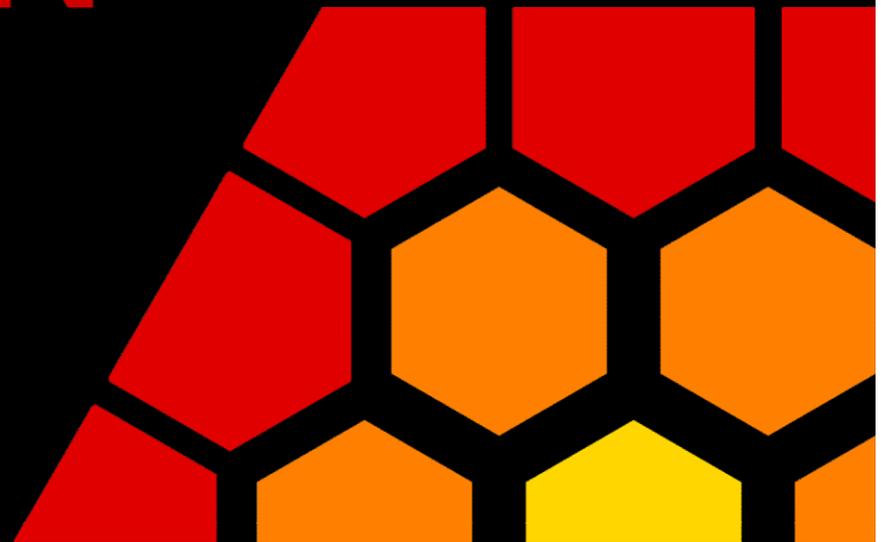


EMBERION

Broaden your Vision





Graphene-Based High Performance Infrared Photodetectors

Chris Bower
Research Director, Emberion Limited,
Cambridge, UK

Application Areas



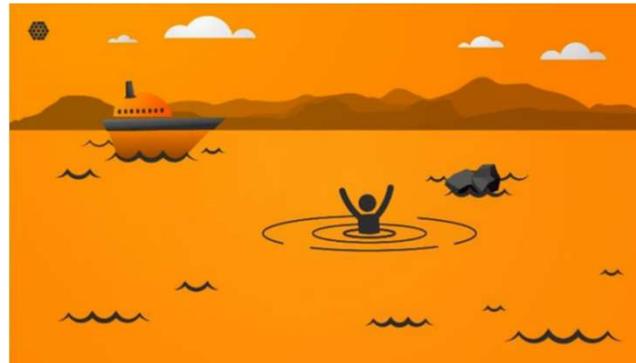
Automotive night vision



Thermal



Machine vision



Surveillance & hyperspectral imaging

© Emberion 2017



Emberion in a Nutshell

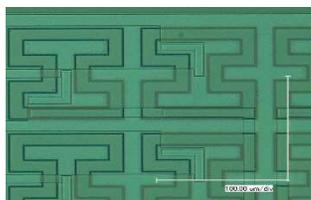
- Customer and application driven company
- Photodetectors and imagers for night vision, machine vision, spectroscopy, hyperspectral and X-ray imaging
- Venture capital funded spin-out from Nokia's R&D
- Operating in Cambridge, UK, and Espoo, Finland
- A team of 20 top experts with long experience in product development and applied research





