Content :

New substrate for GaN (QST®)

26/Apr/2024
SEH Europe Ltd.   A.Tamura

Introduction

Shin-Etsu Chemical Group position in the World

Shin-Etsu

Not visible for anybody, but

From Shin-Etsu Chemical Website

Shin-Etsu Everywhere!!!

ShinEtsu Handotai → SEH
(Handotai stands for Semiconductor in Japanese)

Presentation for Incize 10yr anniversary Apr/2024

GaN on QST Introduction

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1. Introduction

GaN: excellent material

・high breakdown voltage and high switching frequency,

Substrates for epitaxial

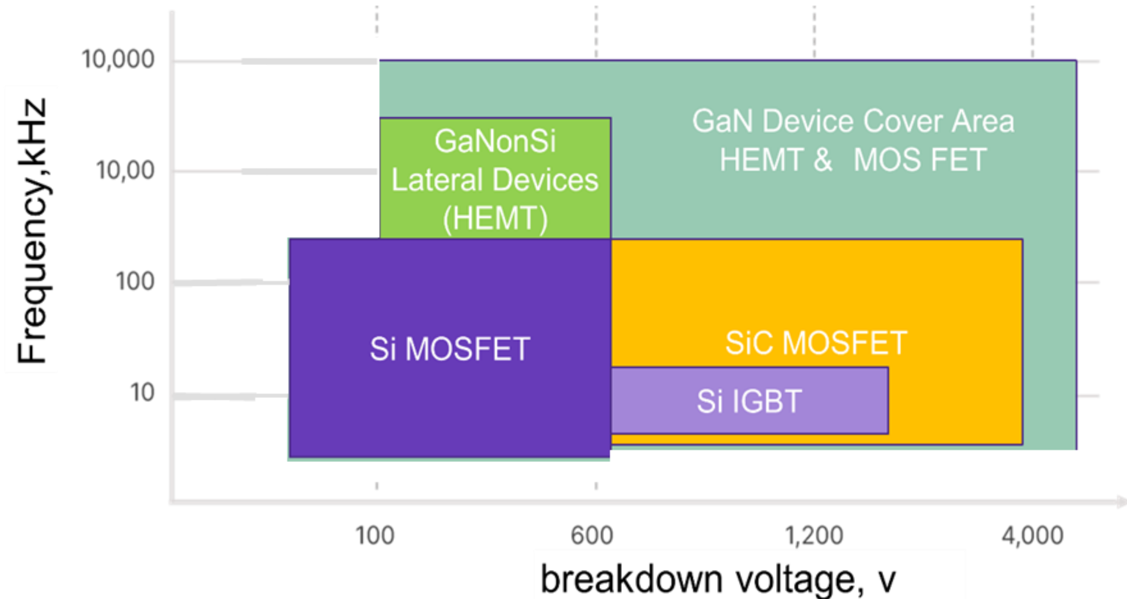
・Bulk GaN : Diameter less than 6“ ⇒ **very expensive**

・Other substrates: Si, Sapphire, SiC

The GAP in coefficient of thermal expansion**(CTE)** ⇒**Thick epitaxial is not possible**

Substrates to solve this problem

QST® is proposed as a composite substrate that enables the world of true GaN



QST® ???

