第42卷第2期
2013年2月

光 子 学 报
ACTA PHOTONICA SINICA

Vol. 42 No. 2
February 2013

doi:10.3788/gzxb20134202.0132

基于共面波导微带线的光探测器高频电参量提取

徐光辉[1,2],柴广跃[1],黄长统[1],何黎明[1],徐健[1],廖世东[1],冯丹华[1]
(1 深圳大学 光电子器件与系统教育部重点实验室,广东 深圳 518060)
(2 昂纳光通信(集团)有限公司,广东 深圳 518057)

摘　要:针对不能在片测量的光探测器芯片,本文提出了一个简单而有效的实验方案来提取其等效电路模型的高频电参量.首先设计了和微波探针匹配的共面波导微带线,测量其输出反射系数,测试结果与理论设计符合很好;然后将芯片装载到微带线上,测量包含光探测器的整个测试结构的输出反射系数.仿真中涉及光探测器测试结构的等效电路模型,包含光探测器、键合金丝和共面波导微带线等因素.通过拟合已测的整个测试结构的输出反射系数,提取了光探测器的高频电参量.

关键词:光探测器;共面波导微带线;等效电路模型;参量提取

中图分类号:O43　　**文献标识码**:A　　**文章编号**:1004-4213(2013)02-0132-3

High Frequency Electrical Parameter Extraction for Photodetectors Based on Coplanar Waveguide Microstrips

XU Guang-hui[1,2], CHAI Guang-yue[1], HUANG Chang-tong[1],
HE Li-ming[1], XU Jian[1], LIAO Shi-dong[1], FENG Dan-hua[1]
(1 *Key Laboratory of Optoelectronic Devices and Systems of the Ministry of Education and Guangdong Province*, *Shenzhen University*, *Shenzhen*, *Guangdong* 518060, *China*)
(2 *O-Net Communications Co. Ltd.*, *Shenzhen*, *Guangdong* 518060, *China*)

Abstract: For no on-wafer measurement of photodetectors (PDs), a simple and effective method to determine high frequency electrical parameters of the equivalent circuit model is presented. Firstly, a coplanar waveguide (CPW) microstrip matched with the microwave probe is designed, and the measured output reflection coefficient shows good agreement with the theoretical design. The chip is mounted on the CPW microstrip and the output reflection coefficient of the PD test-fixture is measured. The equivalent circuit model including the PD, the bondwire and the CPW elements is simulated. By fitting the measured output reflection coefficient of the test-fixture, high frequency electrical parameters of the PD are extracted.

Key words: Photodetector; Coplanar waveguide microstrip; Equivalent circuit model; Parameter extraction

0 Introduction

PDs are important optical devices in high-speed optical communication systems and optoelectronic integrated circuits (OEICs). Recently, optical commucation transmission date rates have increased from 40 Gbps to 100 Gbps. For designing and optimizing high speed performances of OEICs, efficient and accurate equivalent circuit models of PDs are extremely important[1-2]. At the same time, to obtain the accurate model parameters, the accurate measurement of PDs is required. A kind of PDs with the ground-signal-ground (GSG) electrode can be directly performed the on-wafer measurement by using the matched microwave probe[3-5].

For no on-wafer measurements of PDs, there

Foundation item: The Ministry of Science and Technology of China (No. 2008DFA11010) and the National Foundation of Natural Science and Technology (No. 61076043)

First author: XU Guang-hui(1986—), male, M. S. degree, mainly focuses on high speed photodetectors. Email: ghxu06@126.com

Corresponding author: CHAI Guang-yue(1959—), male, professor, mainly focuses on the packaging of high speed opto-electronics devices and high power light emitting diodes. Email: gychai@szu.edu.cn

