

Who will benefit from micro LEDs with new generation GaN-on-Si?

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CONNECT

Outline

- Introducing ALLOS
- GaN-on-Si for (conventional) LEDs
- GaN-on-Si for micro LEDs
- Conclusions

Introducing ALLOS

ALLOS is all about GaN-on-Si

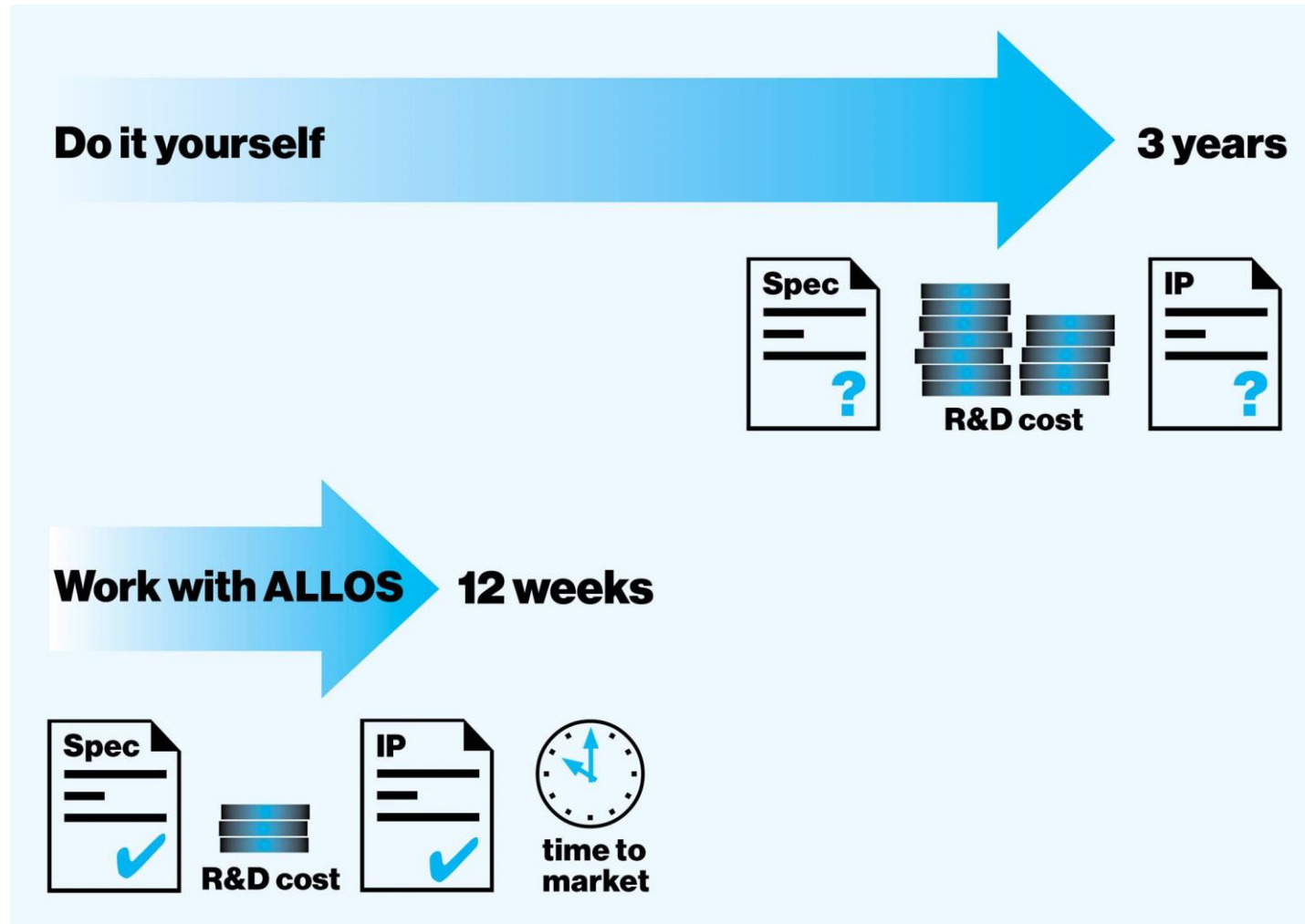
**ALLOS is a fabless
IP licensing and
technology company**

