



# Semi-fabless manufacturing of graphene enhanced SWIR image sensors

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# Emberion Oy

High-performance infrared imaging products for a broad wavelength range from visible light to LWIR

- First products for vis-SWIR range imaging for spectrometry, night and machine vision
- Broadband imagers offer unforeseen opportunities for hyperspectral imaging

Spin-off from Nokia, based on Nokia's long-term research in the EU Graphene Flagship

- Co-founded in 2016 by employees and two VC Funds managed by a Finnish VC Verso Capital Oy

A team of 26 top experts representing a unique combination of skills and experience:

- Nanomaterials and sensor development in Cambridge, UK
- Electronics and system design in Espoo, Finland

Leadership in top-notch industrial R&D programs

- Spearhead project leader in EU Graphene Flagship project and working with the Graphene Foundry project
- Established business relationships with CMOS foundries
- Working with AMO (University of Aachen), Graphenea, Cambridge University and VTT



# Emberion VIS-SWIR Products



## Cameras:

### VGA camera

- For night and machine vision applications, hyperspectral imaging and medical imaging
- Versatile camera system designed and optimized for Emberion high-performance image sensors – ready for various machine vision applications
- Available: August 2020



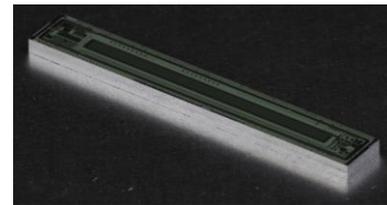
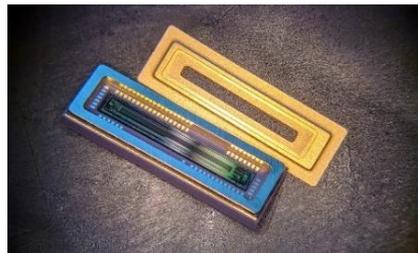
## Image sensors:

### VGA sensor array of $640 \times 512$ pixels

- For night and machine vision applications, hyperspectral imaging and medical imaging
- Single-chip digital imaging sensor for VIS-SWIR
- Available: August 2020

### Linear array of 512 pixels

- For diffraction spectrometry, gas detection, line scan camera applications & medical diagnostics
- Single-chip digital photodetector array for VIS-SWIR
- Available: January 2021

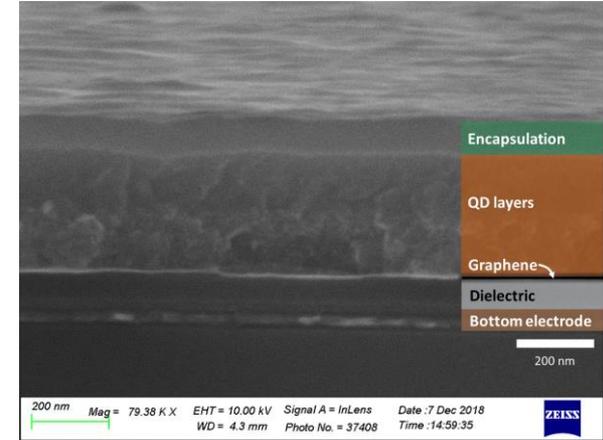
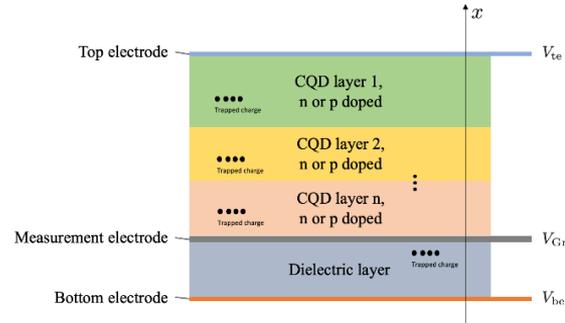


# VIS-SWIR Detector Technology



## Technology in brief

- Ultra-sensitive image sensors based on a layered colloidal quantum dot and graphene photodiodes
- Broad wavelength range (400 - 2000 nm) achieved by careful engineering of the light absorber layers
- Photosensitive layers are monolithically integrated on optimized CMOS readout IC: both linear array and VGA sensor configurations



## Unique benefits

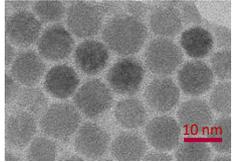
- Broad and tailorable spectral range
- Low noise (NEP, NEI)
- Large dynamic range
- Scalable pixel size
- Cost efficient manufacturing

# What makes our products unique



Emberion owns unique competence to integrate leading-edge materials science into skillful engineering of integrated circuits, camera electronics and optical systems.

