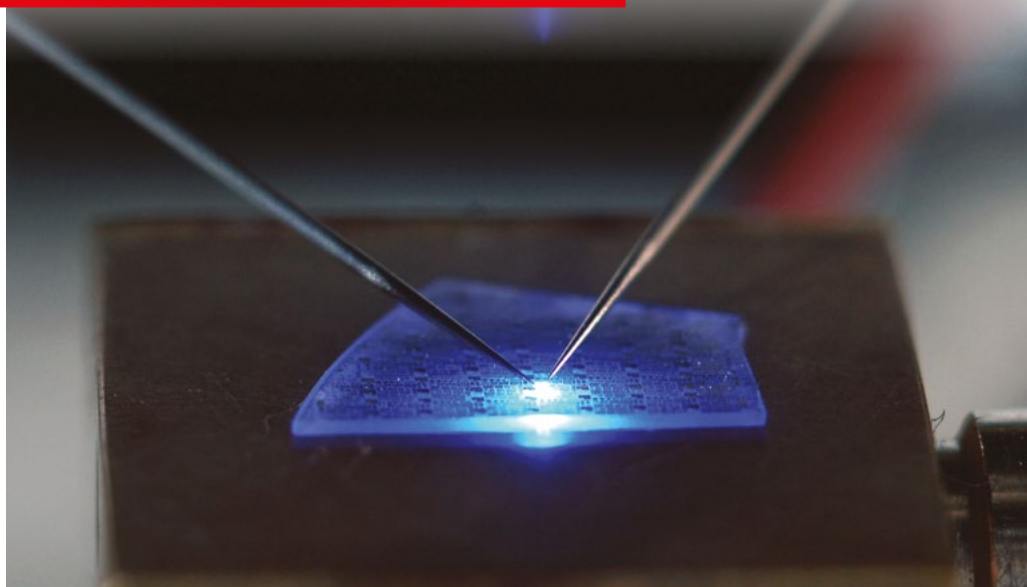


leti
cea tech

MICRO-LED ARRAYS

Tomorrow's smart lighting
and display technology



Leti, technology
research institute

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Micro-LEDs: Next generation for smart lighting, displays and optical communications

The next generation of smart lighting products will better control lighting intensity, shape, direction and color by integrating pixelated light sources, while display applications will be more energy efficient. GaN micro-LED technology fulfills both these projections by combining the efficiency of GaN LED direct emission and potential for manufacturing few micron size LEDs.

**Key requirements:
More brightness & Smallest pitch**
Micro-LED arrays meet both requirements resulting in high performance, low consumption, compact products.



DISPLAY

Projection, flexible, transparent, head-up & head-mounted displays

- More pixels
- Energy saving
- Brighter
- Better image quality: contrast, color saturation (true red, true green, true blue), view angle
- Robust
- More functionalities: transparent screens, foldable screens, autonomous energy harvesting

SMART LIGHTING

Automotive lighting, outdoor lighting, indoor lighting, etc.

- Better use of time, space & intensity
- Non-visual effects
- Health and wellness
- Better light usage by spatial, intensity, data and color control

OPTICAL COMMUNICATIONS

More than light: visible light communication

- For high performance computing
- Chip to chip interconnects
- Modulation bandwidth up to 1.8 GHz
- Already existing dense micro-LED infrastructure and know-how

CEA-LETI'S COMPLETE MICRO-LED ARRAY PROCESS

LETI'S VALUE PROPOSITION EMBRACES A COMPLETE DESIGN TO SYSTEM CHAIN

CHALLENGES

GaN pixelization

- Auto aligned process for optimizing process flow
- Pitch reduction: down to ~1 μm
- Planar interfaces for optimizing hybridization

Hybridization

- Wide hybridization portfolio
- Cold process: micro-tubes for hybridization down to 10 μm pitch
- Direct heterogeneous bonding for smaller pitch down to 1 μm
- Metal/metal or oxide/oxide direct bonding