**We are enabling our
customers to master
GaN-on-Si on 150 and
200 mm wafer diameter**

**Based on 18 years track
record at University
Magdeburg and our
predecessor company
AZZURRO**

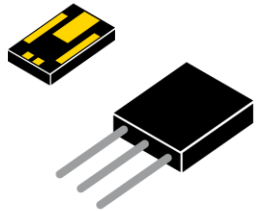
**We are continuously
developing our
epiwafer technology to
stay ahead**

Turn-key technology transfer ensures that customers can achieve their objectives in GaN-on-Si quickly and safely



ALLOS' leading GaN-on-Si epiwafer technology is available for all four major market segments

HPE



GaN-on-Si enables more efficient high power electronic devices out of silicon lines

RF



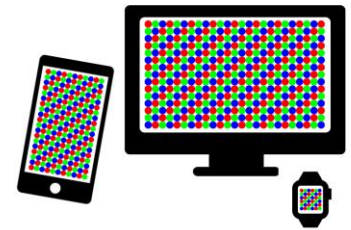
GaN-on-Si provides higher performance and lower cost for RF devices

LED



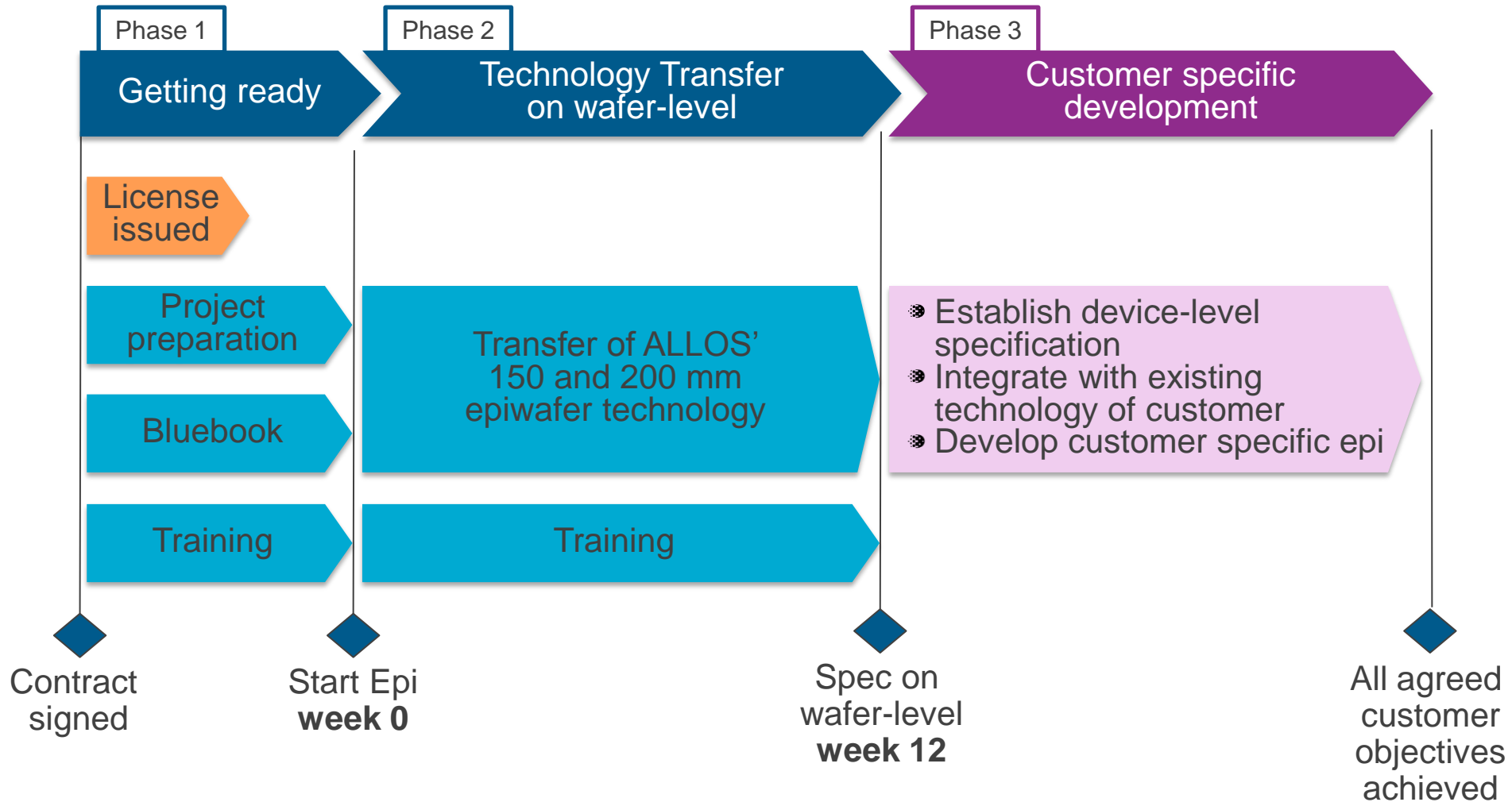
GaN-on-Si is a niche today but very high cost saving potential remains attractive for the future

