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MONOLITHIC NEAR INFRARED IMAGE SENSORS ENABLED BY QUANTUM DOT PHOTODETECTOR

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IISW 2017, HIROSHIMA, JAPAN


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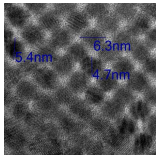
IMAGE SENSORS AT IMEC

VISIBLE AND NON-VISIBLE IMAGING

(multicolor) OPD

Holst Centre

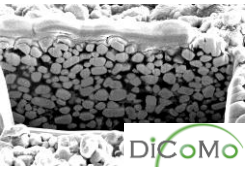
QD, OPD



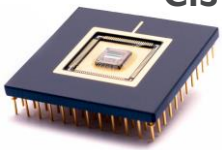
UNIVERSITEIT GENT

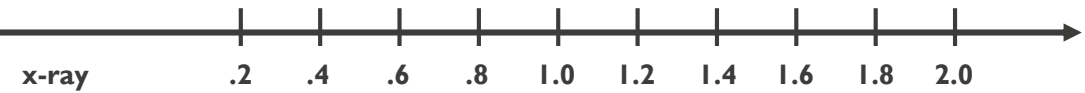
UHASSELT
KNOWLEDGE IN ACTION

hybrid OPD



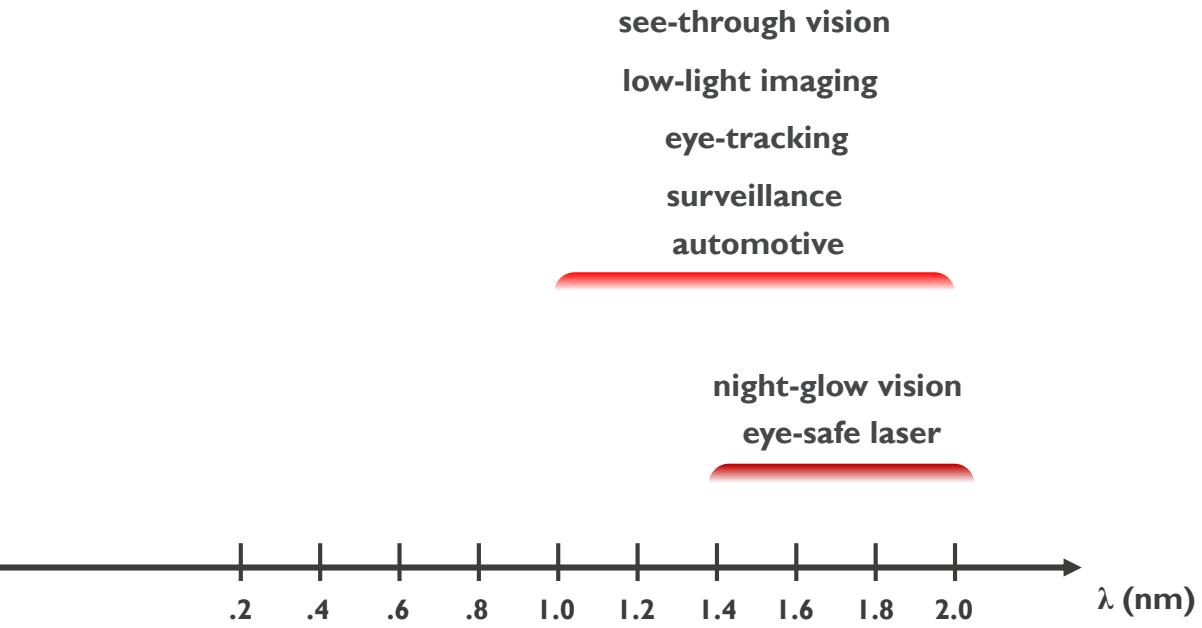
CIS





NEAR INFRARED RANGE

APPLICATIONS

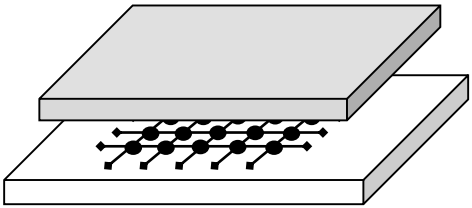


NEAR INFRARED RANGE

INTEGRATION

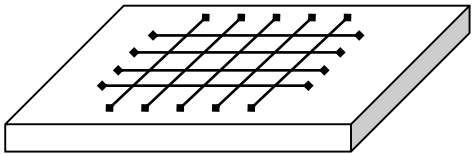
hybrid / flip-chip

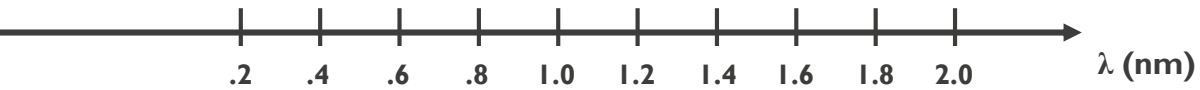
NIR, IR
1 MPx
14 µm pixel



monolithic

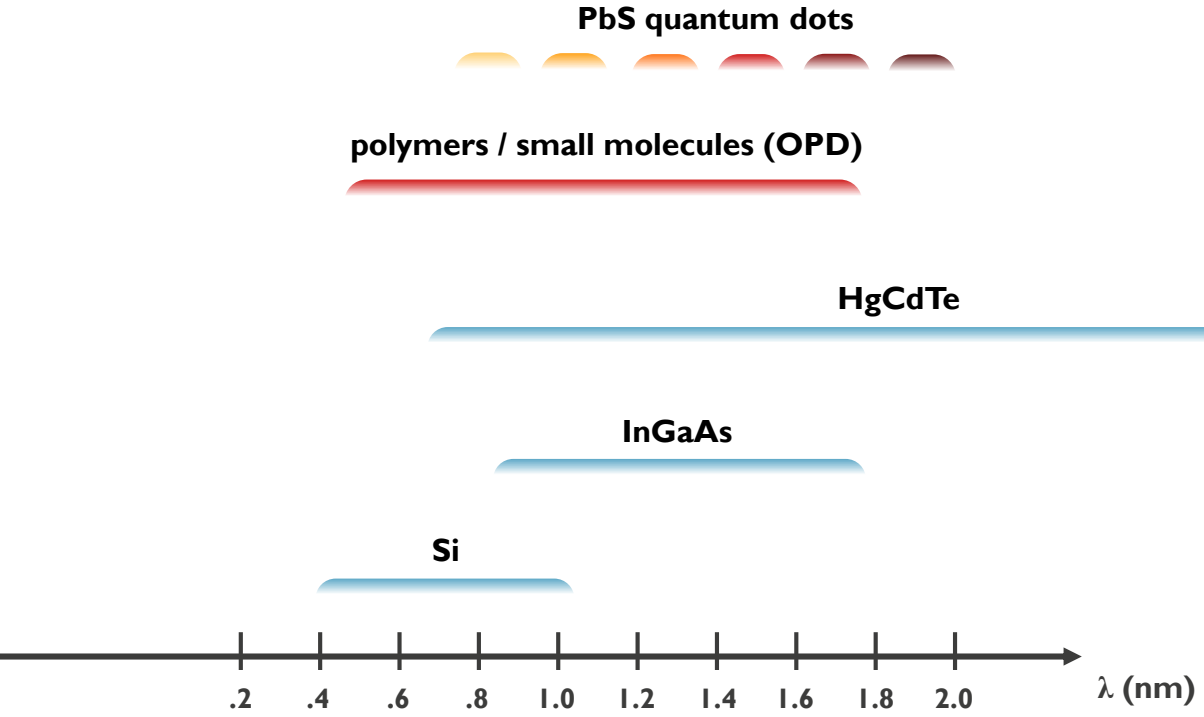
VIS
>>10 MPx
0.9 µm pixel





NEAR INFRARED RANGE

