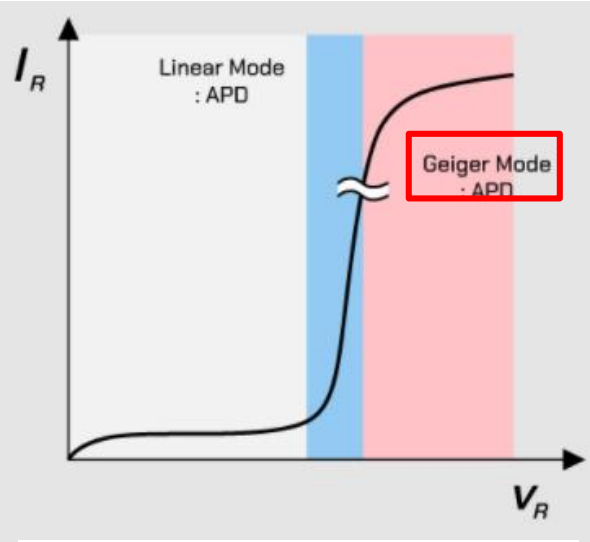
2021-1~2022-1 Works

SPAD



Operation mode	Reverse voltage	Gain
Linear Mode	Below breakdown voltage	Dozens to several hundred
Geiger Mode	Above breakdown voltage	10^5 to 10^6

SPAD Design

- **GF 40nm process**
- **DB 110nm CIS process**
- **GF 55nm BCD process**

TCAD Simulation

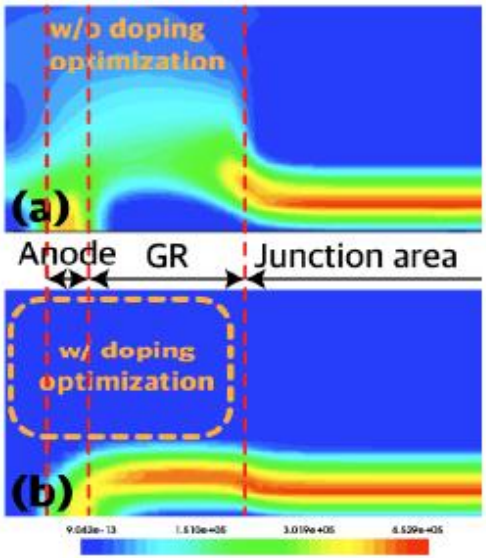


Fig. 3. TCAD simulation results for the back-illuminated SPAD: E-field profiles (a) w/o and (b) w/ doping optimization at $V_E = 2.5$ V.

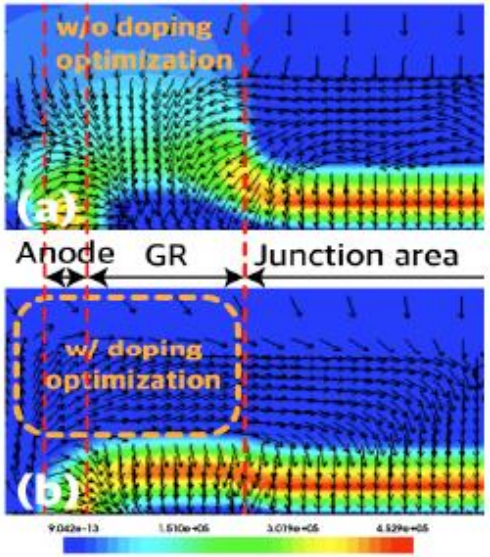


Fig. 4. TCAD simulation results for the back-illuminated SPAD: Carrier flows (a) w/o and (b) w/ doping optimization.

