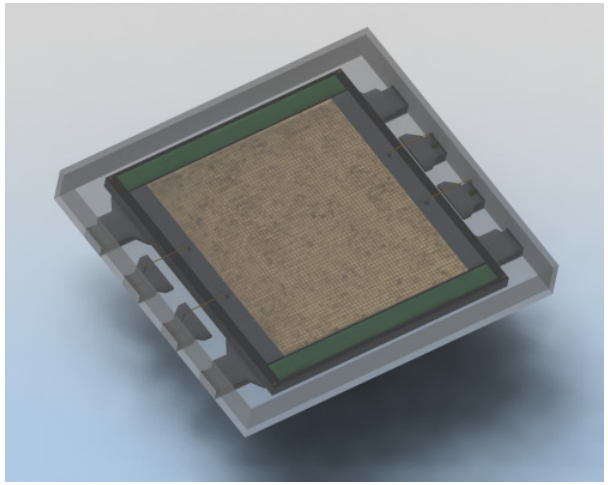
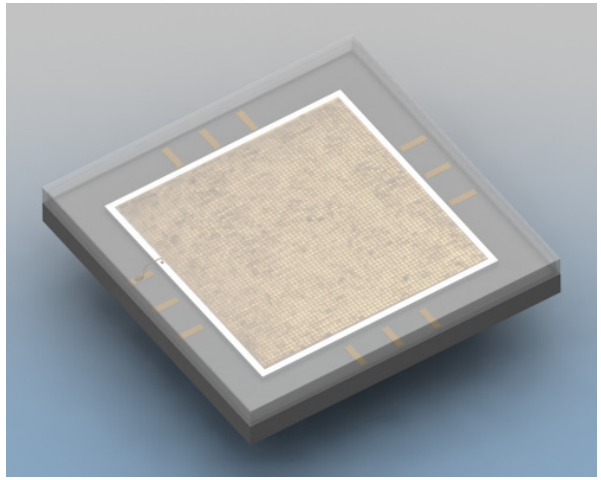
Silicon Photomultiplier Technology at STMicroelectronics

Industry-academia matching event on SiPM and related technologies





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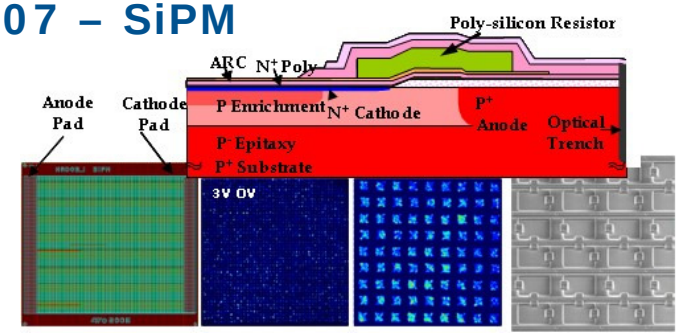
Outline

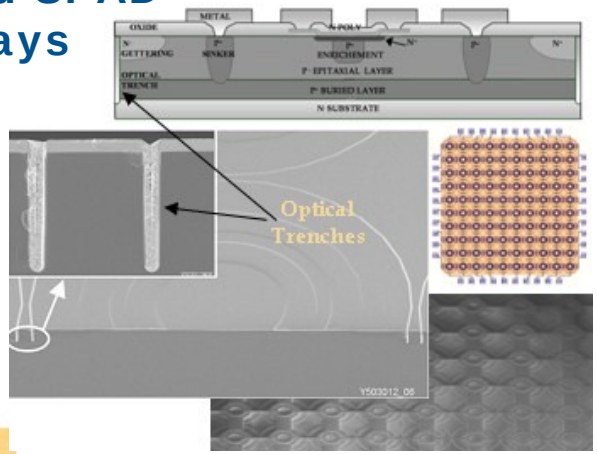
- From SPAD to SiPM
- SiPM Technology
- STM short term technology roadmap
- SiPM package capability
- SiPM product portfolio and roadmap
  - SMP35CN features
- Other Sensors Technologies