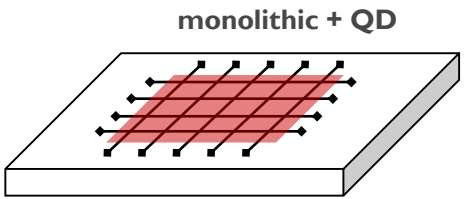
MATERIALS

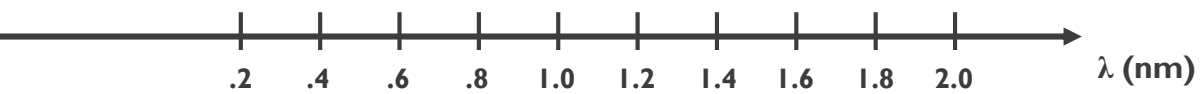


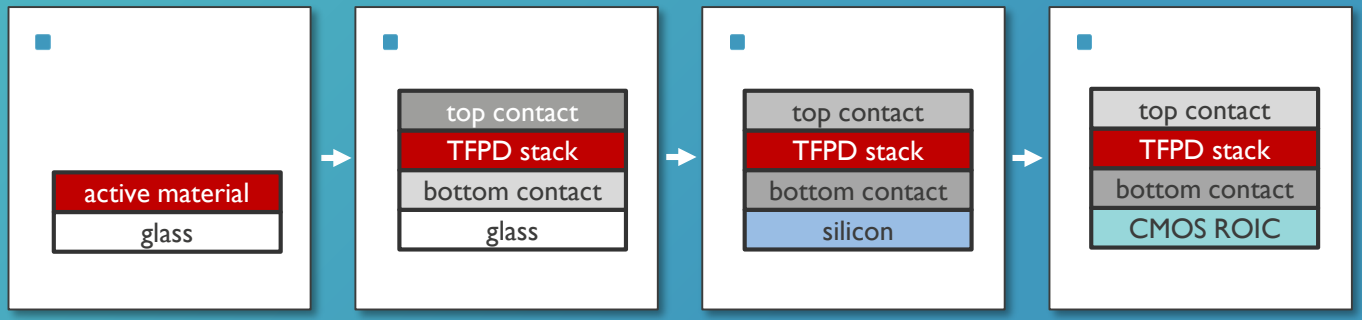
NEAR INFRARED RANGE

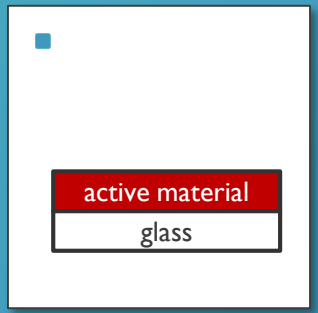
INTEGRATION

VIS, NIR, VIS+NIR
>1 MPx
<5 µm pixel



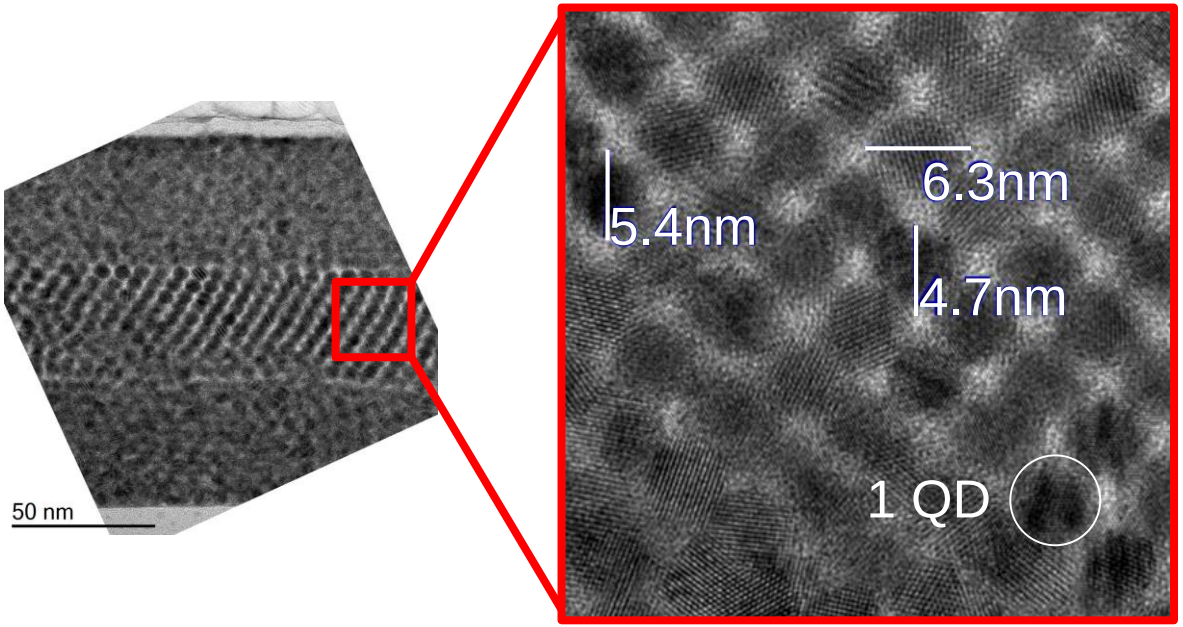


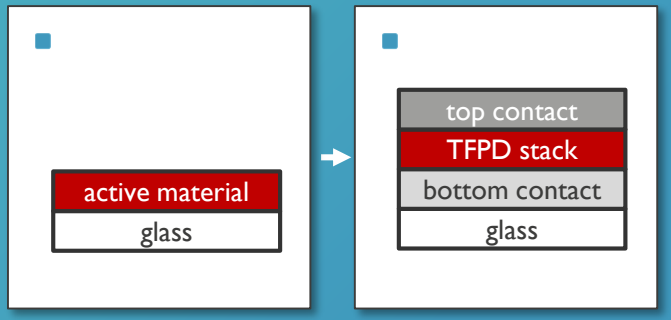

active material
glass
top contact
TFPD stack
bottom contact
glass
top contact
TFPD stack
bottom contact
silicon
top contact
TFPD stack
bottom contact
CMOS ROIC