Micro LED



Only GaN-on-Si can deliver the super-uniform, CMOS-compatible large epiwafers needed for micro LEDs

Customer project example for license & technology transfer



GaN-on-Si for (conventional) LEDs

Why is GaN-on-Si only a niche in conventional LEDs?

GaN-on-Si has no advantages on existing 2” and 100 mm processing lines

- Similar quality like GaN-on-sapphire is possible but difficult
- Eroding sapphire prices, lowered growth time by PSS, etc. reduced the GaN-on-sapphire disadvantages on epiwafer level

GaN-on-Si requires many changes to LED making

- Only feasible with thin-film flip-chip LED technology
- Full cost benefit is only realized with WLCSP

Investment in cost-efficient 200 mm line is too big for any pure LED maker

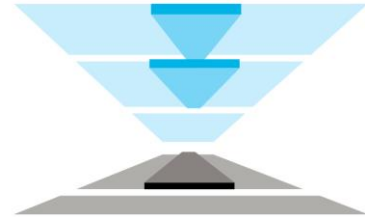
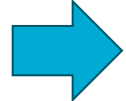
- 200 mm GaN-on-Si epiwafers can be processed in existing CMOS lines
- A single large scale CMOS line could process over 1.6 million 2” wafer equivalents per month representing more than 20 % of LED capacity today

Partnering with a 200 mm foundry requires volume and commitment

- 200 mm foundries want to see sustainable long-term business opportunity
- Becomes attractive when market grows and internal capacity needs extension

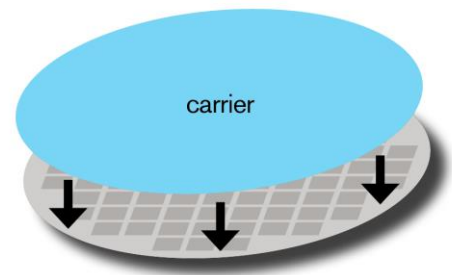
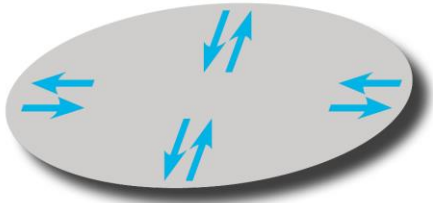
GaN-on-Si enables efficiency gains in process steps after epitaxy

