Study on the structure characteristics of HgCdTe infrared detector using laser beam-induced current

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Abstract

The structure characteristics of typical *n^+-on-p* HgCdTe infrared detector have been studied by laser beam-induced current (LBIC). The dependence of LBIC on laser wavelength, junction depth and localized leakage has been presented. The spreading length of minority carrier of p-type region (*Lsp*) is extracted by the exponential decay fitting of the curve of LBIC. It is found that the peak magnitude of LBIC and junction depth approximates to a linear relationship for practical values of device fabrication. The *Lsp* monotonously increases with junction depth. A notable shift of LBIC profile is observed when localized leakage exists. This provides a powerful explain for LBIC applying to characterize the structure and process uniformity of HgCdTe infrared detector.

I. INTRODUCTION

HgCgTe infrared detectors are becoming one of the most important dectectors due to its superior performance [1-3]. However, seeking a high-yield and low cost technology is still challenging for infrared dectectors' continuous development. At present, amounts of works have been done on the growth of high quality materials and fabrication techniques of devices. Characterization of individual devices is also an important procedure for practical device applications. Traditionally, individual devices within these large 2-D arrays have been characterized after flip-chip hybrid bonding to the silicon readout circuitry. However, in comparatively low-yield technologies such as large infrared focal plane arrays, significant cost savings would be expected to result if nondestructive yield and uniformity characterization were to be undertaken at an earlier stage in the fabrication process. As an attractive candidate, laser beam induced current (LBIC) is a qualitative manner, which has been used for a number of years [4-8]. In this technique a focused laser beam is scanned across the surface of the semiconductor, and the current flowing in the external circuit between two nominally shorted ohmic contacts on either side of the scan area is measured, as shown in Fig. 1. the remote ohmic contacts can be removed when finish the measurement. Hence, nondestructive characterization is performed because no electrical contacts to individual devices are needed.

Since the induced current is highly dependent on large number parameters, analysis of LBIC measurements is still a challenging task. Correlations of LBIC signal on various device parameters are needed for the technique to gain wider practical applications.

This paper presents a system study of the dependence of LBIC signals of typical *n^+-on-p* HgCdTe infrared detector on laser wavelength, junction depth and localized leakage.

II. DEVICE STRUCTURE AND SIMULATION MODEL

The core structure of HgCdTe infrared detector is *p-n* junction. This paper focuses on the special case of a single, isolated, ideal *p-n* junction diode structure, where the length of *p*-type region is $200\mu m$, the thickness is $8\mu m$. The initial junction depth is $1\mu m$, the n-type region is $20\mu m$ in length. The typical *n^+-on-p* device structure is then formed with doping density of N_a=1×10^{16}cm^{-3} and N_d=1×10^{17}cm^{-3}. In addition, only front-side illumination is considered. Simulations of LBIC on $Hg_{0.78}Cd_{0.22}Te$ long-wavelength infrared photodiodes at 120K is performed using a commercial semiconductor modeling package.

For plain drift-diffusion simulation the well known Poisson equation and continuity equations are used. The optical generation rate can be expressed by:

$$G^{opt}(z) = J(x,y,z_0)\cdot\alpha(\lambda,z)\cdot\exp\left[-\left|\int_{z_0}^{z}\alpha(\lambda,z)dz\right|\right] \qquad (1)$$

where λ is the wavelength, $J(x,y,z_0)$ is the optical beam spatial variation of intensity over a window where rays enter the device, z_0 is the position along the ray where absorption begins, and $\alpha(\lambda, z)$ is the absorption coefficient along the line[7, 9].

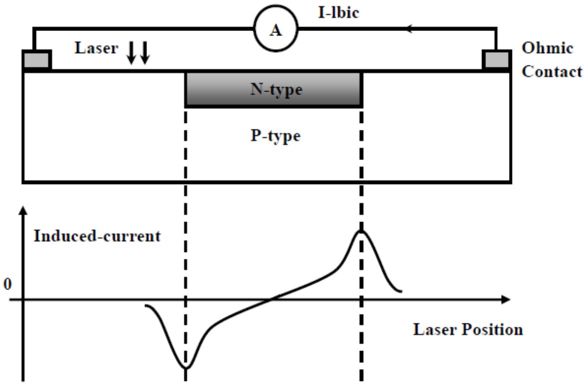

Fig. 1 LBIC measurement configuration and the typical bipolar LBIC profile

III. RESULTS AND DISCUSSION

The dependence of LBIC profile on laser wavelength is shown in Fig. 2. Almost no change is found for wavelength

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ranging from $0.40\mu m$ to $1.3\mu m$, which indicates the depth of laser penetration is shallow compared with the depth of junction. That's to say, the light absorption only exists in the surface of our device.