Color conversion

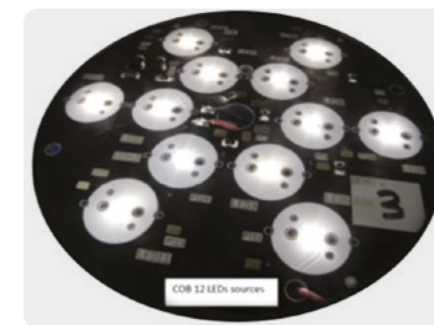
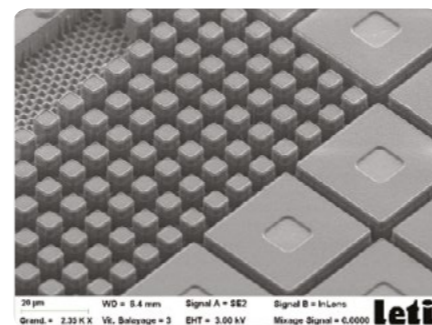
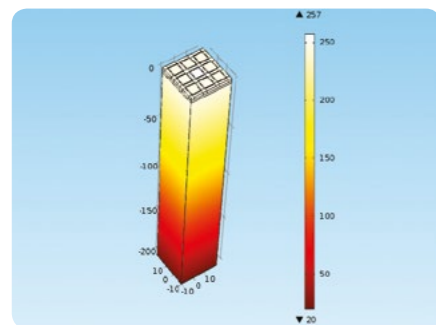
- Quantum dots
- 2D Quantum wells
- Nano grain phosphors

Thermal packaging

- Thermal resistance reduction
- ASIC thinning
- TSV

Active matrix

- High current active matrix fabrication



DESIGN & SIMULATION

- Ray tracing
- Semiconductor structure simulation: Silvaco
- Multiphysics simulations: Comsol
- Light extraction tools

MATERIALS & SUBSTRATES

- LED structure growth on Sapphire or other substrates
- MOCVD growth
- GaN nanowire growth
- Epitaxy on patterned substrates
- Semipolar growth

PROCESS/DIES

- Advanced LED process: VTF, TFFC
- LED array process: pixelation down to 3 μm pitch
- IC silicon active matrix for LED driving
- 10 μm pitch or less connectors
- 3D heterogeneous integration
- Bonding of LED arrays on CMOS active matrices

DEVICES

- High voltage LED chips
- Chip scale packages
- Microdisplays

MODULE

- Smart drivers
- Chip on board
- Smart sensors with embedded electronics

SYSTEMS

- Smart lighting systems:
- Lifi (new advanced communication system)
- Optical Systems:
- Head Mounted displays (HMDs)
 - Head Up Displays (HUDs)

INFRASTRUCTURE

Four InGaN MOCVD epitaxy reactors dedicated to R&D and industrial process development.

Full process line dedicated to III-V compound semiconductors from 2" to 12" wafer (wafer thinning & bonding, etc.)

Device simulation & characterization platform tools: goniometer, light spectrum emission diagram, infrared thermography, etc.

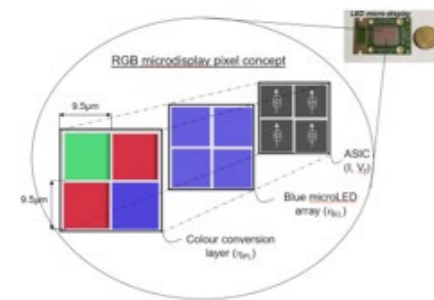
Pilot line for LED die packaging: various technologies (chip to case, chip to wafer, wafer to wafer), LED matrix hybridization, etc.

MICRO-LED TECHNOLOGY EXAMPLES



CEA-LETI MICRO-LED TECHNOLOGY CAPABILITIES FOR YOUR APPLICATION REQUIREMENTS

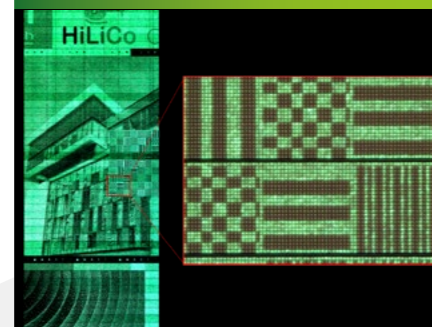
MICRO-LED DISPLAYS



Building blocks for micro-LED displays

- Modelling to predict reachable white light with respect to ASIC capabilities, blue colour micro-LED efficiency and colour conversion
- ASIC design
- microLED technology
- Colour conversion
- E. Quesnel et al., J Soc Inf Display. 2020;1-14.