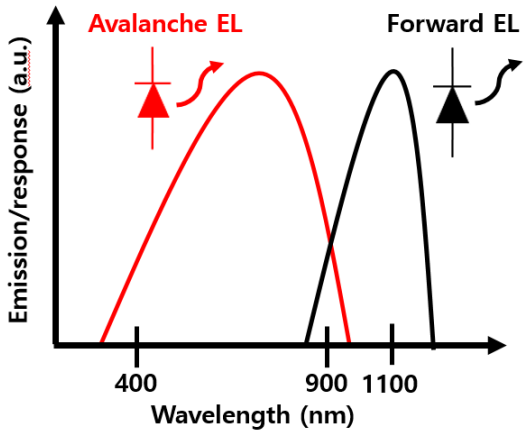
Doping-Optimized Back-Illuminated Single-Photon Avalanche Diode in Stacked 40 nm CIS Technology Achieving 60% PDP at 905 nm

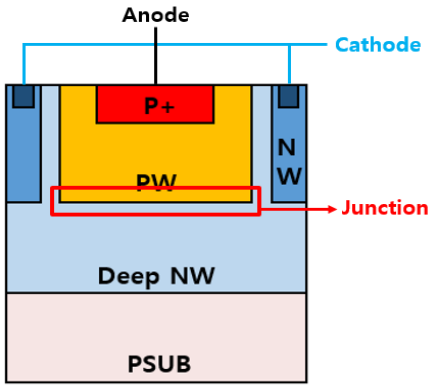
Eunsung Park[1,2], Won-Yong Ha[1], Doyoon Eom[1,*], Dae-Hwan Ahn[1], Hyuk An[3], Suhyun Yi[3], Kyung-Do Kim[3], Jongchae Kim[3], Woo-Young Choi[2,*], and Myung-Jae Lee[1,*]

(2022 IEDM co-author)

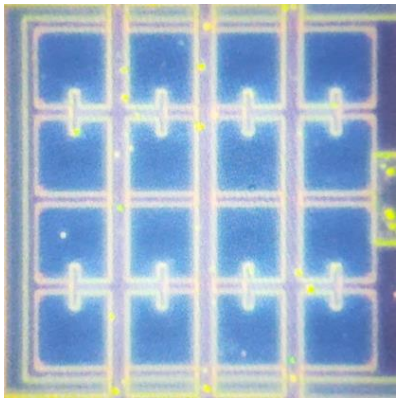
2021-1~2022-1 Works

AMLED (Avalanche Mode LED)

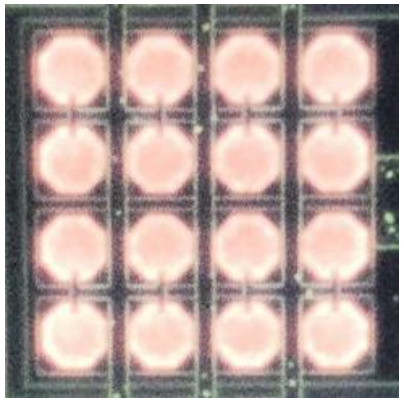




(LED Structure)

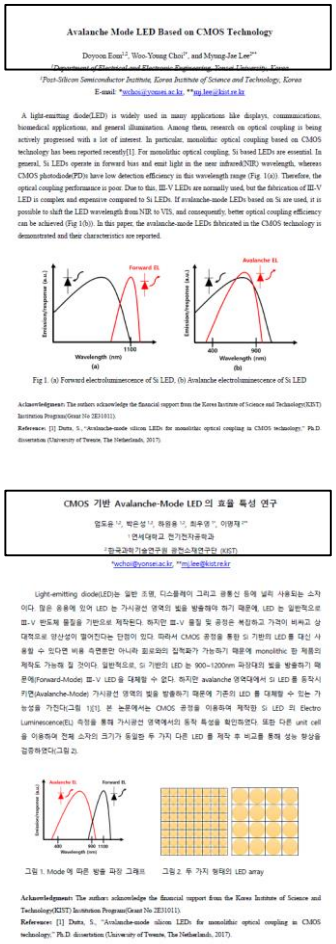


(Below V_{br})