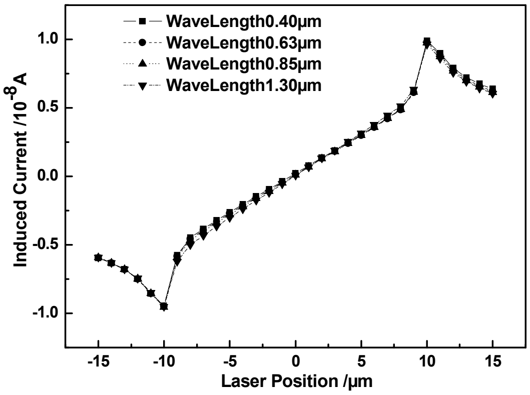

Fig. 2 Dependence of LBIC profile on laser wavelength

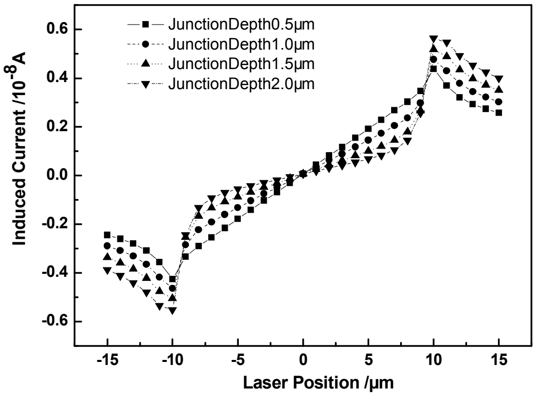

Fig. 3 LBIC profile with different p-n junction depth

Fig. 3 shows the LBIC profile with different *p-n* junction depth. It is found that the peak magnitude of LBIC and junction depth approximates to a linear relationship for practical values of device fabrication. An exponential decay model is used to extract the theoretical spreading length of minority carrier by fitting the LBIC curve in *p*-type region. The *Lsp* monotonously increases with junction depth. Then the value of *Ls* can be used to provide a direct qualitative indication of process uniformity.

Fig. 4 gives simulated LBIC profiles of devices with and without localized leakage caused by metal contaminations. The leakage was modeled by including a small piece of metal that was ohmic to both sides of the junction. The side length of square metal is about $0.2\mu m$. Asymmetry is apparent with localized leakage. The shift in zero point of LBIC current is clearly linear with the leakage position.

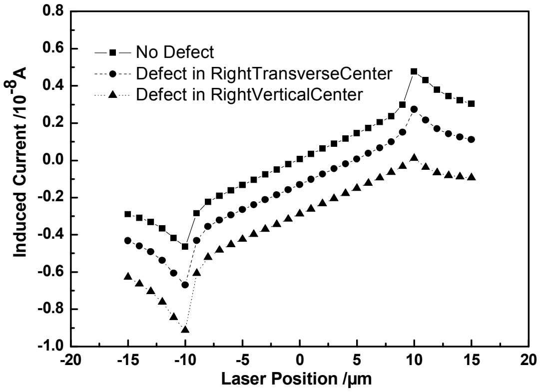

Fig. 4 Simulated LBIC profiles of devices with and without localized leakage caused by metal contaminations

IV. CONCLUSION

The dependence of LBIC on laser wavelength, junction depth and localized leakage has been presented to depict the structure characteristics of typical n^+*-on-p* HgCdTe infrared detector. The spreading length of minority carrier of *p*-type region is extracted by the exponential decay fitting of the curve of LBIC. It is found that the peak magnitude of LBIC and junction depth approximates to a linear relationship for practical values of device fabrication. The *Lsp* monotonously increases with junction depth. A notable shift of LBIC profile is observed when localized leakage exists. This provides a powerful explain for LBIC applying to characterize the structure and process uniformity of HgCdTe infrared detector.

REFERENCES

[1] A. Rogalski, [Infrared Detectors], Gordon and Breach Publishers, Amsterdam, 391(2000).

[2] S. C. Shen, "Comparison and competition between MCT and QW structure material for use in IR detectors," Microelectronics J. 25, 713-739(1994).

[3] Jun Wang, Xiao-Shuang Chen, Wei-Da Hu*, Lin Wang , Wei Lu , Faqiang Xu , Jun Zhao , Yanli Shi , Rongbin Ji, Amorphous HgCdTe infrared photoconductive detector with high detectivity above 200 K, Applied Physics Letters, 99, 113508-1-113508-3 (2011).

[4] D. A. Redfern, E. P. G. Smith, C. A. Musca, J. M. Dell, and L. Faraone, "Interpretation of current flow in photodiode structures using laser beam-induced current for characterization and diagnostics," IEEE Transactions on Electron Devices, VOL. 53, No. 1, Jan. 2006.

[5] D. A. Redfern, W. Fang, K. Ito, C. A. Musca, J. M. Dell, and L. Faraone, "Low temperature saturation of p-n junction laser beam induced current signals," Solid State Electron., vol 48, pp. 409-414, 2004.

[6] F. Yin, W. D. Hu, B. Zhang, Z. F. Li, X. N. Hu, X. S. Chen and W. Lu, Simulation of laser beam induced current for HgCdTe photodiodes with leakage current, Optical and Quantum Electronics, 41, 805-810(2009).

[7] Fei Yin, Weida Hu, Zhijue Quan, Bo Zhang, Xiaoning Hu, Zhifeng Li, Xiaoshuang Chen, Wei Lu "Extraction of electron diffusion length in HgCdTe photodiodes using laser beam induced current" ACTA PHYSICA SINICA, 58, 7884-7890 (2009)

[8] J. Bajaj and W. E. Tennant, "Remote contact LBIC imaging of defects in semiconductors," J. Cryst. Growth 103, 170-178(1990).

[9] W. D. Hu, X. S. Chen, F.Yin, Z. J. Quan, Z. H. Ye, X. N. Hu, Z. F. Li and W. Lu, "Analysis of temperature dependence of dark current mechanisms for long-wavelength HgCdTe photovoltaic infrared detectors," J. Appl. Phys. 105, 104502-1-104502-8 (2009).