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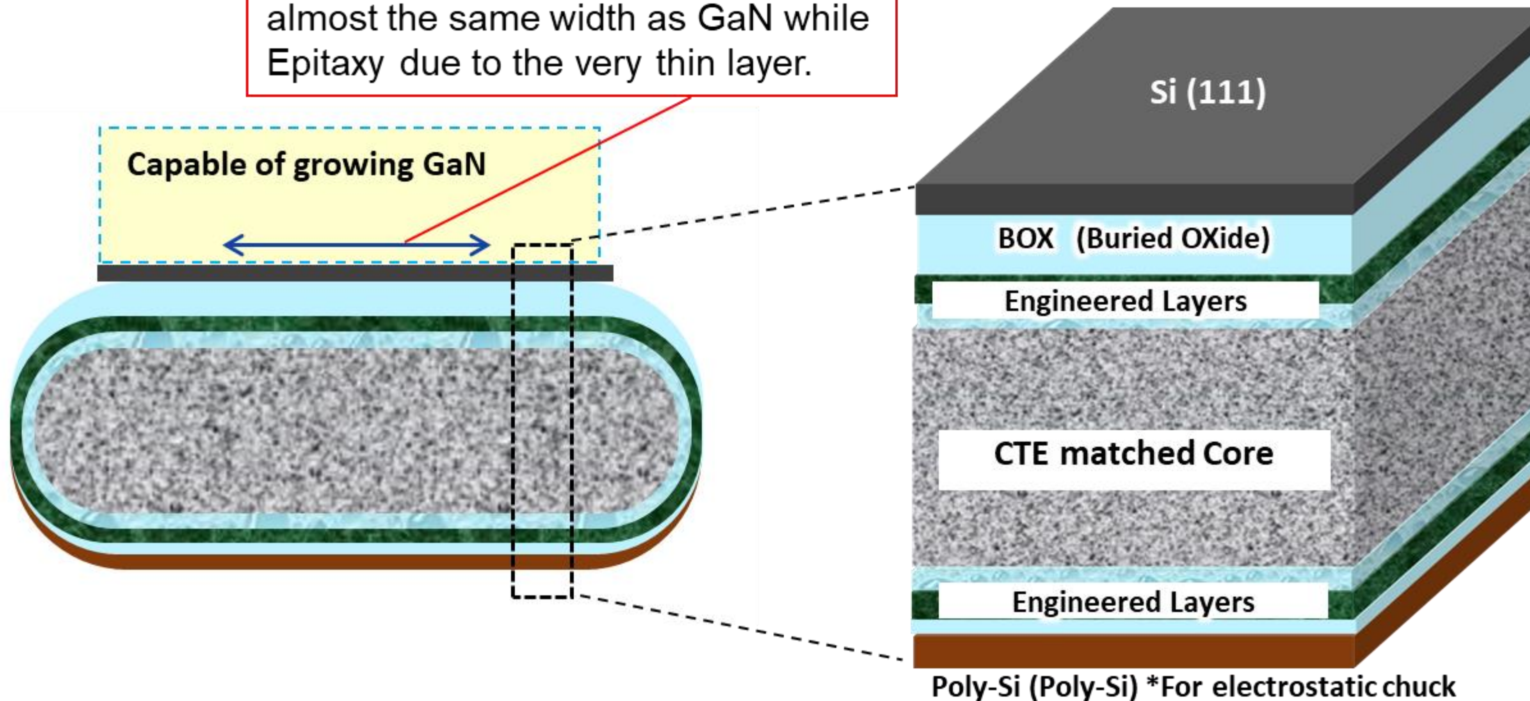
2-1. What is QST® substrate?

QST® : Qromis Substrate Technology

(Shin-Etsu Chemical got the License Package in 2019.)

Basic concept : Matching the Thermal Expansion Coefficient (CTE) with GaN.

(*) Si<111> lattice also expanded to almost the same width as GaN while Epitaxy due to the very thin layer.