From SPAD to SiPM

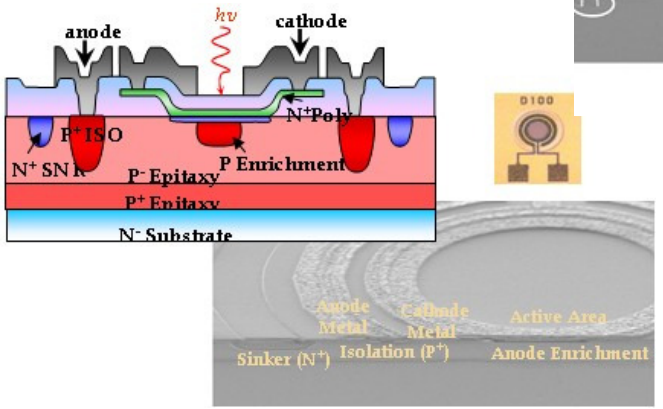
2007 – SiPM



2005 – Optically Isolated SPAD Arrays

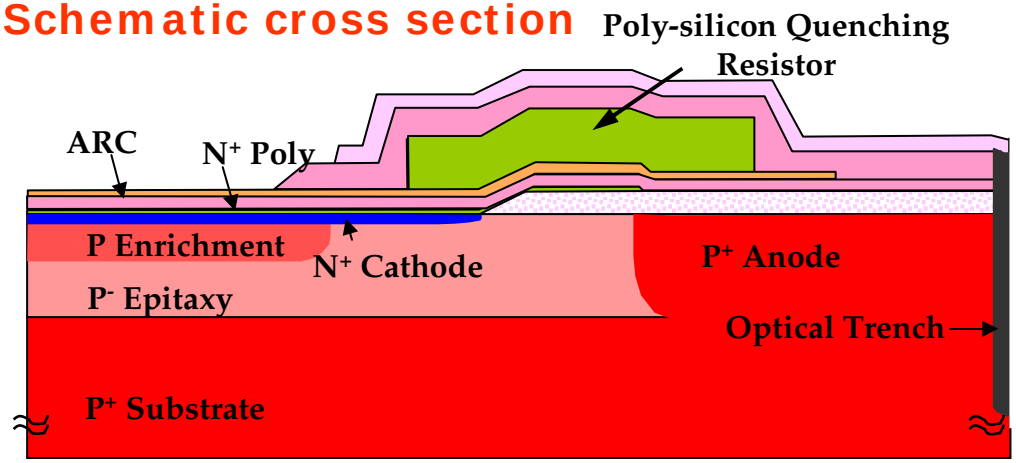


2000 – Single Pixel SPAD

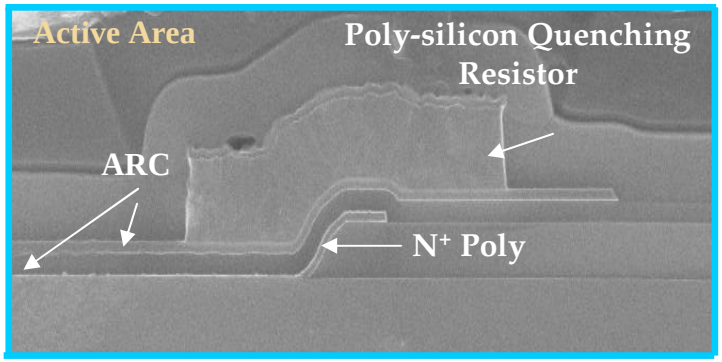


ST SiPM technology

Schematic cross section



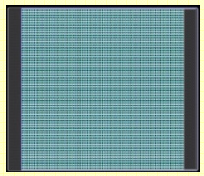
SEM cross sections



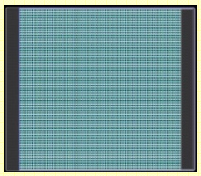
- Shallow junction
- In-situ doped poly-silicon cathode layer
- Integrated poly-silicon resistors
- Thin optical trench with metal filling
- Tunable Anti-reflection coating
- Dedicated gettering techniques
- Double layer passivation

