MONOLITHIC NEAR INFRARED IMAGE SENSORS ENABLED BY QUANTUM DOT PHOTODETECTOR

IMAGE SENSORS AT IMEC

VISIBLE AND NON-VISIBLE IMAGING

(multicolor) OPD

QD, OPD

hybrid OPD

CIS

x-ray

\( \lambda \) (nm)
NEAR INFRARED RANGE

APPLICATIONS

- see-through vision
- low-light imaging
- eye-tracking
- surveillance
- automotive

- night-glow vision
- eye-safe laser
NEAR INFRARED RANGE

INTEGRATION

**Hybrid / Flip-Chip**
- NIR, IR
- 1 MPx
- 14 μm pixel

**Monolithic**
- VIS
- >>10 MPx
- 0.9 μm pixel

λ (nm)

-.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0
NEAR INFRARED RANGE

MATERIALS

- PbS quantum dots
- polymers / small molecules (OPD)
- HgCdTe
- InGaAs
- Si

λ (nm)
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
COLLOIDAL QUANTUM DOT ABSORBER

150 NM THICK ACTIVE LAYER
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* > 10¹¹ JONES
PHOTODETECTOR STACK DEVELOPMENT

RISE TIME (10% TO 90%): ~12.5 \mu s

FALL TIME (90% TO 10%): ~51 \mu s
PHOTODETECTOR STACK DEVELOPMENT

PHOTO/DARK RATIO IMPROVEMENT AT LOW TEMPERATURE

193K PACKAGE AN OPTION FOR SPECIFIC APPLICATIONS

- IR LED illumination
- 40 dB
- 63 dB

QDPD on glass, IR LED
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

![Transmission vs Wavelength Graph](image)

- **Optimized**
- **Reference**

**Wavelength (nm)**
1100 1200 1300 1400 1500 1600 1700

**Transmission (%)**
20 30 40 50 60 70

*Transfer matrix method modelling*
ADJUSTMENT FOR TOP ILLUMINATION

TUNING OF LAYER THICKNESSES WITH OPTICAL MODELLING
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
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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embracing a better life
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