Emberion's innovative products are based on:



- 1) Low cost manufacturing of new nanocrystalline photon absorber layers** monolithically on complex CMOS wafers. Nanocrystalline materials enable broad wavelength range: 400-2500 nm & 3000-5000 nm.

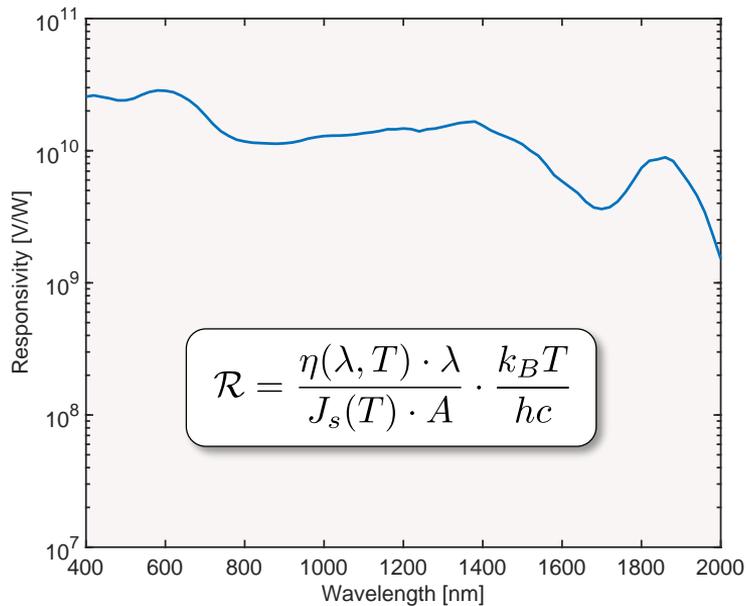


- 2) High performance readout electronics** based on Emberion's patented measurement principle. Our CMOS integrated readout electronics enable low power consumption and high frame rate necessary for machine vision.



- 3) Use of 2D graphene in image sensor pixels** enable extreme simplification of the fabrication process together with significant improvements in noise performance and stability, enabling operation at higher temperatures.