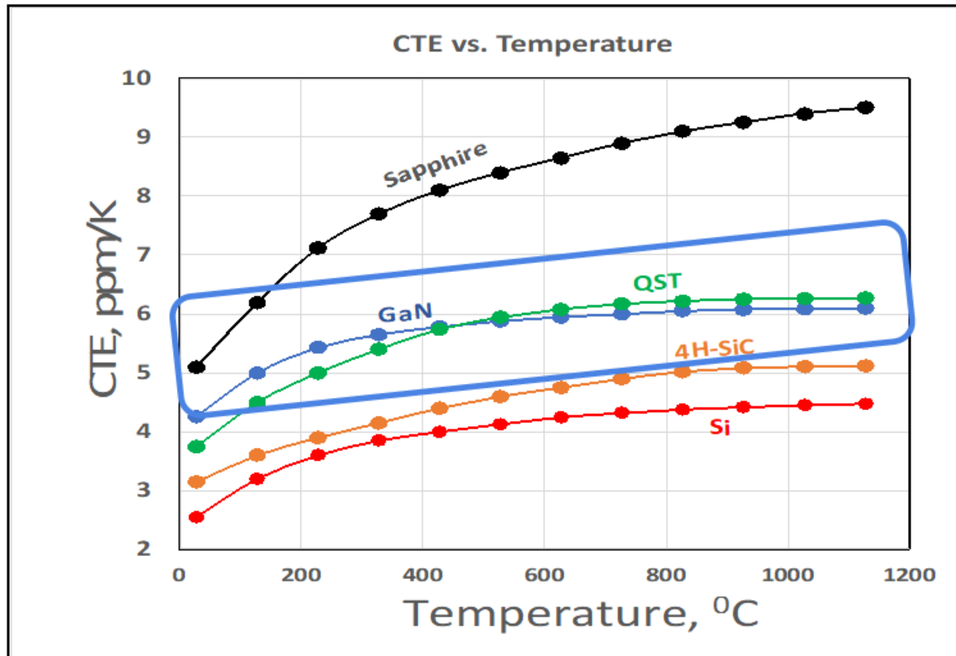


QST substrate feature

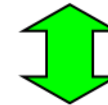
2-2. QST® substrate feature 1

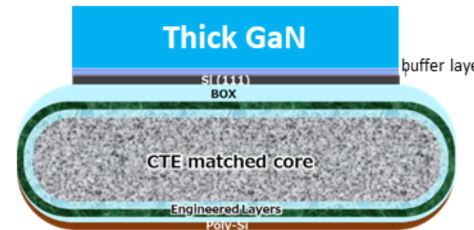
CTE Matching → Realizes high-quality **thick GaN** growth with **small warpage**.

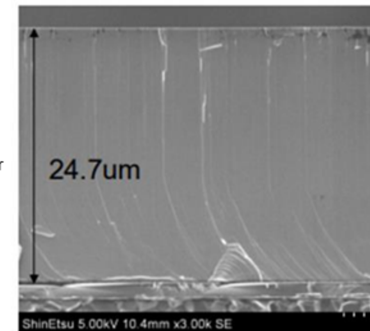
Comparison of CTE by substrate material



GaN on Si warps significantly due to tensile stress because the thermal expansion coefficients of GaN and Si are significantly different!







- ✓ High voltage resistance = Thick GaN (>=20um)
- ✓ Defect Density 5E6 /cm2 = 1/1000 of GaN on Si

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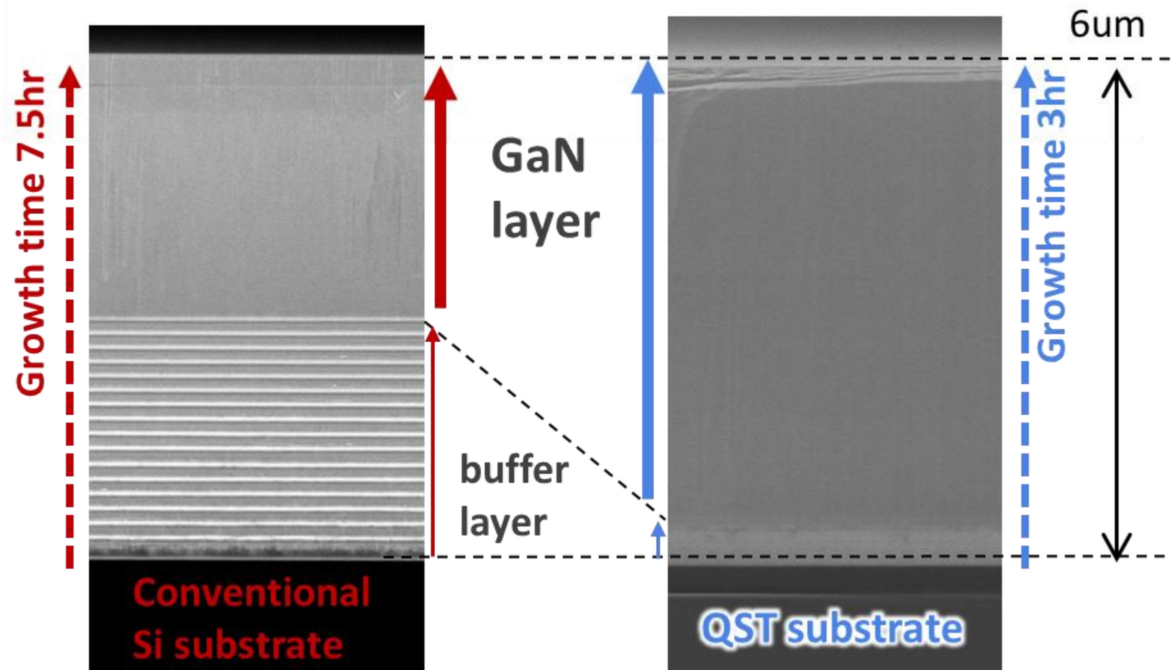
2-3. QST® substrate feature 2

