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Irsens RTD 2009

FNSNF

A Ge-on-Si Single-Photon Avalanche Diode Optimized for Infrared Wavelengths

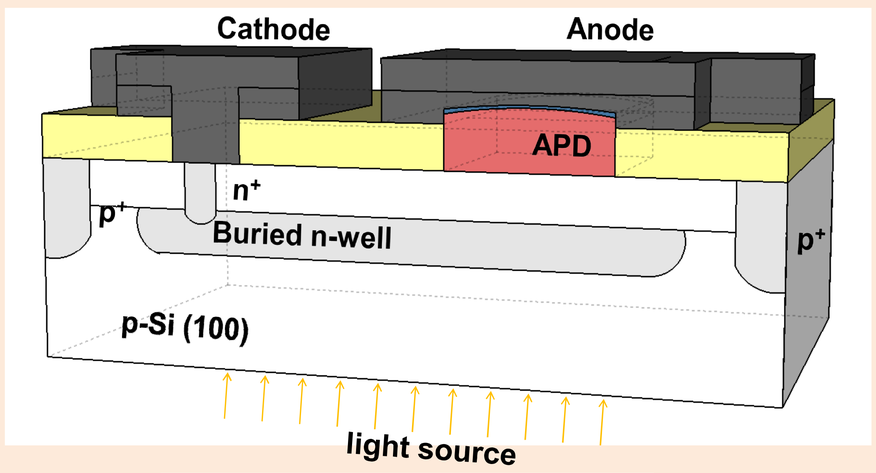
Mahdi Aminian[1], Amir Sammak[2], Lis Nanver[2], Edoardo Charbon[1,2]

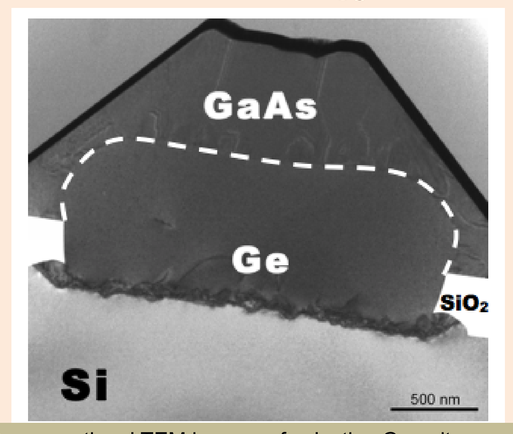
[1]Ecole Polytechnique Fédérale de Lausanne, [2]Delft University of Technology

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

- **Main goal**
  - Create a Germanium SPAD array
  - Near-infrared detection range (~1.2-1.6μm)
- **Why Ge-on-Si**
  - Ge bandgap of 0.67eV
  - Suitable for near-infrared applications
- **What has been done**
  - Simulations of various Ge structures
  - Testing of other Ge photodetectors in Geiger mode

Ge-on-Si SPAD Process Flow





Cross-sectional TEM images of selective Ge epitaxy grown on patterned Si followed by in-situ growth of a GaAs layer