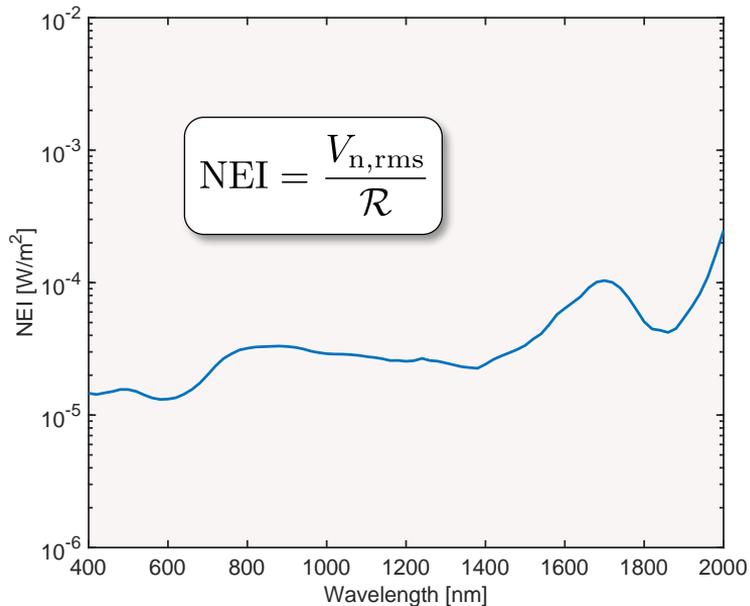
# Wavelength Dependency



$$T = 0^\circ\text{C}$$

$$A = 20 \times 20 \mu\text{m}^2$$

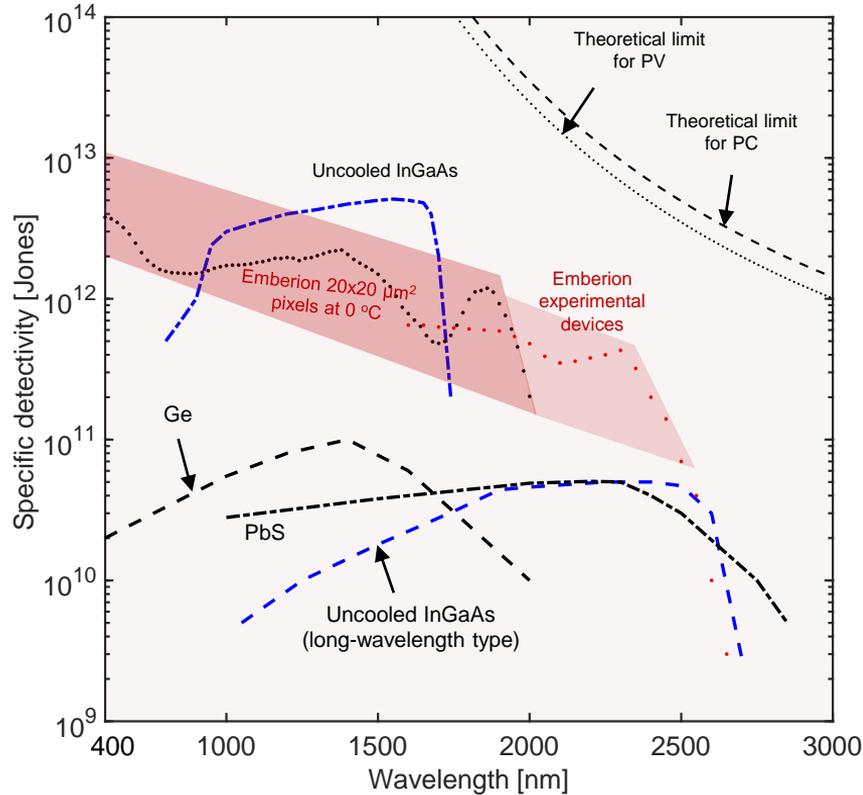
$$J_s(0^\circ\text{C}) = 5 \cdot 10^{-5} \frac{\text{mA}}{\text{cm}^2}$$



$$V_{n,\text{rms}} = 150 \mu\text{V}$$

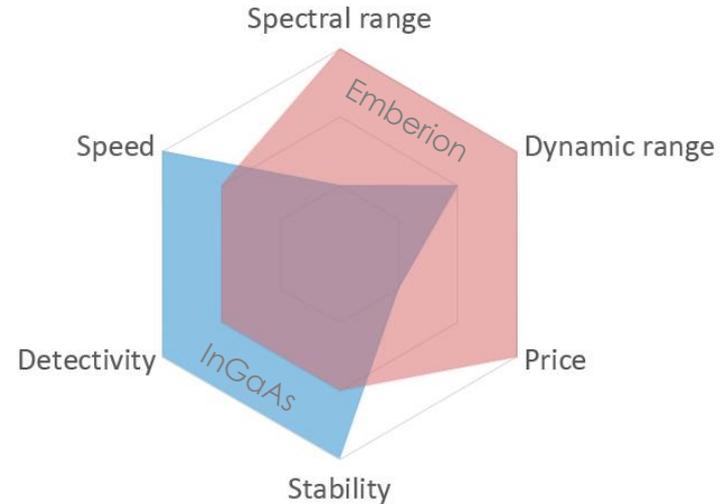
(Input referred total voltage noise)

# Emberion 20x20 $\mu\text{m}^2$ pixel detectivity



Our VIS-SWIR 20x20  $\mu\text{m}^2$  pixels show high detectivity over large wavelength range. Their performance at wavelengths above 1750 nm is superior.