SiPM Technology short term roadmap

P-on-N technology

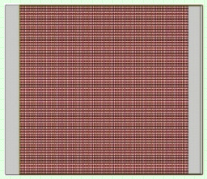


Process demonstrator

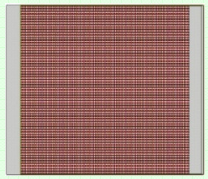


SiPM prototype

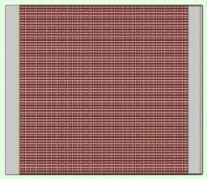
N-on-P technology



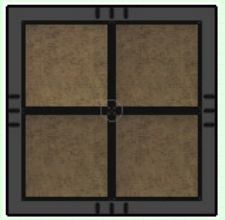
Low dark current



Increased fill factor



Faster rise time

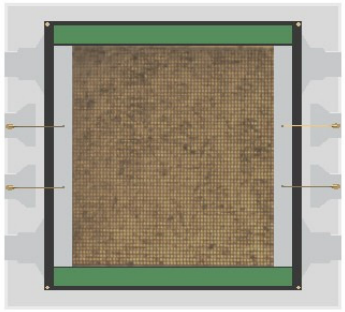


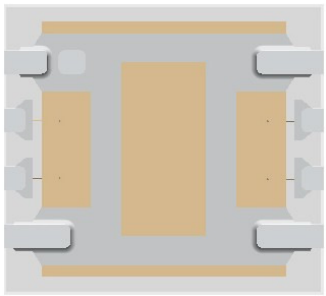
Single die SiPM array

Today

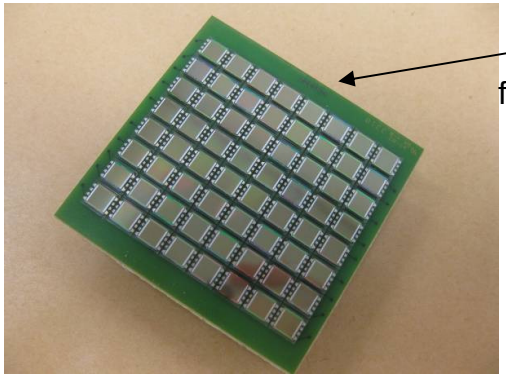
Time

STM package capability



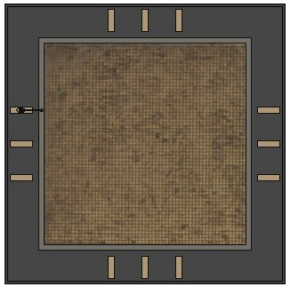


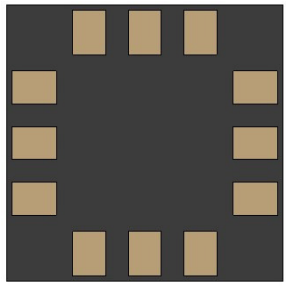
Transparent QFN package



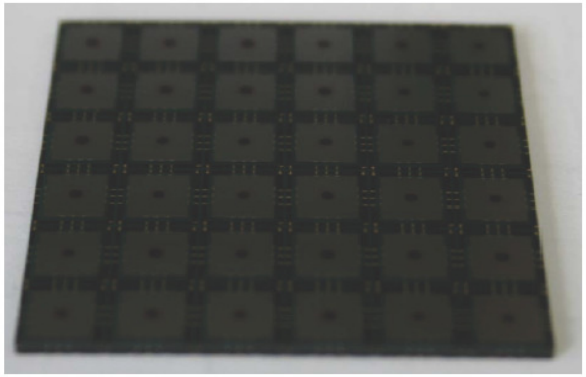
Developed with Philips cooperation in the framework of EU funded project CSI

QFN Tile





Transparent LGA package



Array on LGA substrate

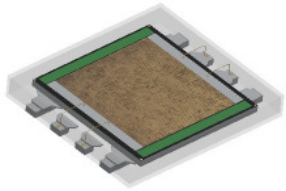
→ TSV program ongoing in STM

Product Portfolio & Roadmap

SPM22N

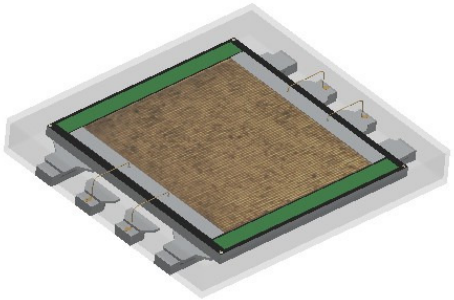
N-on-P
Single die array

SPM10CN



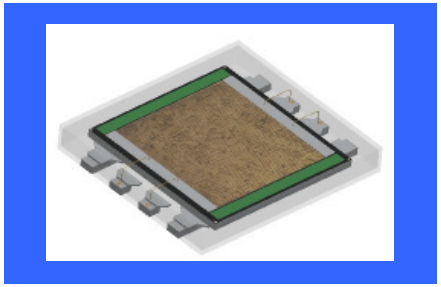
N-on-P
QFN 2.5mmx3mm
1x1mm active area

SPM35CN



N-on-P
QFN 5mmx5.5mm
3.5mmx3.5mm active area

SPM35CP



P-on-N
QFN 5mmx5.5mm
3.5mmx3.5mm active area

Time

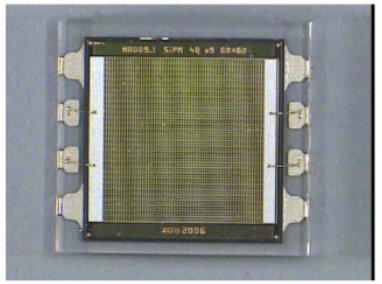
SPM35AN Electro-Optical Performances Summary