active material
glass

COLLOIDAL QUANTUM DOT ABSORBER

150 NM THICK ACTIVE LAYER



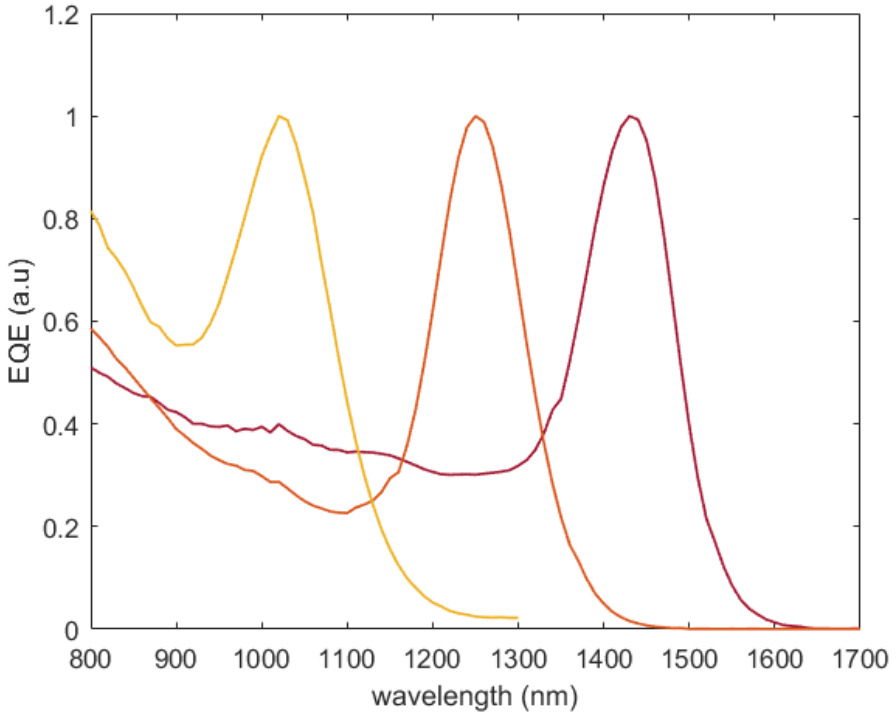

active material
glass
top contact
TFPD stack
bottom contact
glass

PHOTODETECTOR STACK DEVELOPMENT

TUNING OF ABSORPTION PEAK WITH QD SIZE

↓ SMALLER QD

↓ LOWER ABSORPTION PEAK

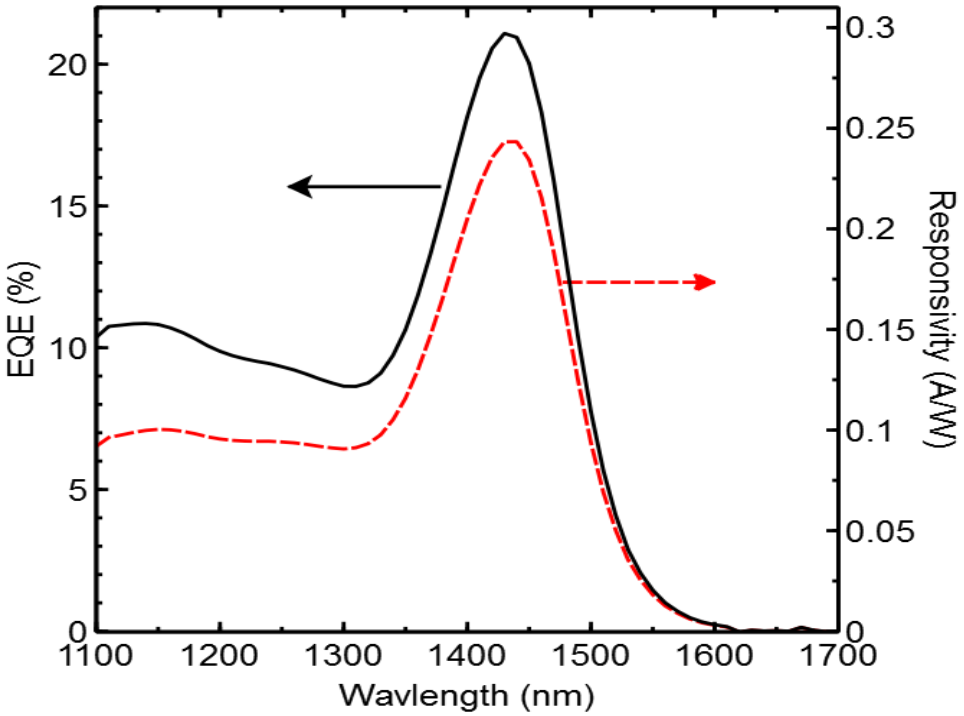