Minimizes thermal distortion → **Simplified buffer layer**
(Shortens TAT! & Save material resources! *TAT=Turn Around time)

Thin Si layer naturally matching while Epi growth.

Buffer layer can be simplified

Growth time is cut in half!

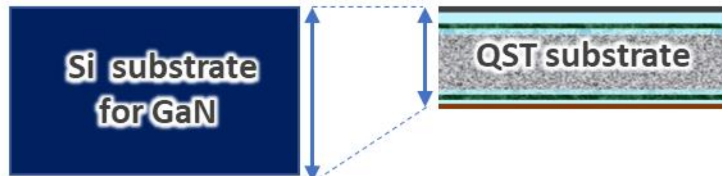


Comparing with on Si with 6μm GaN growth

2-4. QST® substrate features 3, 4

Possible to utilize **same process line for Si.**
Potential for **large Diameter** for GaN.

Standard substrate thickness



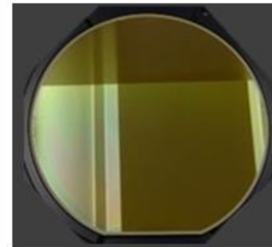
t=1000~1500µm
for warpage prevention

6” t=625µm
8” t=725µm
(SEMI Standard)

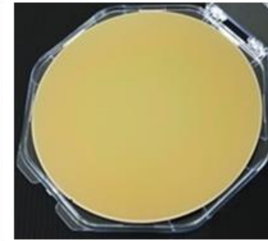
Limited to semiconductor devices with special specifications

Can utilize general semiconductor equipment!

Realization of large diameter



6” GaN on QST
t = 625µm
(13.0um GaN)



8” GaN on QST
t= 725µm
(7.8um GaN)

under development
From 2024
Sample schedule

12” GaN on QST

Reduce traditional vertical GaN cost to 1/10

[2”GaN substrate]

chip cost
1

<Substrate cost>
Equal or below

[6”,8”QST substrate]