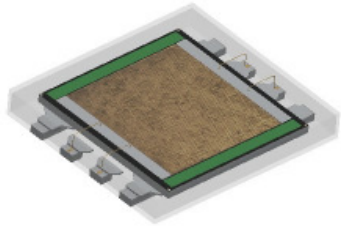
Test condition: @ 3V OV and 25 °C

Array area	3.5x3.5 mm²
Number of microcells/ Fill Factor	3600/ 45%
Quenching Resistor Value	230 kΩ
Breakdown Voltage (BV)	28.0 V
dBV/ dT	30mV/ °C
Operating Overvoltage Range	1V÷5V OV
Gain	$3.2x10^6$
Dark Count Density @ 0.5 p.e.	0.6 MHz/ mm²
Afterpulsing Probability	< 3%
Cross talk Probability†	< 1%
PDE @ 420 nm	16%
SPTR @ 405 nm	180 ps
Energy Resolution @ 511 KeV	12%
Coincidence Timing Resolution @ 511 KeV	320 ps
Package	Transparent QFN

SMP35AN

3.5x3.5 mm² SiPM in QFN package

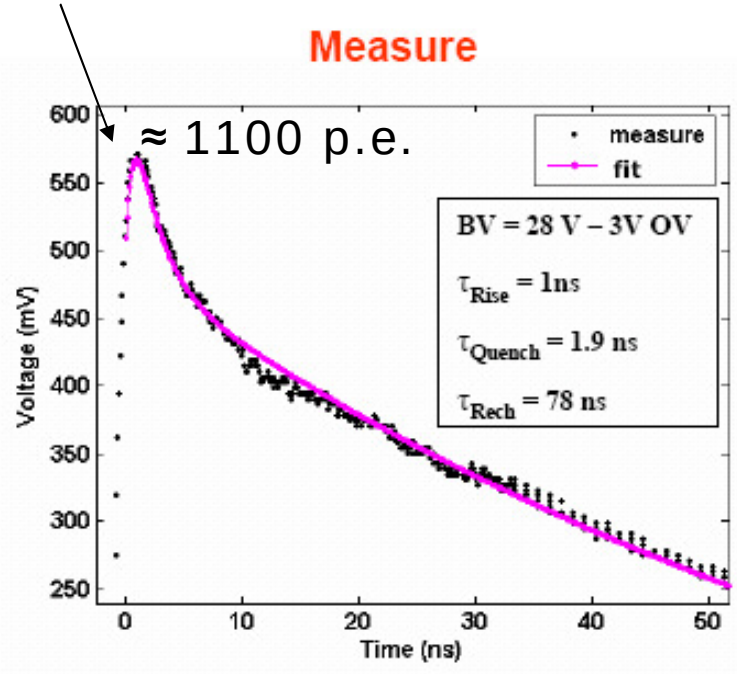


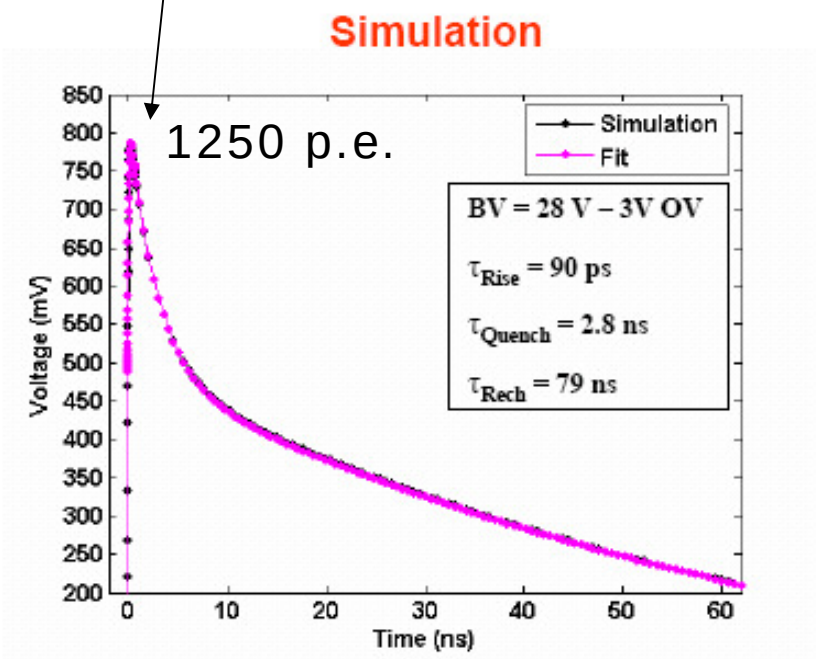


SiPM pulse shape

Optical Source PiLas @ 410 nm (FWHM≈40 ps)

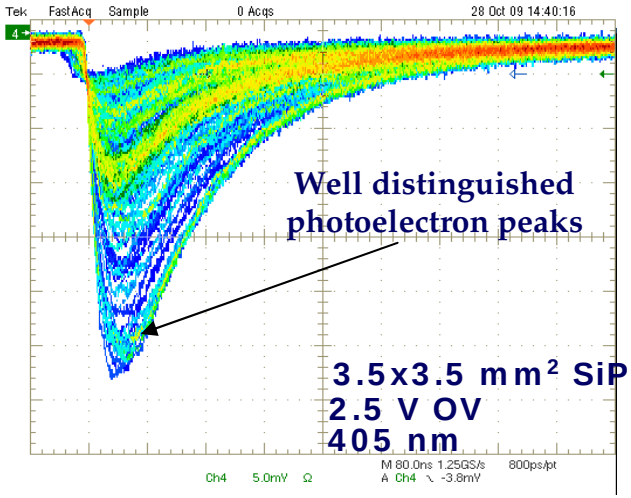
From SiPM SPICE Model





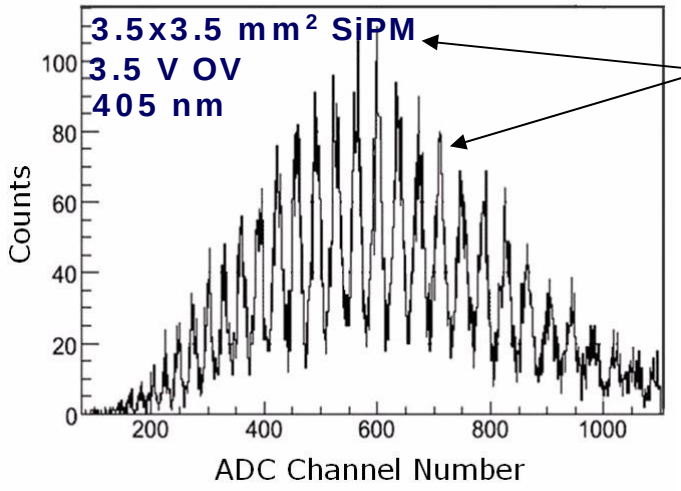
Main results on large area SI PM samples