P-Si (100) substrate

↓

Deep buried n implantation + 0.5μm n-Si epi growth

↓

p^+ and n^+ plug implantation for guard ring and substrate contacts

↓

SiO_2 coverage and opening windows to Si

↓

n-Ge growth + PureGaB

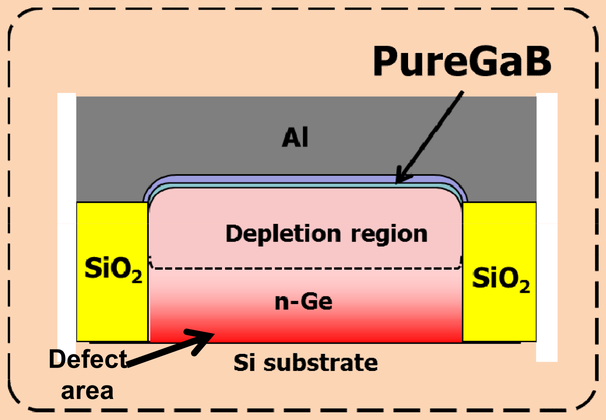
↓

First Al coating

↓

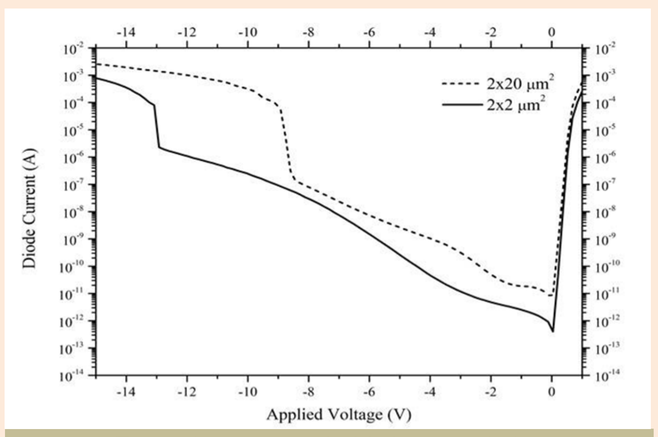
Contact opening + Second Al + selective etching

- **Ge-on-Si epitaxial growth**
  - Selective Ge epitaxy on Si (1μm-thick)
  - Very low density of threading dislocations
  - Can be tens-of-microns large
- **PureGaB deposition**
  - Depletion region above defect area
  - Ga deposition to form the ultra shallow p^+-doping (~5 nm)
  - B deposition to avoid Al spiking and further oxidation

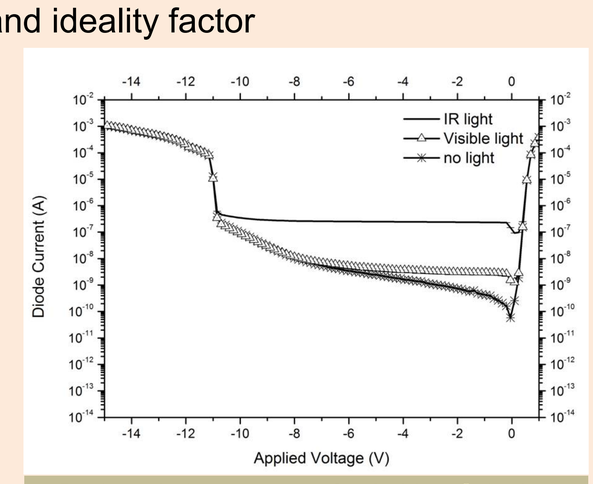


Ge-on-Si APD Experimental Results

- **Specifications of Ge APDs**
  - Can be operated both in proportional and in Geiger mode
  - Low dark counts and reasonably high sensitivity at room temperature
  - Low values of reverse current, series resistance and ideality factor



Exceptionally good I-V characteristics



Dark and photo current for 2x20μm² device

Performance (APD/linear mode)	Min.	Typ.	Max.	Unit
Active area	4		40	μm^2
Breakdown voltage for 2×2 μm^2	9			V
Breakdown voltage for 2×20 μm^2			13	V
Breakdown voltage		11		V
Dark current @ 1V reverse bias	2		20	pA

Performance (Geiger mode)				
Excess bias voltage	0		4	V
DCR @ Ve = 1V	10		60	kHz
I_H/I_{ref} @ V_e=3V			25	%
FWHM Time jitter			900	ps

Performance summary

Toward A Ge-on-Si SPAD Array

- 4×4 Ge SPAD array designed and under fabrication
- Pixel and Row decoder to address a specific SPAD pixel or entire row
- Read-out circuits for pulse shaping

- **Future work**
  - Fabrication and test of Ge SPAD array

Nano-Tera annual meeting, Marriott Hotel, Zürich, 26th-27th April, 2012