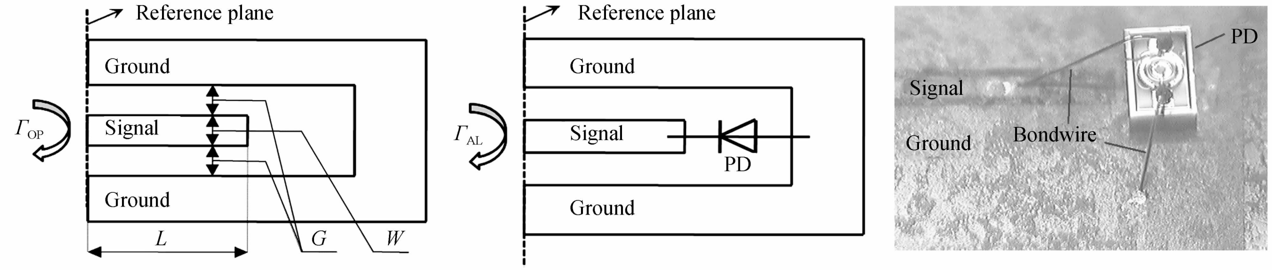
Received: Jun. 5, 2012; **Accepted**: Nov. 1, 2012

have been few works focused on these measurements to date. And the PDs are widely used in high speed optical commucation systems. HALE Paul D. *et al*. developed a measurement procedure with the SMA test-fixture which had a frequency range limited to about 6 GHz and was difficult to perform a rigorous system calibration[6]. ZHANG Sheng-li *et al*. presented a measurement method which required the complicated calibration and introduced many excess parasitic elements which reduced the precision of the measurement[7].

In order to overcome these difficulties, we will present a simple and effective method to determine the parameters of the equivalent circuit model based on the output reflection coefficient of the test-fixture. In this paper, we will describe the basic procedure of designing the test-fixture and extracting the high frequency electrical parameters of PDs. The measurement data simulation is performed with Agilent Advanced Design System (ADS) software.

1 The model and measurement method

To match with the GSG microwave probe, the CPW microstrip with the characteristic impedance of 50 Ω is designed and fabricated, as shown in Fig. 1(a). A schematic for the CPW microstrip test-fixture with the PD mounted is shown in Fig. 1(b), and the corresponding sample is shown in Fig. 1(c). The important structure size parameters of the CPW are summarized in Table 1, the size parameters of W, G and L in Table 1 are labeled in Fig. 1(a), of which H is the height of the CPW, T is the gold layer thickness and Er is the dielectric constant.



(a) Structure illustration of the CPW　(b) Schematic for the PD test-fixture　(c) Photograph of the sample

Fig. 1　The PD is mounted on the CPW microstrip

Table 1　Basic size parameters of the CPW

W/μm	G/μm	L/mm	T/μm	H/mm	Er
86	45	2	5	0.38	9.5

The corresponding equivalent circuit model of the test-fixture is shown in Fig. 2. The small-signal equivalent circuit of the PD involves both the optical part for the photocurrent frequency response $I_{op}(\omega)$ and the electrical part including the series resistance R_P and the total capacitance C_P[8-9]. The CPW model can be replaced by the two-port network. L_B is the inductance of the bondwire. It is noted that the optical part of the PD is neglected in this model simulation and measurement, due to the factor that the optical part does not affect the output electrical coefficient, as long as we are only concerned with the electrical parameter extraction. So in Fig. 1, Γ_{OP} is the output reflection coefficient of the CPW, Γ_{AL} is the output electrical reflection coefficient of the test-fixture.

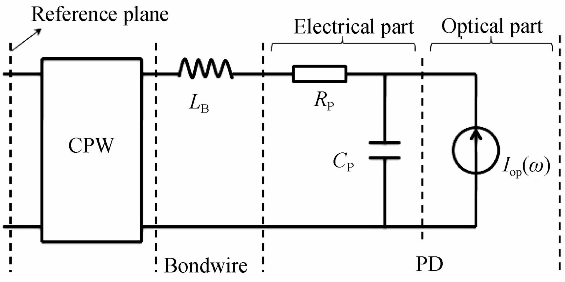


Fig. 2　Equivalent circuit model of the PD test-fixture

2 The measurement result and simulation

Fig. 3 compares the measured and simulated Γ_{OP} of the CPW in the frequency range of 0.2 GHz

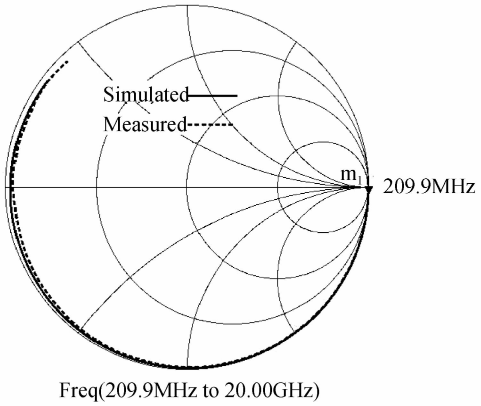


Fig. 3　Comparison of measured and simulated Γ_{OP} for the CPW on Smith Chart

to 20 GHz. We find that the CPW sample agrees well with the model. Besides, it shows that the CPW is matched well with the GSG microwave probe and the input RF signal is almost totally reflected. So the model of the CPW can be used in the following model simulation of the test-fixture.

