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Poonglim Resort, Jeju

Proceeding

Exit

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학술발표 T2C 오름홀 (II)

광연결 및 광논리 10:45~12:30

좌장 : 길상근(수원대)

10:45(초청논문)
T2C-1 ■ **플라즈모닉 회절광학을 이용한 광연결**
이병호, 김휘(서울대)

11:15
T2C-2 ■ **고유연성 광도파로를 이용한 광 연결 시스템**
이우진, 황성환, 임정운, 노병섭(KOPTI)

11:30
T2C-3 ■ **배열된 장주기 광섬유 격자를 이용한 NRZ 신호 클럭 추출**
전시욱, 김태영, 박창수(GIST), Masanori Hanawa(Univ. Yamanashi, Japan)

11:45
T2C-4 ■ **전광 그레이코드/이진코드 변환기**
정영진, 박남규(서울대), 손창완, 전영민, 이석(KIST)

학술발표 T3A 다루홀

광소자 16:00~17:00

좌장 : 변영태(KIST)

16:00(초청논문)
T3A-1 ■ **Improved Light Output of Photonic Crystal Light Emitting Diode Fabricated by Anodized Aluminum Oxide Nano-patterns**
박준모, 오진경, 류상완(전남대),조성수, 권광우(㈜나이넥스)

16:30
T3A-2 ■ **CMOS Compatible Avalanche 광검출기의 등가회로 모델**
이명재, 강효순, 최우영(연세대)

16:45
T3A-3 ■ **디스펜서 시스템을 사용한 자외선 광학접착제 마이크로렌즈 어레이의 제작**
김재훈, 김경태, 홍준희, 이현행, 박시현(조선대)

An Equivalent Circuit Model for CMOS Compatible Avalanche Photodetectors

Myung-Jae Lee*, Hyo-Soon Kang, and Woo-Young Choi
Department of Electrical and Electronic Engineering, Yonsei University

Abstract We present an equivalent circuit model for CMOS-compatible avalanche photodetectors (CMOS-APDs) which models the rf-peaking effect in photodetection frequency response. The model includes an inductive component for avalanche delay and dual current sources for time delay of photogenerated carriers.

CMOS-compatible photodetectors (CMOS-PDs) can provide cost-effective solutions for 850 nm optical access networks because integrated optical receivers including photodetectors and electronic circuits can be realized with mature CMOS technology [1]. However, CMOS-PDs have the inherent drawback of low bandwidth-efficiency product due to the narrow depletion region formed by p+/n-well and n-well/p-substrate junctions [1]. To overcome this drawback, avalanche photodetectors (APDs) are very attractive because of their internal gain. We have previously reported the bandwidth enhancement by rf-peaking effect in photodetection frequency response of CMOS-APDs due to an inductive component in avalanche region [2]. In this work, we introduce the equivalent circuit model of CMOS-APDs for characterizing rf-peaking effect in photodetection frequency response.

Fig. 1 shows the equivalent circuit model of CMOS-APDs based on its physical structure. The photodetectors are implemented using the pn junction of p+ source/drain to n-well regions. In the model, L_a is the avalanche region inductance and R_a is the dissipative resistance in avalanche region [3]; C is the total depletion region capacitance between the p+ region and n-well region; R_d is the drift region resistance, R_j is the depletion region resistance, and R_s is the inactive region resistance; R_{well}, C_{sub1}, R_{sub}, and C_{sub2} are the n-well/p-substrate components [4]; C_p, L_p, R_p, and C_{pad} are the parasitic elements due to interconnects and pads, respectively. In contrast to low bias conditions, when the CMOS-APDs operate in sufficient high bias conditions which are satisfied with the avalanche process, the avalanche region is modeled as a shunt combination of an inductor and a

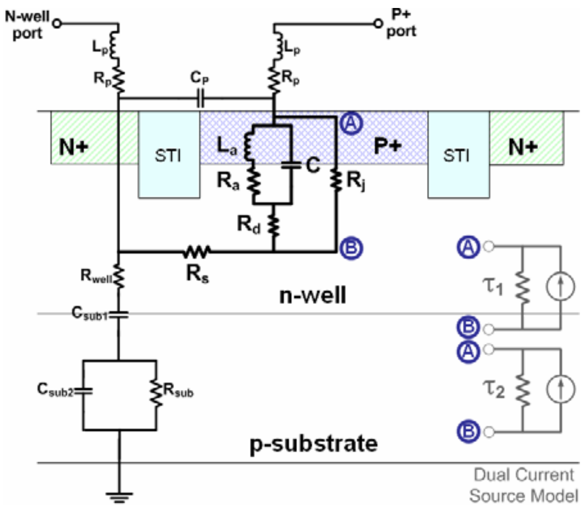

Fig. 1. CMOS-APDs model based on its physical structure.

capacitor as in impact ionization avalanche transit-time (IMPATT) diodes [5]. The inductance, L_a, is inversely proportional to current. In order to characterize the optical response of the CMOS-APD, photogenerated current is also modeled. The photodetection frequency response of a photodiode is limited by RC time, carrier-transit time, and diffusion time constant [6], thus the time constants should be considered in the current source model. For considering both the high-speed holes generated in depletion region and the low-speed holes generated in charge neutral region, the model is added by dual current sources which include time delay constants as shown in Fig. 1 [7].