Excellent manufacturability



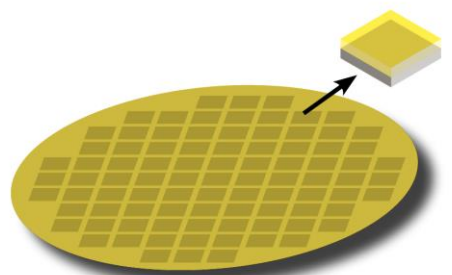
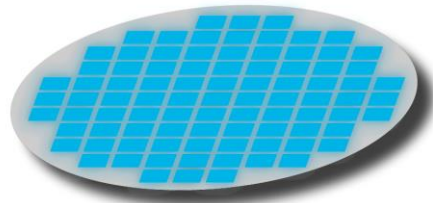
Usage of 200 mm silicon processing lines

Controlled bow by strain-engineering



Thin-film LED bonding is more efficient with flat epiwafers

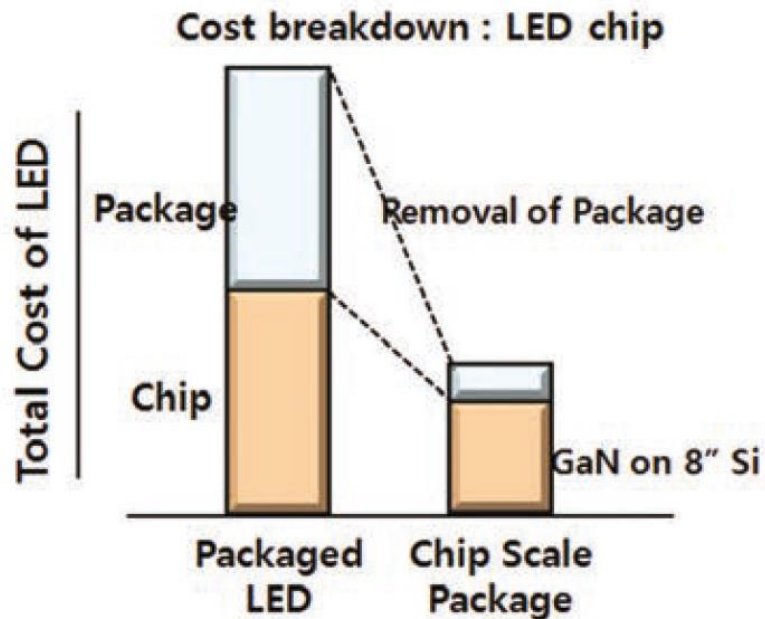
Superior wavelength uniformity



High-yielding wafer-level chip-scale packaging

Samsung sees over 60 % cost saving potential

Samsung's cost model for 200 mm GaN-on-Si LED*



- Samsung projects that moving from 100 mm on-sapphire to 200 mm on-silicon can save more than 60 % of cost
- WLCSP reduces packaging cost by more than 80 %
- Using 200 mm silicon lines for LED production saves 50 % of chip cost



Who will be the first to move to this attractive new cost curve?

* Samsung in Compound Semiconductor Magazine 03/2016

GaN-on-Si for micro LEDs

Why are we in this room looking at micro LEDs?