(Above V_{br})

Conference



Avalanche Mode LED Based on CMOS Technology

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A light-emitting diode(LED) is widely used in many applications like displays, communications, biomedical applications, and general illumination. Among them, research on optical coupling is being actively progressed with a lot of interest. In particular, monolithic optical coupling based on CMOS technology has been reported recently[1]. For monolithic optical coupling, Si based LEDs are essential. In general, Si LEDs operate in forward bias and emit light in the near infrared(NIR) wavelength, whereas CMOS photodiode(PD)s have low detection efficiency in this wavelength range (Fig. 1(a)). Therefore, the optical coupling performance is poor. Due to this, III-V LEDs are normally used, but the fabrication of III-V LED is complex and expensive compared to Si LEDs. If avalanche-mode LEDs based on Si are used, it is possible to shift the LED wavelength from NIR to VIS, and consequently, better optical coupling efficiency can be achieved (Fig 1(b)). In this paper, the avalanche-mode LEDs fabricated in the CMOS technology is demonstrated and their characteristics are reported.

Fig 1. (a) Forward electroluminescence of Si LED, (b) Avalanche electroluminescence of Si LED

Acknowledgement: The authors acknowledge the financial support from the Korea Institute of Science and Technology(KIST) Institution Program(Grant No 2E31011).

Reference: [1] Dutta, S., "Avalanche-mode silicon LEDs for monolithic optical coupling in CMOS technology," Ph.D. dissertation (University of Twente, The Netherlands, 2017).

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CMOS 기반 Avalanche-Mode LED의 효율 특성 연구

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Light-emitting diode(LED)는 일반 조명, 디스플레이 그리고 광통신 등에 널리 사용되는 소자이다. 많은 응용에 있어 LED 는 가시광선 영역의 빛을 방출해야 하기 때문에, LED 는 일반적으로 III-V 반도체 물질을 기반으로 제작된다. 하지만 III-V 물질 및 공정은 복잡하고 가격이 비싸고 상대적으로 양산성이 떨어진다는 단점이 있다. 따라서 CMOS 공정을 통한 Si 기반의 LED 를 대신 사용할 수 있다면 비용 측면뿐만 아니라 회로와의 집적화가 가능하기 때문에 monolithic 한 적층의 제작도 가능해 질 것이다. 일반적으로, Si 기반의 LED 는 900~1200nm 파장대의 빛을 방출하기 때문에(Forward-Mode) III-V LED 을 대체할 수 없다. 하지만 avalanche 영역대에서 Si LED 를 동작시키면(Avalanche-Mode) 가시광선 영역의 빛을 방출하기 때문에 기존의 LED 를 대체할 수 있는 가능성을 가진다[그림 1](1). 본 논문에서는 CMOS 공정을 이용하여 제작한 Si LED 의 Electro Luminescence(EL) 측정을 통해 가시광선 영역에서의 동작 특성을 확인하였다. 또한 다른 unit cell 을 이용하여 전체 소자의 크기가 동일한 두 가지 다른 LED 를 제작 후 비교를 통해 성능 향상을 검증하였다[그림 2].

그림 1. Mode 에 따른 방출 파장 그래프 그림 2. 두 가지 형태의 LED array

Acknowledgement: The author acknowledge the financial support from the Korea Institute of Science and Technology(KIST) Institution Program(Grant No 2E31011).

References: [1] Dutta, S., "Avalanche-mode silicon LEDs for monolithic optical coupling in CMOS technology," Ph.D. dissertation (University of Twente, The Netherlands, 2017).

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Future Plan (2022-2)

- **Masters degree graduation thesis**
  - **[DB 110nm CIS] SPAD measurement**
  - **[DB 110nm CIS / GF 55nm BCD] AMLED measurement**
- **TCAD Simulation**
  - **SPAD parameter simulation**
- **2022.08~ : GF 55nm BCD BSI (measurement / analysis)**