar result in the sample after high power laser irradiation, as shown in Fig. 4(b). It indicates that leakage current is induced in HgCdTe photodiode irradiated by high power laser.

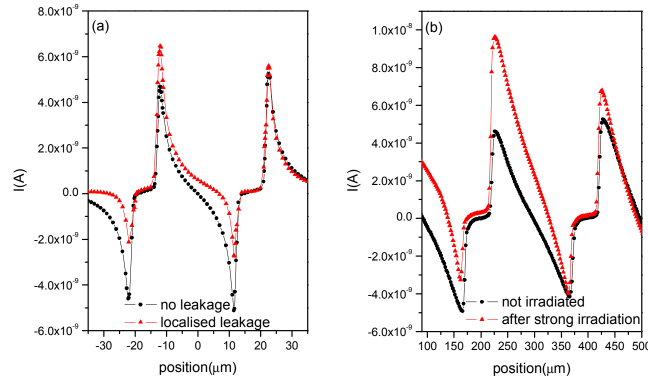

Fig. 4. (a) Simulation results of devices with different leakage paths, and (b) experiment results.

IV. CONCLUSION

In this paper, the effect of junction leakage current on LBIC in HgCdTe photovoltaic detector is simulated, and different leakage paths caused by different reasons in HgCdTe photodiode arrays are calculated. The simulation results are in good agreement with the experiment data. Simulation results show that the LBIC characterization is of great importance for HgCdTe photovoltaic detector arrays. From the LBIC results we can determine the existence of the junction leakage current, and also determine the origin of the leakage current.

REFERENCES

[1] W. D. Hu, X. S. Chen, Z. J. Quan, Z. F. Li, Q. J. Liao, Z. H. Ye, X. N. Hu, and W. Lu, "Simulation and design consideration of photoresponse for HgCdTe infrared photodiodes", *IEEE International Conference on Numerical Simulation of Optoelectronic Devices*, NUSOD. 08, Nottingham, 2008.

[2] D. A. Redfern, C. A. Musca, J. M. Dell, and L. Faraone, "Characterization of electrically active defects in photovoltaic detector arrays using laser beam-induced current", *IEEE Transactions on Electron Devices*, vol. 52, pp. 2163-2174, 2005.

[3] C. A. Musca, D. A. Redfern, J. M. Dell, and L. Faraone, "Laser beam induced current as a tool for HgCdTe photodiode characterization", *Microelectronics Journal*, vol. 31, pp. 537-544, 2000.

[4] W. Y. Cai, *The characteristics of imaging spectrum for infrared devices*, (Doctor's dissertation of Shanghai Institute of Technical Physics, Shanghai, 2003).

[5] D. A. Redfern, *Laser Beam Induced Current for quantitative photodiode characterization*, (Doctor's dissertation of the University of Western Australia, Nedlands, 2003).

[6] Device simulator Sentaurus Device (former ISE-DESSIS) Ver. A-2008. 08.