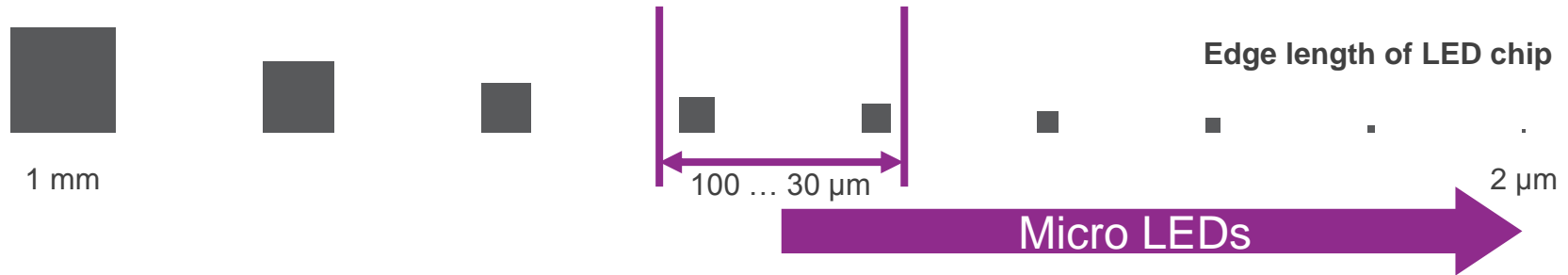
Consumer benefits

- Longer battery life for mobile devices
- Higher resolution display
- Better color and black level
- Display readable in sunlight
- Added functionality like integrated finger print and other sensors

Industry benefits

- New application and new market for LED companies and
- ... semiconductor companies and
- ... transfer technology providers
- For display companies it is an alternative to the OLED “duopoly”
- Huge (!!) market opportunity

What turns a LED into a micro LED?



→ Its size! Micro LEDs are really much much smaller than conventional LEDs!

And they come in the millions – for each consumer device!

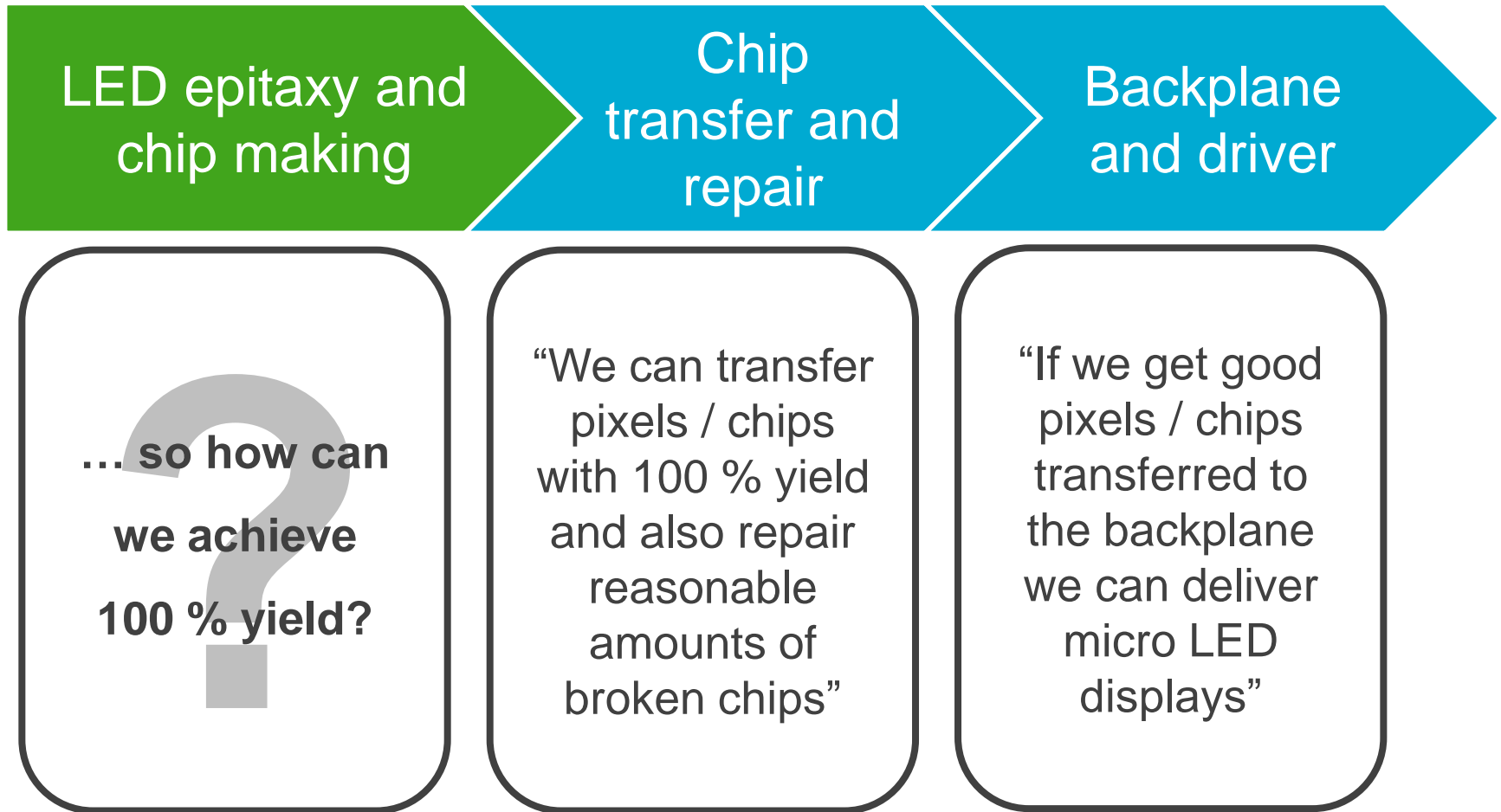
→ Micro LEDs will require a quantum leap in the way LEDs are manufactured!