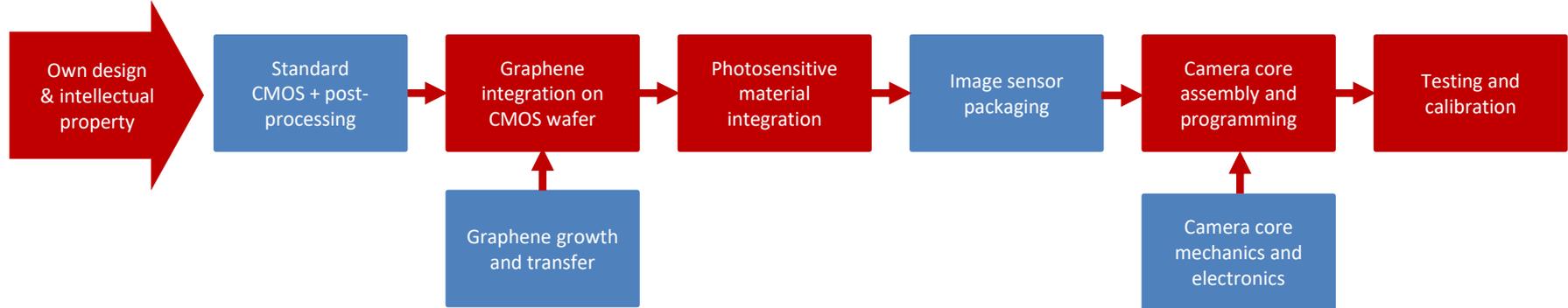
Typical measured detectivity of a 20x20  $\mu\text{m}^2$  pixel using 100 ms exposure time is shown as dots inside the shaded area depicting achievable range.



# Semi-Fabless Manufacturing



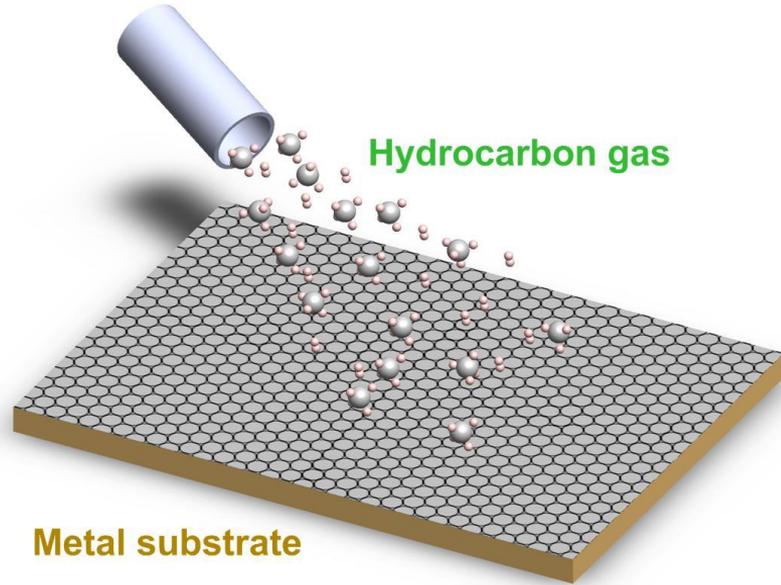
- **Semi-fabless operation:** We utilize subcontractors for various established manufacturing steps but keep all the **performance critical steps in house**
- Emberion manages the whole manufacturing process through its captive know-how and IPR and concentrates own resources on the new value adding processes
- Overall system design by Emberion