PHOTODETECTOR STACK DEVELOPMENT

EQE > 10% IN NEAR INFRARED FROM A 150 NM THIN-FILM

DARK CURRENT @ -1 V: ~ μA/CM²

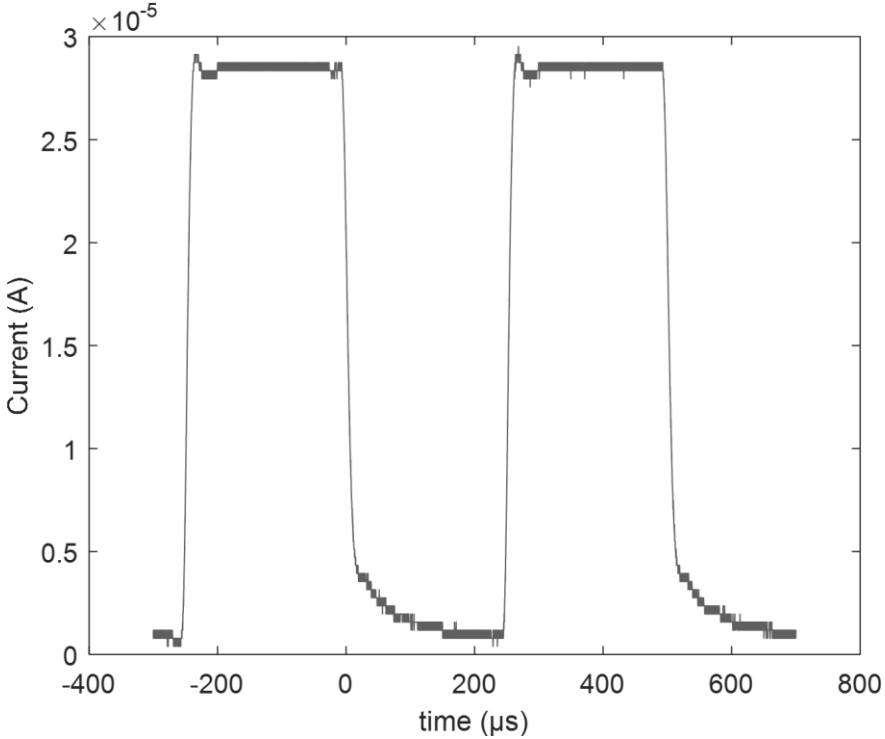
DETECTIVITY: D* > 10^{11} JONES



PHOTODETECTOR STACK DEVELOPMENT

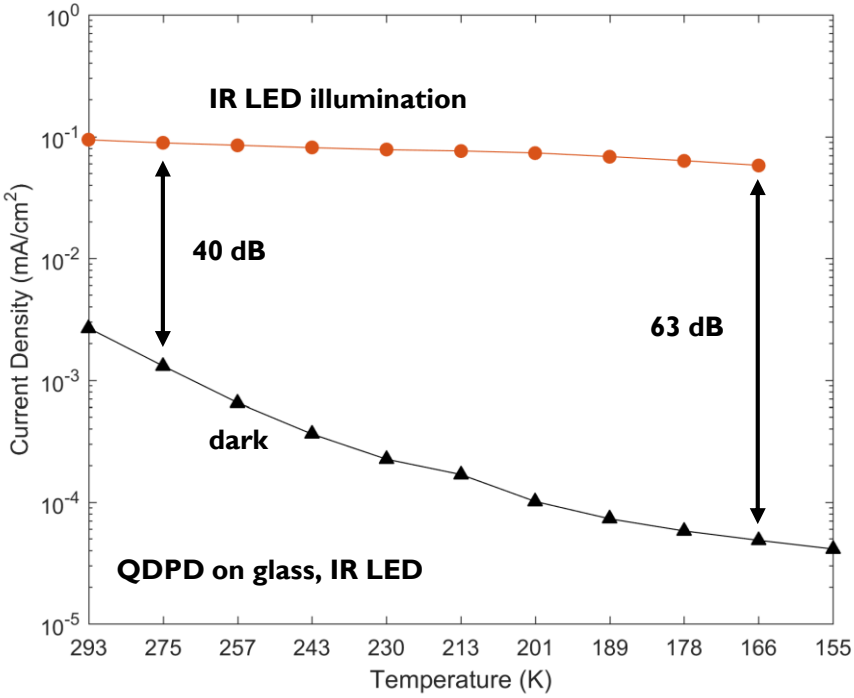
RISE TIME (10% TO 90%): ~12.5 μs

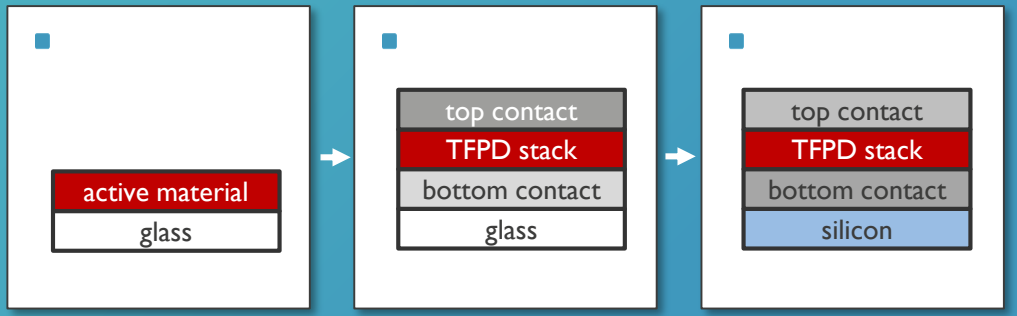