Why do micro LEDs require a quantum leap in manufacturing?

- A simple full HD display has 1920 x 1080 pixel (= 2,073,600)
- Using RGB will require more than 6,000,000 micro LED chips
- Today consumers do not accept pixel errors

Achieved yield translating into amount of pixels failing
90.00000%	622,080.00
95.00000%	311,040.00
99.00000%	62,208.00
99.90000%	6,220.80
99.99000%	622.08
99.99900%	62.21
99.99990%	6.22
99.99999%	0.62

Who is enabling the micro LED industry?



Comparing the suitability of the LED and silicon industry for high yield and cost-efficient micro LED production

LED industry status today

- 2" and 100 mm dominant
- Bad uniformity and yield
- Processing equipment not suitable for micro LED
- Batch processes
- No sufficient cleanrooms
- Used to binning

Silicon industry status today

- 200 and 300 mm in huge volumes
- Incredible uniformity and yield
- High resolution lithography and other equipment available
- Single wafer processes
- Cleanroom class 100 and higher
- All tuned for "1 bin"

Comparing the suitability of the LED and silicon industry for high yield and cost-efficient micro LED production

LED industry status today

- 2" and 100 mm dominant
- Upgrade**
- Bad uniformity and yield

- Processing equipment not suitable for micro LED

- Batch processes
- Upgrade**
- No sufficient cleanrooms

- All tuned for "1 bin"

Outsource
to existing
silicon lines

Adapt
philosophy

Silicon industry status today

- 200 and 300 mm in huge volumes
 - Incredible uniformity and yield
 - High resolution lithography and other equipment available
- Can be used as it is**
- Single wafer processes
 - Cleanroom class 100 and higher
 - All tuned for "1 bin"

What you need to “upgrade” LED epitaxy for micro LED

- **Utilize existing resources**

- Advanced LED epitaxy know-how and IP
- Deploy thin-film flip-chips with high efficiency at (super) low driving currents
- Use existing epitaxy facility with upgraded cleanroom class