The equivalent circuit model of the test-fixture in Fig. 2 is simulated in ADS software and the photocurrent response $I_{op}(\omega)$ is set to the open. Under reverse bias voltage of 3 V and 3.5 V, the measured magnitude and phase frequency responses of Γ_{AL} are shown in Fig. 4 and Fig. 5, respectively. For the different voltages of 3 V and 3.5 V, their magnitude or phase frequency responses are identical, and the result shows the electrical parameters of the PD do not change with the normal work voltage. By fitting the output electrical reflection coefficient Γ_{AL} of the test-fixture, we extract the high frequency parameters of the PD and the bondwire, as following: $R_P = 15.8\ \Omega, C_P = 0.184\ \text{pF}, L_B = 1.01\ \text{nH}$. The fitted magnitude and phase frequency responses of Γ_{AL} are shown in Fig. 4 and Fig. 5, respectively.

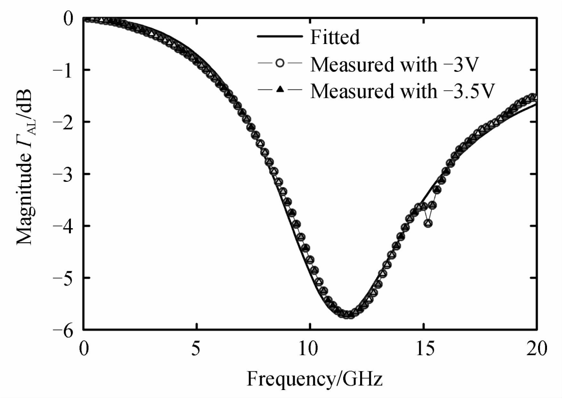


Fig. 4 The measured and fitted magnitude frequency responses of Γ_{AL}

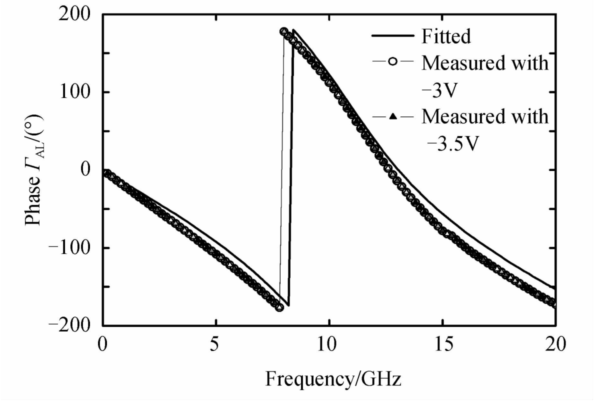


Fig. 5 The measured and fitted phase frequency responses of Γ_{AL}

3 Conclusion

High frequency electrical parameters of the model and parasitic elements are extracted based on the output reflection coefficient of the test-fixture. The extraction method is mainly focusing on the no on-wafer measurements of PDs. For the optical response extraction of PDs, we firstly obtain electrical parameters and parasitic elements without the optical input. By inputting optical signal, the overall high frequency responses of the test-fixture are measured, and the optical response parameters of the PD can be obtained by excluding electrical parameters and parasitic elements from the overall high frequency responses.

In addition, the method is also applicable to parameter extraction for a complicated circuit model of PDs and the data fitting and optimization can be processed with Optimizer of ADS software.

Acknowledgment: *The authors would like to thank Institute of Hebei Semiconductor for providing the device. One of the authors, Guanghui Xu, would also like to thank Prof. Z. Duan for the encouragement and the Prof. J. Gao of East China Normal University, for fruitful discussions and high frequency measurement support.*

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