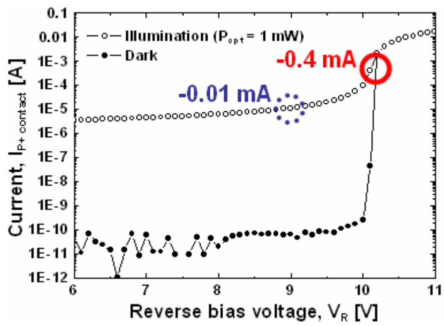

Fig. 2. I-V characteristics of the CMOS-APD under dark and illumination conditions. The incident optical power is 1mW.

We measured two-port s-parameters and photodetection frequency response at different bias conditions using vector network analyzer accompanied by 850 nm laser diode and electro-optic modulator. The measured frequency range is from 50 MHz to 13.5 GHz. To inject optical signal to the device, multimode lensed fiber was used and all measurements were done on-wafer. Fig. 2 shows the current-voltage characteristics of the CMOS-APD.

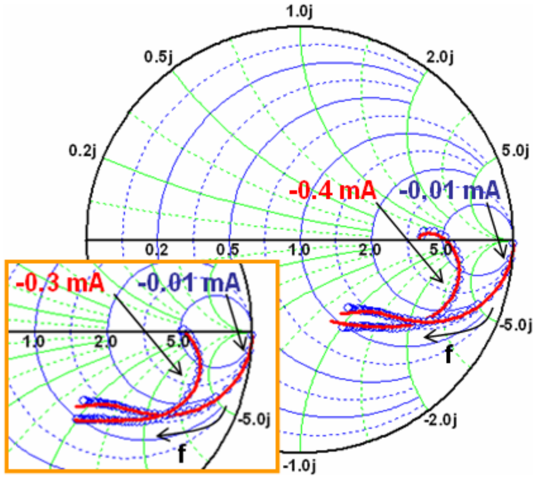

Fig. 3. Comparison of measured and fitted reflection coefficient of p+ port (from 50 MHz to 13.5 GHz). The hollow circles represent measured data and solid lines indicate fitting results.

Table 1. Intrinsic values of the equivalent circuit of the CMOS-APD.

	-0.01 mA	-0.3 mA	-0.4 mA
L_a [nH]	—	14	10.5
R_a [Ω]	—	140	70
C [fF]	330	200	220
R_d [Ω]	—	4.16	4.16
R_j [Ω]	—	1000	700
R_s [Ω]	45	68	24

For accurate parameter extraction of intrinsic components, we use the open-short deembedding method. Fig. 3 shows the measured and fitted reflection coefficient of the CMOS-APD at p+ port on Smith chart at three different bias currents, I_{p+} = -0.01, -0.3, and -0.4 mA, under 1 mW optical illumination. The simulation results agree well with the measured data. The table 1 shows the extracted intrinsic values under three different bias conditions. When the avalanche process occurs, an inductive component is generated.

Fig. 4 shows the measured and fitted photodetection frequency response of the same device under aforementioned bias conditions. This figure clearly shows the occurrence of the rf-peaking caused by an inductive component in avalanche region. The 3-dB bandwidth increases significantly from 1.03 to 3.83 GHz when the bias current increases form -0.01 to -0.4 mA.

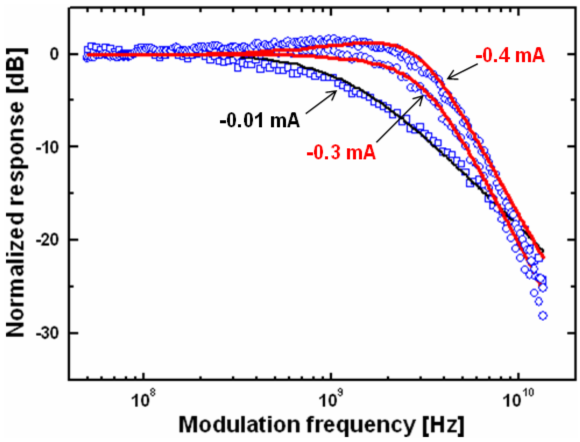

Fig. 4. Comparison of measured and fitted photodetection frequency responses of the CMOS-APD. The symbols represent measured data and solid lines indicate fitting results.

In summary, we presented the equivalent circuit model for CMOS-APDs. The proposed equivalent circuit model fits well with both the measured reflection coefficient at p+ port and photodetection frequency response. The physical origin of rf-peaking in the CMOS-APD is clarified by the inductive component in avalanche region using the equivalent circuit model.

References

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