- **Apply the right epitaxy technology (“software”)**

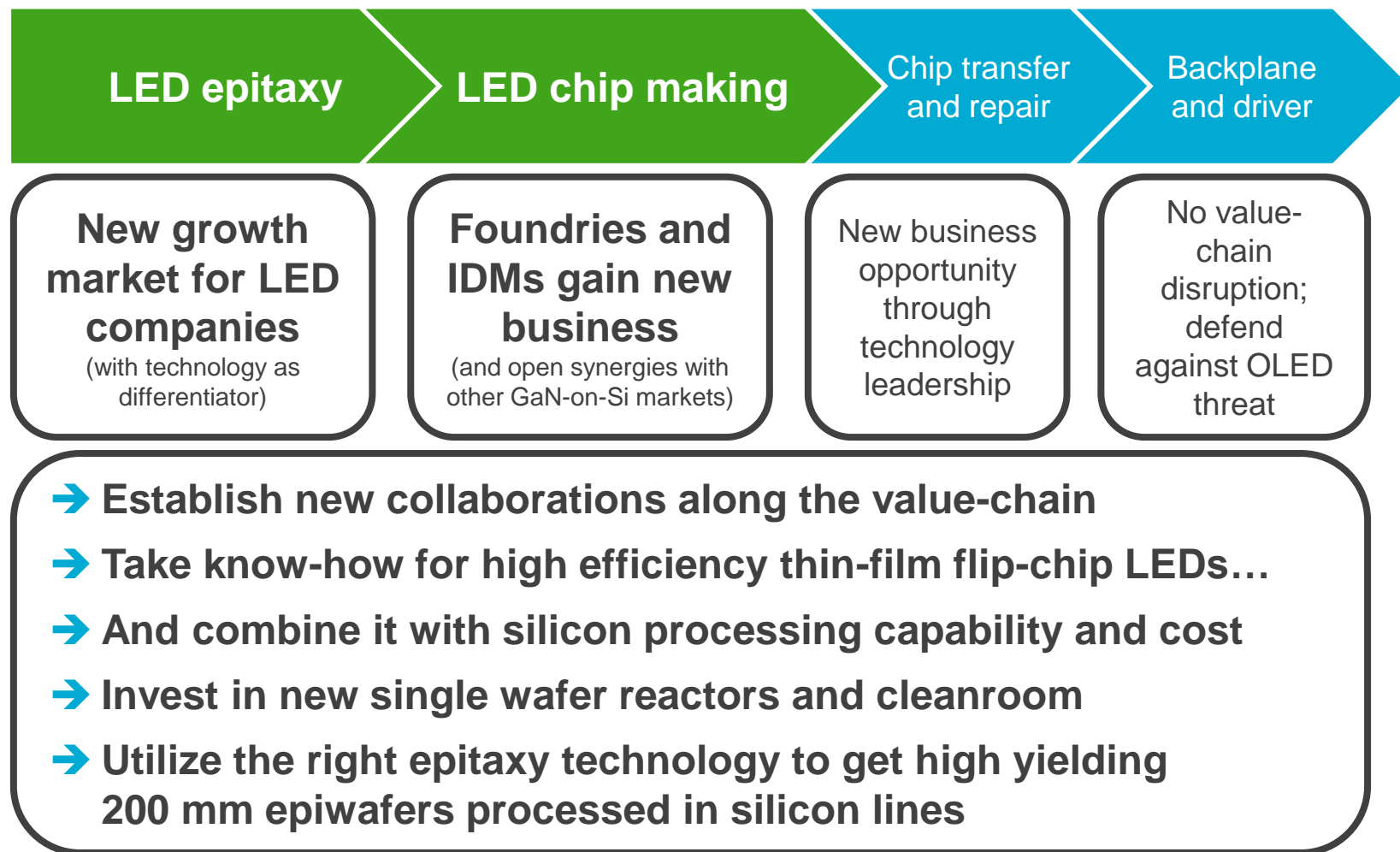
- True “1 bin” super-uniformity to achieve required yield level
- Enable 200 mm diameter (and 300 mm next)
- Ready for processing in silicon lines: No cracks, no bow, no meltback, etc.
- High crystal quality for best possible LED performance
- All the above is only possible with GaN-on-Si

- **Take advantage of the new reactor designs (“hardware”)**

- Single wafer growth chamber for breakthrough reproducibility and yield
- Novel single wafer reactor designs for low cost of ownership

Conclusions

Only GaN-on-Si can enable the micro LED market opportunity for everybody to benefit



Thank you very much for your attention!

I am happy to take any questions now or after the session and please contact me for any enquiries you may have:

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