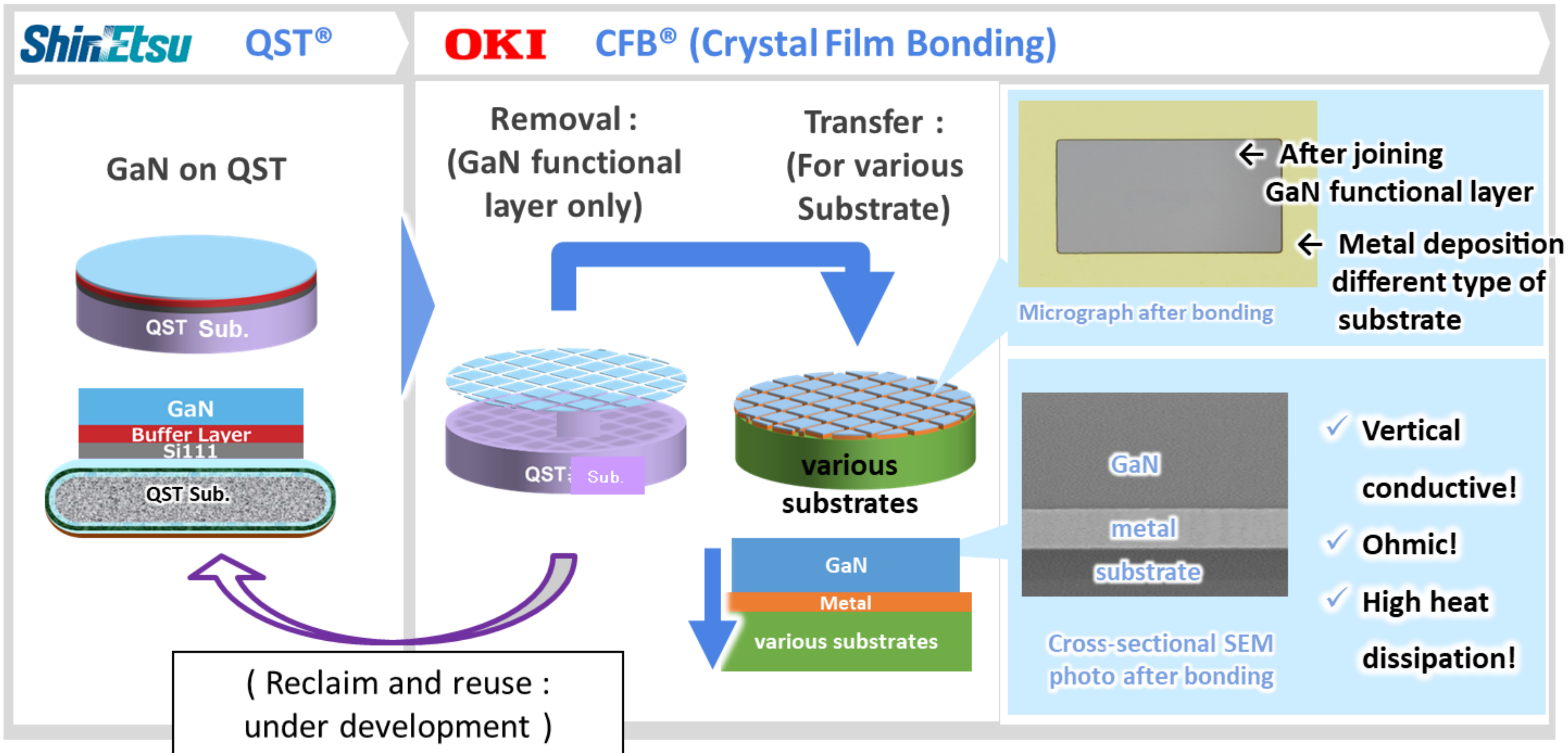
chip cost
1/10 or less

2-5. QST® substrate features 5

"Solution proposal" for QST® x CFB® for vertical GaN

QST® enables to utilize CFB® process to transfer GaN layer to various Substrates.

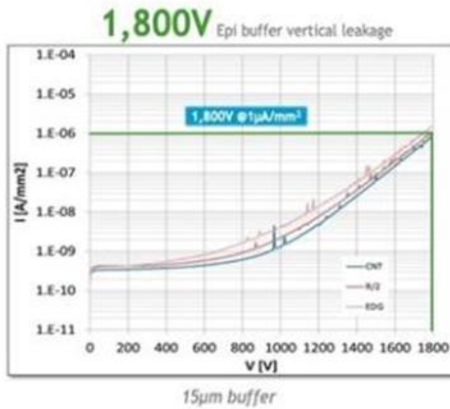
Removing Insulating Buffer Layer/ Bonding to a conductive Substrate with high heat dissipation.