FALL TIME (90% TO 10%): ~51 μs



PHOTODETECTOR STACK DEVELOPMENT

PHOTO/DARK RATIO IMPROVEMENT AT LOW TEMPERATURE
193K PACKAGE AN OPTION FOR SPECIFIC APPLICATIONS

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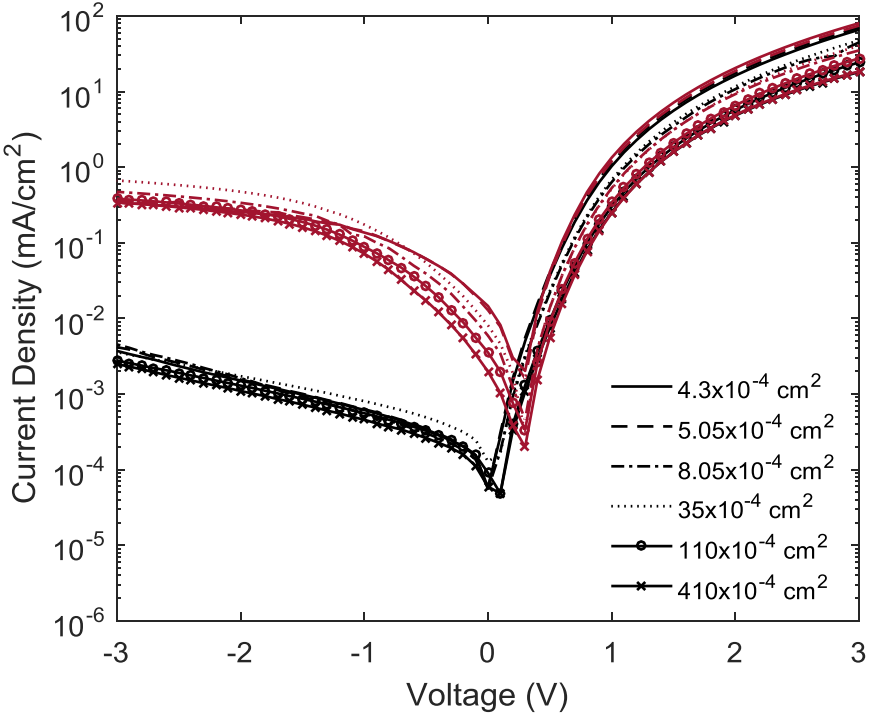
bottom contact
glass
top contact
TFPD stack
bottom contact
silicon