Emberion Technology Palette

Graphene Transducers

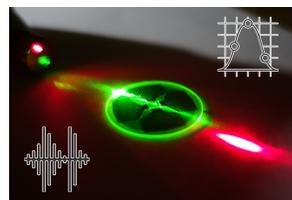


Ultrasensitive graphene charge transducer

Very large arrays of graphene transducers

Low noise detection

Photonic absorbers



Nanocrystalline broad spectrum photonic absorbers

Radiation absorbers for thermal cameras

Wide spectral range

Electronics integration



CMOS post-processed detector arrays – beyond VGA resolution

Integration of graphene detector arrays on polymer substrates

Scalable resolution

Imager modules

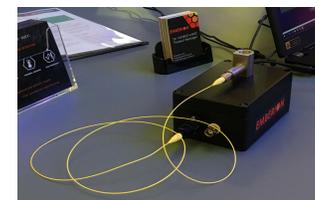


Image processing solutions based on efficient processing HW

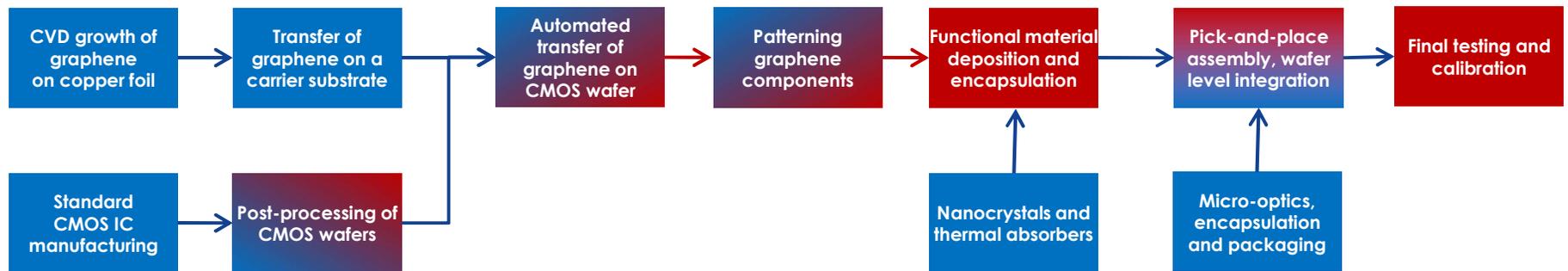
Mechanics and optics designed according to the application needs

Plug-and-play integration

Emberion's Semi-Fabless Manufacturing Flow



Emberion manages the whole production process through captive know-how and concentrates its resources on the most value adding parts of the process



Overall system design by Emberion through own captive know-how & IP



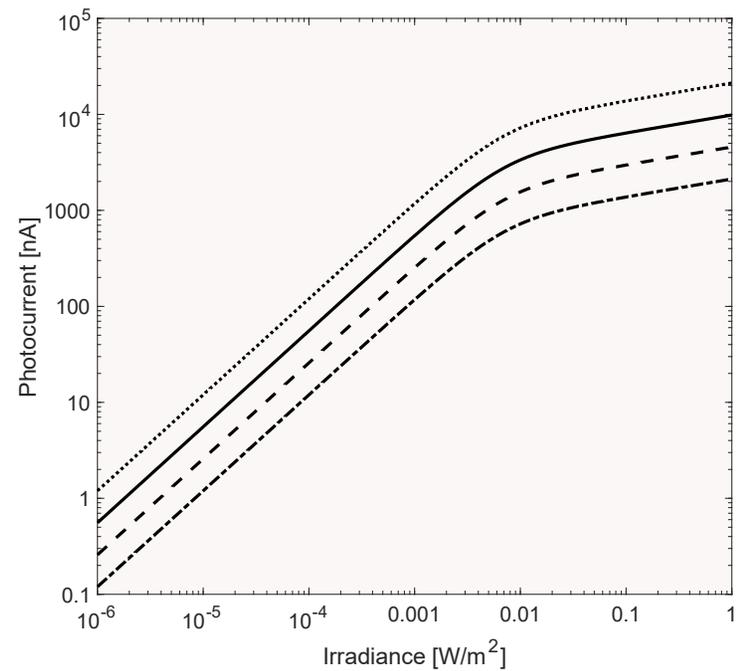
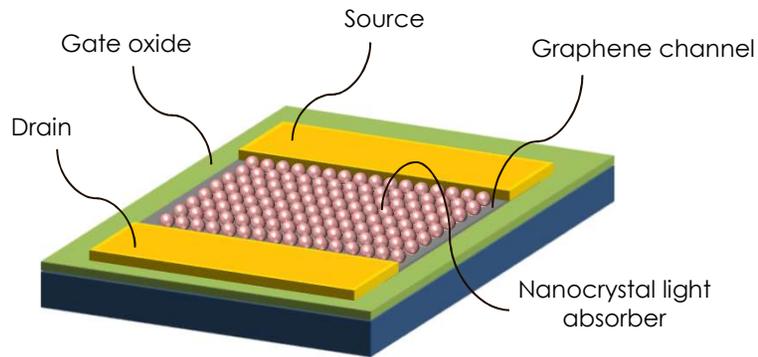
Why Graphene