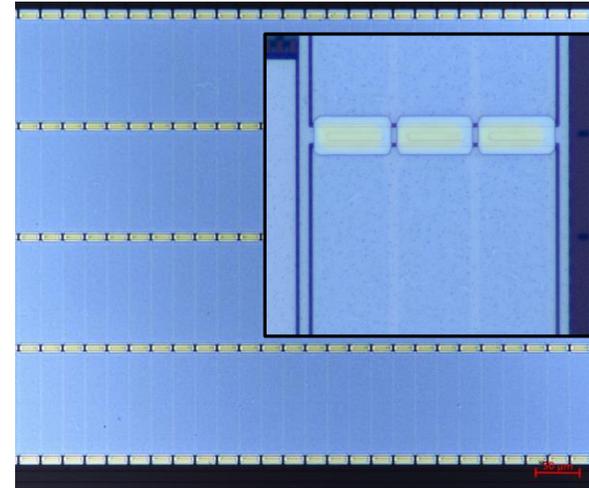
# Two Phases of Graphene Fabrication



2D molecular graphene layer is grown on catalytic copper surface



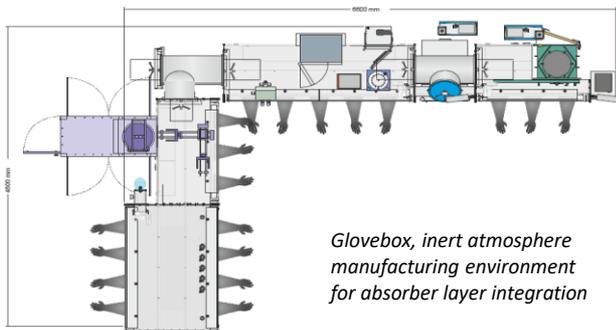
Graphene is transferred onto a planarized CMOS wafer using polymer carrier film



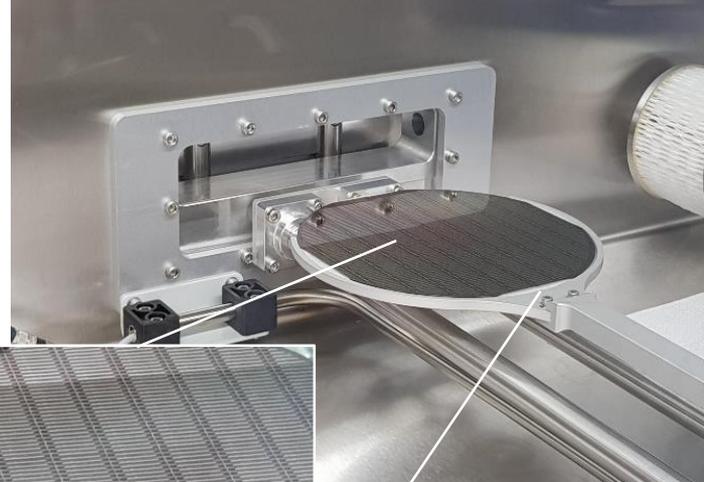
*Graphene electrodes on Emberion's 512-pixel linear array image sensor*

# Cambridge Pilot Manufacturing Line for Absorber Integration

- Capability of 500 image sensors per month in 2020
- Functionalization of 5-10 CMOS wafers per week in 2021
- Scalable to volume of 200 image sensor per day by 2022



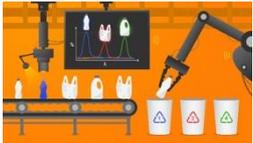
*Glovebox, inert atmosphere manufacturing environment for absorber layer integration*



# Emberion's Mission



Emberion's short-wave and mid-wave infrared (SWIR, MWIR) cameras provide a solution for various applications driven by machine vision and artificial intelligence:



- 1) Our significantly wider spectral information in **industrial machine vision systems** enables broader use, new applications. Affordable SWIR & MWIR cameras enable plastic waste sorting in a big way – incl. black plastics.



- 2) Our low noise SWIR & MWIR performance enable excellent situational awareness in **demanding surveillance, defense, port & border security**. Extreme long-range visibility through fog, smoke, rain, snow & darkness.



- 3) Our low manufacturing cost enables eventual integration of SWIR&MWIR cameras into **level 4 & 5 autonomous vehicles**. Vision through fog and rain together with situational awareness are needed for safety and comfort.



- 4) Our miniature, high performance SWIR image sensors enable accurate and fast **medical imaging and diagnostics**. SWIR imaging can be used for eye inspection, endoscopy, skin cancer and caries diagnostics.

**EMBERION**

[www.emberion.com](http://www.emberion.com)



# This presentation was presented at EPIC World Photonics Technology Summit 2020

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