PHOTODETECTOR OPTIMIZATION ON SILICON

TOP ILLUMINATION

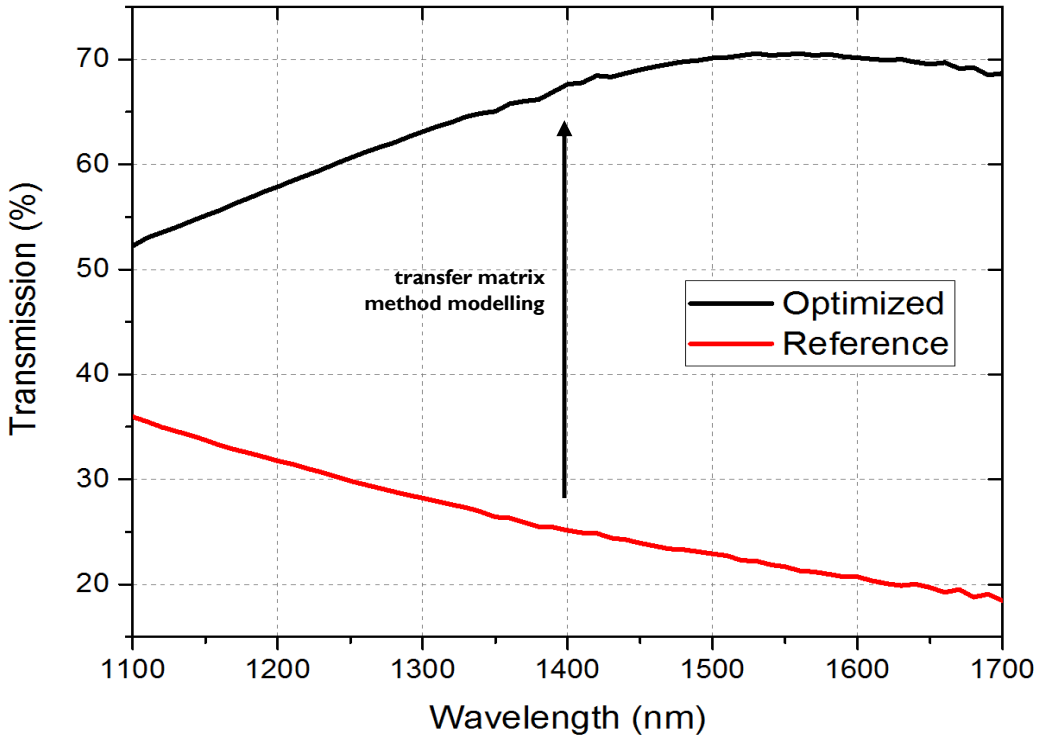
CMOS-COMPATIBLE BOTTOM CONTACT

SEMI-TRANSPARENT TOP CONTACT



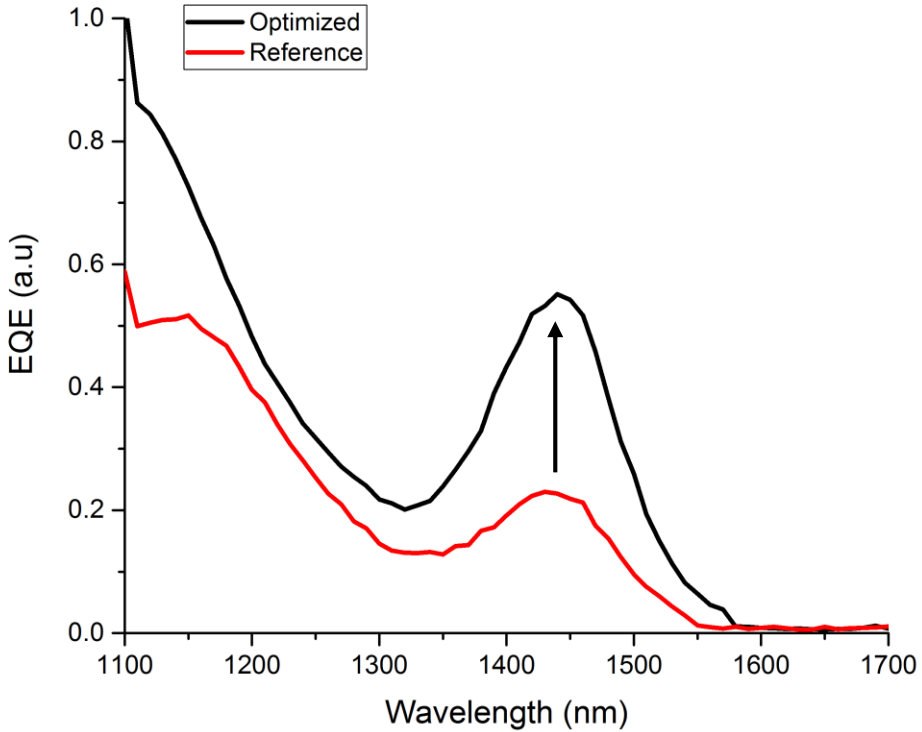
ADJUSTMENT FOR TOP ILLUMINATION

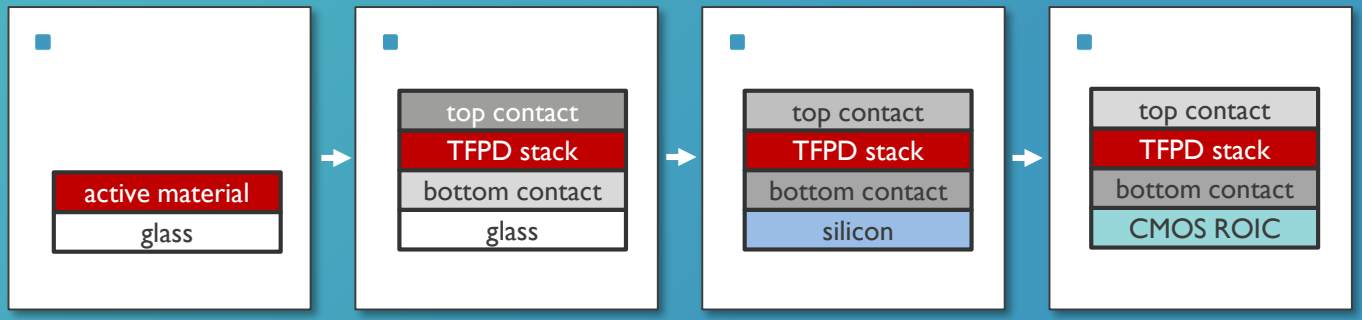
TUNING OF LAYER THICKNESSES WITH OPTICAL MODELLING



ADJUSTMENT FOR TOP ILLUMINATION

TUNING OF LAYER THICKNESSES WITH OPTICAL MODELLING

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silicon
top contact
TFPD stack
bottom contact
CMOS ROIC

OUTLOOK

FROM PIXEL STACK TO MONOLITHIC INFRARED IMAGER

- continuous screening of new materials
  - main focus on quantum dots
  - parallel tracks on OPD (polymers and small molecules)
- scaling up photodetector integration
- two options for the pixel array architecture:
  - VIS+NIR in one plane (enabled by OPD patterning)
  - monochrome NIR (towards 2 µm wavelength)
- dedicated readout circuit design and fabrication
  - to be continued at IISW2019!

THANK YOU!

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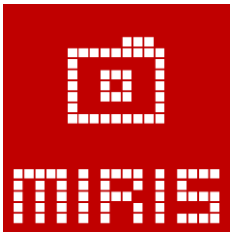

AGENTSCHAP INNOVEREN & ONDERNEMEN

Vlaanderen is ondernemen

imec

GHENT UNIVERSITY

imomec

embracing a better life

IMEC THIN-FILM PHOTODETECTOR TRACK RECORD

- P.E. Malinowski et al. „Monolithic Near Infrared Image Sensors Enabled by Quantum Dot Photodetector", **IISW 2017**
- E. Georgitzikis et al., "Determining charge carrier extraction in lead sulfide quantum dot near infrared photodetectors", **SPIE Nanoscience + Engineering 2017**
- D. Cheyns et al., "Infrared photodetectors based on lead-sulfide quantum dots", **MRS Spring 2017**
