Semi-fabless manufacturing of graphene enhanced SWIR image sensors

Dr. Tapani Ryhänen
CEO, 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 × 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

\[ \mathcal{R} = \frac{\eta(\lambda, T) \cdot \lambda}{J_s(T) \cdot A} \cdot \frac{k_B T}{hc} \]

\[ T = 0 \, ^\circ C \]
\[ A = 20 \times 20 \, \mu m^2 \]
\[ J_s(0 \, ^\circ C) = 5 \cdot 10^{-5} \, mA/cm^2 \]

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

(Input referred total voltage noise)
Our VIS-SWIR 20x20 μm² pixels show high detectivity over large wavelength range. Their performance at wavelengths above 1750 nm is superior.

Typical measured detectivity of a 20x20 μm² 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
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
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 eventually 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.
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