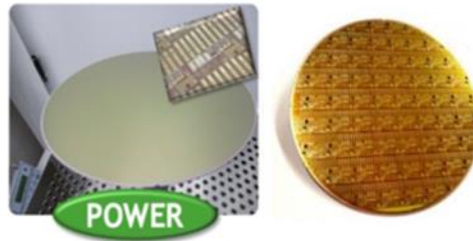


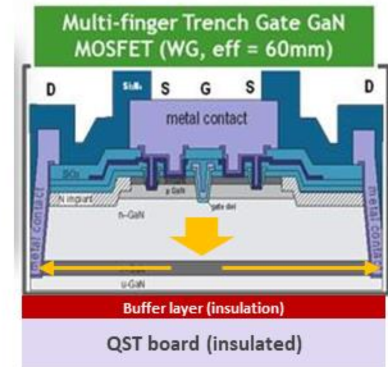
2-6. QST® substrate feature 6

QST substrates have been proven for various GaN devices.
If "vertical conduction" is realized, the possibilities will expand further.

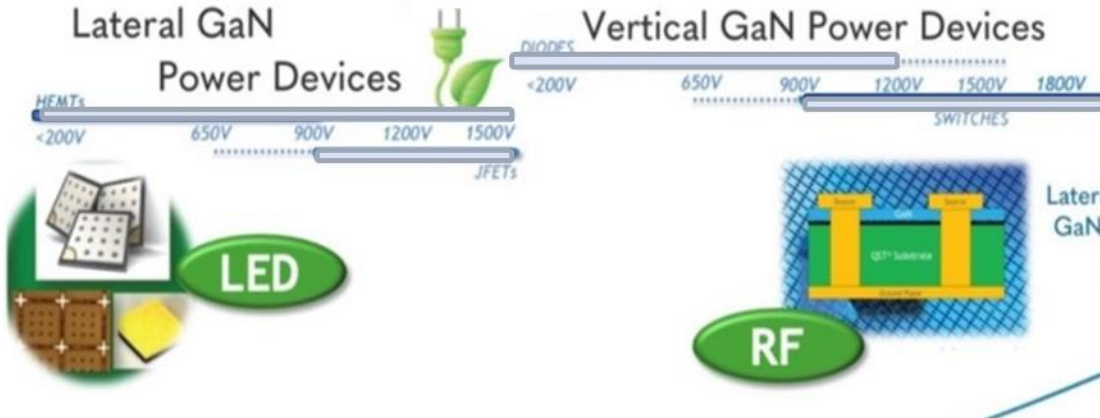
"Proven with various GaN devices"







[Semi-vertical GaN device]



Provided by Qromis

GaN on QST possibilities

Shin-Etsu

Feature 6. Proven with various GaN devices

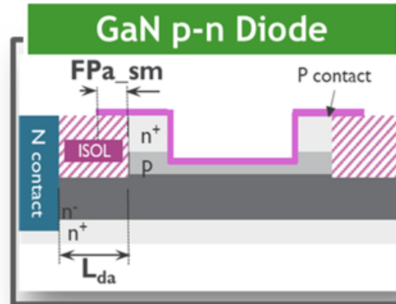
VERTICAL POWER DEVICES on QST®

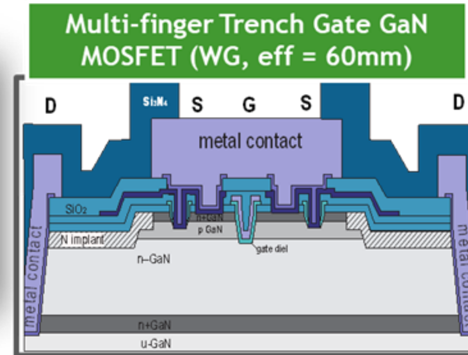
Semi-Vertical GaN Power Switch on QST

GaN p-n Diode and Trench Gate GaN MOSFET on CMOS Fab-friendly Semi-Spec QST®

5μm-thick Drift Layer
2E16 Si/cm³ Doping

- n^+-GaN 200 nm
- pGaN 800 nm, 1E19 Mg/cm³
- n^--GaN 5000 nm
- n^+-GaN 1500 nm
- u-GaN
- *Strain compensation layers*
- AlN 200 nm
- QST®





Gate Dielectric
2.5nm Al_2O_3 and 100nm SiO_2

Provided by Qromis

Various vertical devices are under development due to the ability to grow thick GaN layers