- F. De Roose et al. „A Flexible Thin-Film Pixel Array with a Charge-to-Current Gain of 59μA/pC and 0.33% Nonlinearity and a Cost Effective Readout Circuit for Large-Area X-ray Imaging", **ISSCC2016**
- G.H. Gelinck „X-Ray Detector-on-Plastic With High Sensitivity Using Low Cost, Solution-Processed Organic Photodiodes", **IEEE Transactions on Electron Devices 2016**
- A. Kumar et al. „High performance x-ray imaging detectors on foil using solution-processed organic photodiodes with extremely low dark leakage current," **SPIE Organic Photonics + Electronics 2015**
- F. De Roose et al. „Active Pixel Concepts for High-Resolution Large Area Imagers", **IISW 2015**
- G.H. Gelinck et al. „Flexible X-ray detector with high sensitivity using low cost, solution-processed organic photodiodes," **IISW 2015**
- P. E. Malinowski et al. „Organic Imager on Readout Backplane Based on TFTs With Cross-Linkable Dielectrics," **IEEE Photonics Technology Letters, 2014**
- P. E. Malinowski et al. „Photolithographic patterning of organic photodetectors with a non-fluorinated photoresist system," **Organic Electronics** 15 (10), 2014
- A. Kumar et al. „X-ray imaging sensor arrays on foil using solution processed organic photodiodes and organic transistors," **Proc. SPIE** 9137, Organic Photonics VI, 2014
- G. H. Gelinck et al. „X-ray imager using solution processed organic transistor arrays and bulk heterojunction photodiodes on thin, flexible plastic substrate," **Organic Electronics** 14 (10), 2013
- P. E. Malinowski et al. „Fully Organic Integrated Arrays on Flexible Substrates for X-Ray Imaging," **IISW 2013**