Oscilloscope persistence picture



Source S.Korpar

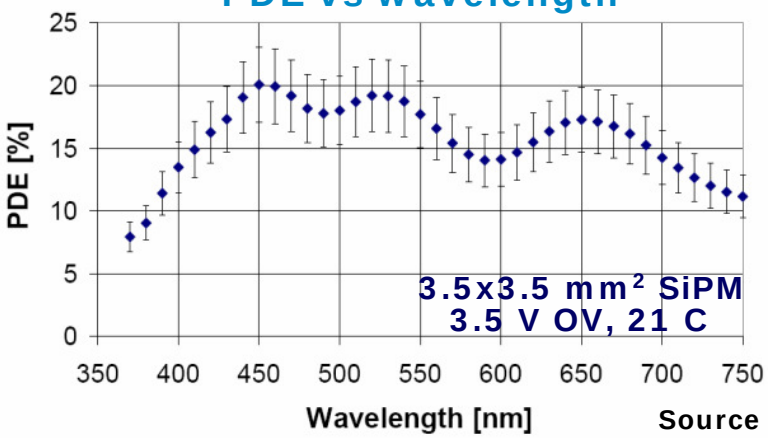
Single photoelectron charge spectrum



Excellent single photoelectron resolution

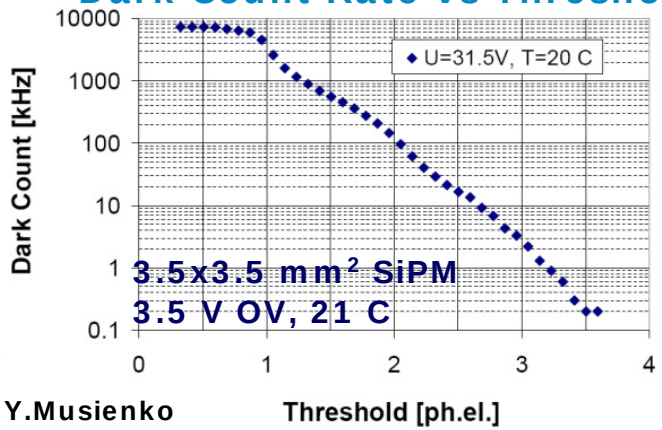
Source A.Ronzhin

PDE vs wavelength



Source Y.Musienko

Dark Count Rate vs Threshold



- PDE @ 420 nm and 3.5 V OV ≈ 17%
- DKR density @ 0.5 p.e. and 3.5 V OV ≈ 0.6 MHz/ mm²

4H-SiC Photodiodes for UV Light Detection

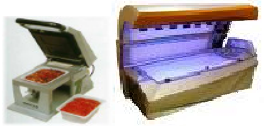
Flame sensing & weather stations

UV Photodetectors

UV meter & UV watch

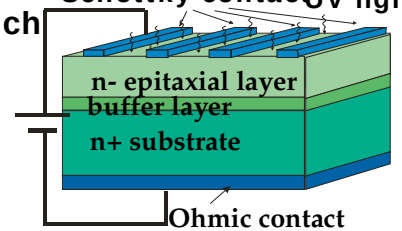
Ozone monitors, pollution monitors

Disinfection & Water purifier



Packing & Tanning checkers

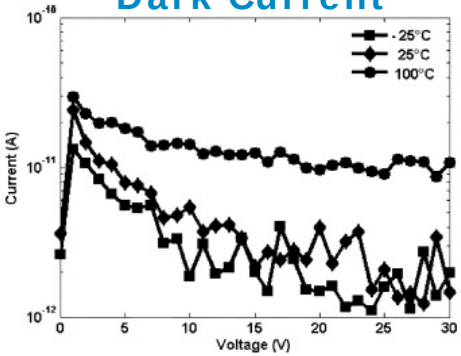
4H-SiC Schottky photodiodes



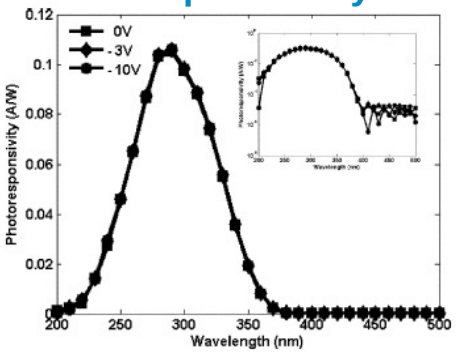
Interdigit layout

TO package with UV glass window

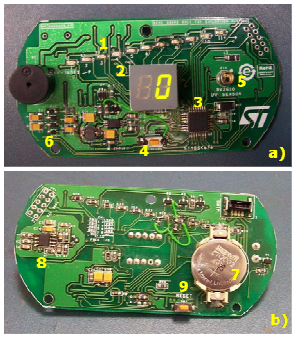
Dark Current



Responsivity



4H-SiC Photodiode Demonstrator Board for UV Index Monitoring



- Working in linear regime (i.e. zero gain)
- Dark current of a few pA also at high temperature
- Max sensitivity in photovoltaic regime (0 V) in the range 200 nm÷380 nm
- Peak responsivity wavelength @ 290 nm (≈45% QE)
- Excellent visible blindness

M.Mazzillo et al., IEEE Photonics Technology Letters, 2009.

M.Mazzillo et al., IEEE Sensors Journal, 2011.

Technology still in engineering phase!

References

- E.Sciacca et al., IEEE Transactions on Electron Devices, 2003.
- E.Sciacca et al., IEEE Photonics Technology Letters, 2006.
- M.Mazzillo et al., Sensors& Actuators A, 2007.
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- M.Mazzillo et al, IEEE Transactions on Nuclear Science 2008,2009,2010.

- STMicroelectronics R&D working team
  - S.Abbisso, B.Carbone, G.Condorelli, C.Di Martino, P.Fallica, M.Mazzillo, A.Piana, A.Russo, D. Sanfilippo, G. Valvo

Thanks