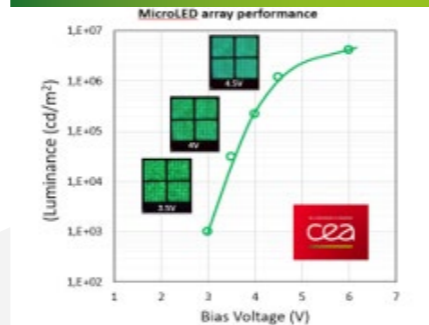
MICRO-LED ARRAY EXAMPLE



CEA-Leti's process flow on 200 mm wafer line

- Green epitaxy on Sapphire 100 mm or Si 200mm.
- 1750 × 1200 pixels at 9.5 µm pitch
- Array size: 11.4 mm x 16.6 mm
- Clean Sky 2 JU H2020 HILICO project

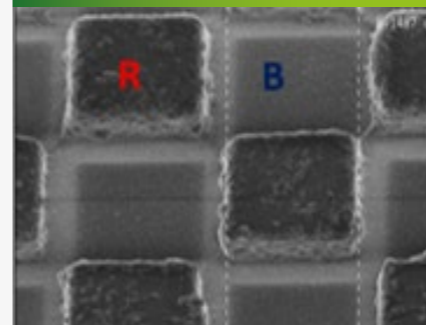
1,000,000 NITS PIXEL ARRAYS



Exceptionally high luminance

- Luminance assessment of Green micro-LED pixel arrays
- Up to 1,000,000 nits green emission!

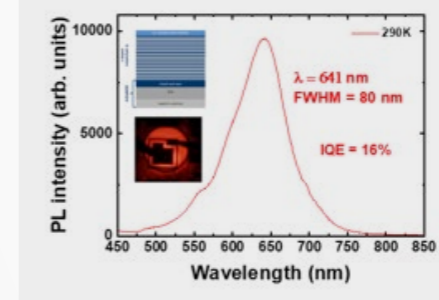
COLOR CONVERSION



Evaluation of colour conversion solutions

- Colour conversion nanoplatelets in solution
- Deposition with photresist
- Red pixel integration on a blue micro-LED pixel array
- Red pixel emission assessment at wafer of 80 individual passive displays
- E. Quesnel et al., Optics Express 20498, Vol. 29, 13 / 21 June 2021

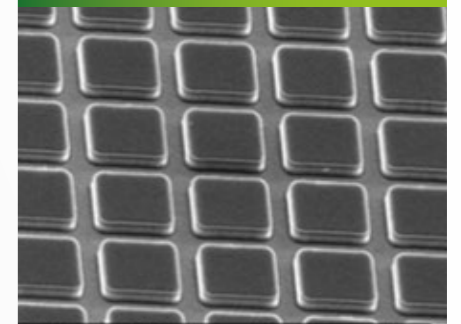
NATIVE COLOUR RED MICRO-LED



Red micro-LED demonstration

- The full InGaN structure is used to realise red light emitting diodes (LEDs).
- This LED structure is composed of a partly relaxed InGaN pseudo-substrate fabricated by Soitec, namely, InGaNOS.
- A. Dussaigne et al, Journal of Applied Physics 128, 135704 (2020)

VISIBLE LIGHT COMMUNICATION



Blue micro-LED for communication

- GaN 10-µm pitch
- Wireless optical link with throughput up to 7.7 Gb/s with DCO-OFDM
- A modulation bandwidth of 1.8 GHz
- L. Maret et al, Optical Wireless Communication Conference (2022)





ABOUT LETI

Leti is a technology research institute at CEA Tech and a recognized global leader in miniaturization technologies enabling smart, energy-efficient and secure solutions. Committed to innovation, its teams create differentiating solutions for Leti's industrial partners.

By pioneering new technologies, Leti enables innovative applicative solutions that ensure competitiveness in a wide range of markets. Leti tackles critical, current global issues such as the future of industry, clean and safe energies, health and wellness, safety & security...

Leti's multidisciplinary teams deliver solid micro and nano technologies expertise, leveraging world-class pre-industrialization facilities.

For 50 years, the institute has been building long-term relationships with its industrial partners providing tailor-made solutions and a clear intellectual property policy.

Leti, technology research institute

Commissariat à l'énergie atomique et aux énergies alternatives

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