	CMOS/Silicon	Graphene	Printed organic electronics	III-V semi-conductors
Electronics performance	✓	✓	X	✓
Large-area deposition	X	✓	✓	X
Flexible substrate	X	✓	✓	X
Low cost fabrication	✓	✓	✓	X
Heterogeneous integration	✓	✓	✓	X



Light-to-Charge Transduction



$$n_{\text{graphene}} \approx QE \cdot \tau \cdot \Phi_{\text{photon}}$$



Competitiveness of Emberion vis-SWIR Technology

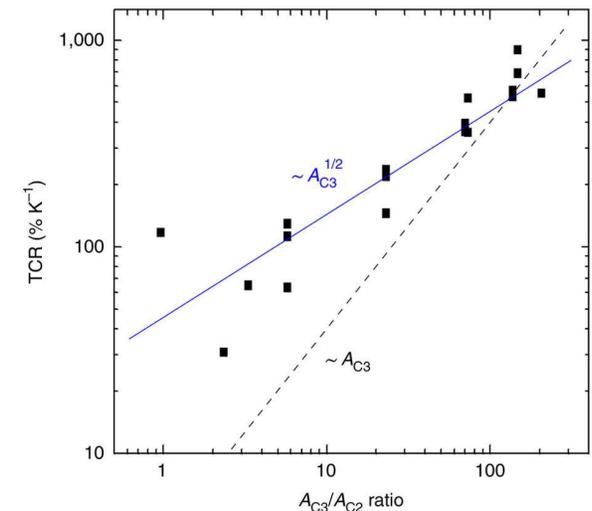
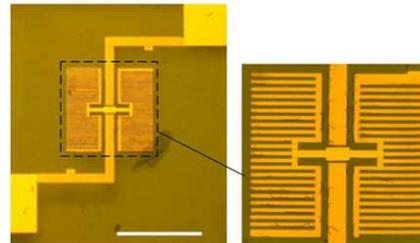
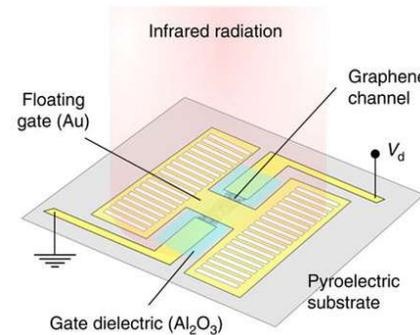
Customer requirements	InGaAs	CMOS	QD diodes	Emberion
Dynamic range; no saturation; anti-blooming				
Low noise, low light performance (extreme night vision)				
Low cost, scalable integration on readout electronics				
Large wavelength range (vis - 2000 nm)				
High video frame rate image capture (> 100 Hz)				



Room Temperature MIR Sensing

Thermal imaging

- Unique combination of pyroelectric detector with a graphene bolometer – 'graphene-based pyroelectric bolometer' leads to TCR up to 900% K⁻¹ (300x300μm²)
- 'H' shaped gate of a GFET is in direct electrical contact with the PZT layer so that charge in the PZT layer is amplified by the GFET
- There is no load resistor so the device operates in direct current mode so does not need an optical chopper
- Uncooled sensitivity <15mK
- Tunable & Selective (Multispectral in one chip) MWIR to LWIR (absorption layer controlled)
- $\pm 0.15^\circ\text{C}$ - Excellent temperature resolution



$$\text{TCR}(R_0) = \frac{1}{R_0} \cdot \frac{dR}{dT} = - \frac{1}{I_0} \cdot \frac{dI}{dT}$$

Where are we today?



Strong value proposition tested with several key players in the selected business verticals

- Graphene sensor technology platform enables integration of high performance photodetectors and other sensors on CMOS and flexible electronics systems

Working for **customer commitment and validation**

- Building on customers' needs and requirements
- Technology maturity to demonstrate our value proposition and to provide samples for customers' R&D and validation processes

We have **an excellent R&D network** that builds a value chain

- Key suppliers and subcontractors
- Local collaborations in Finland and UK
- Graphene Flagship community has been very valuable for us



EMBERION

www.emberion.com