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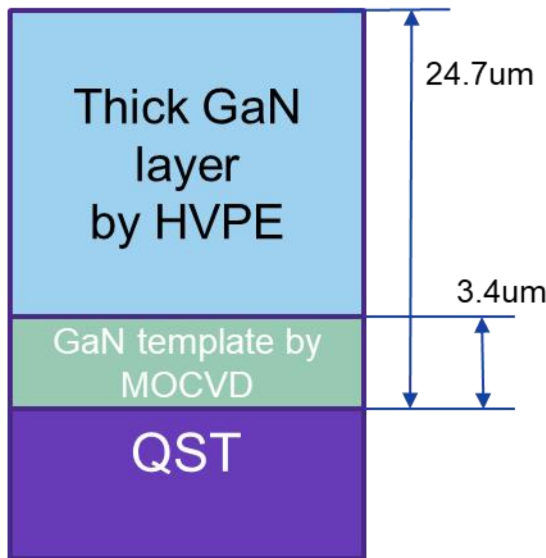
GaN on QST possibilities

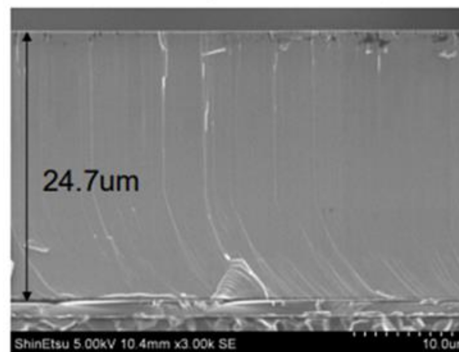
Feature 6. Proven with various GaN devices

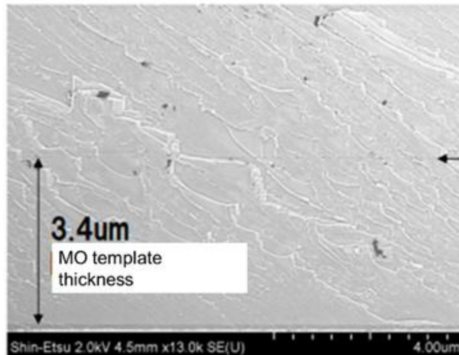
New possibilities for vertical GaN devices

This epi-layer was grown by **Kyma** (USA) on QST GaN template using **HVPE** to grow a 20μm GaN layer.

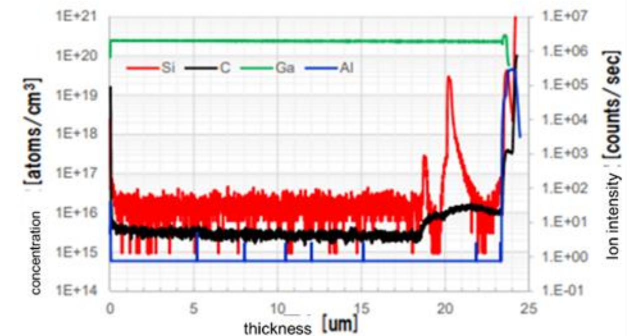


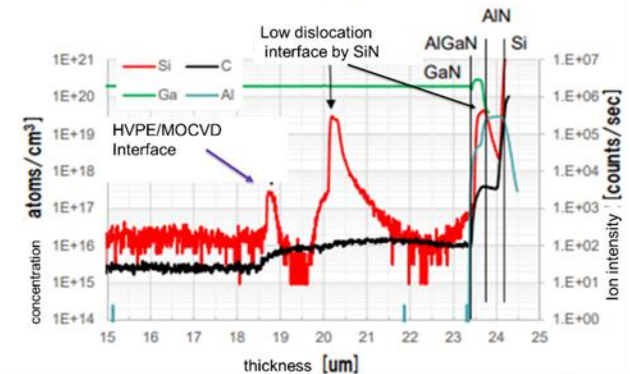
Kyma's GaN/QST





Cross-sectional SEM and SIMS

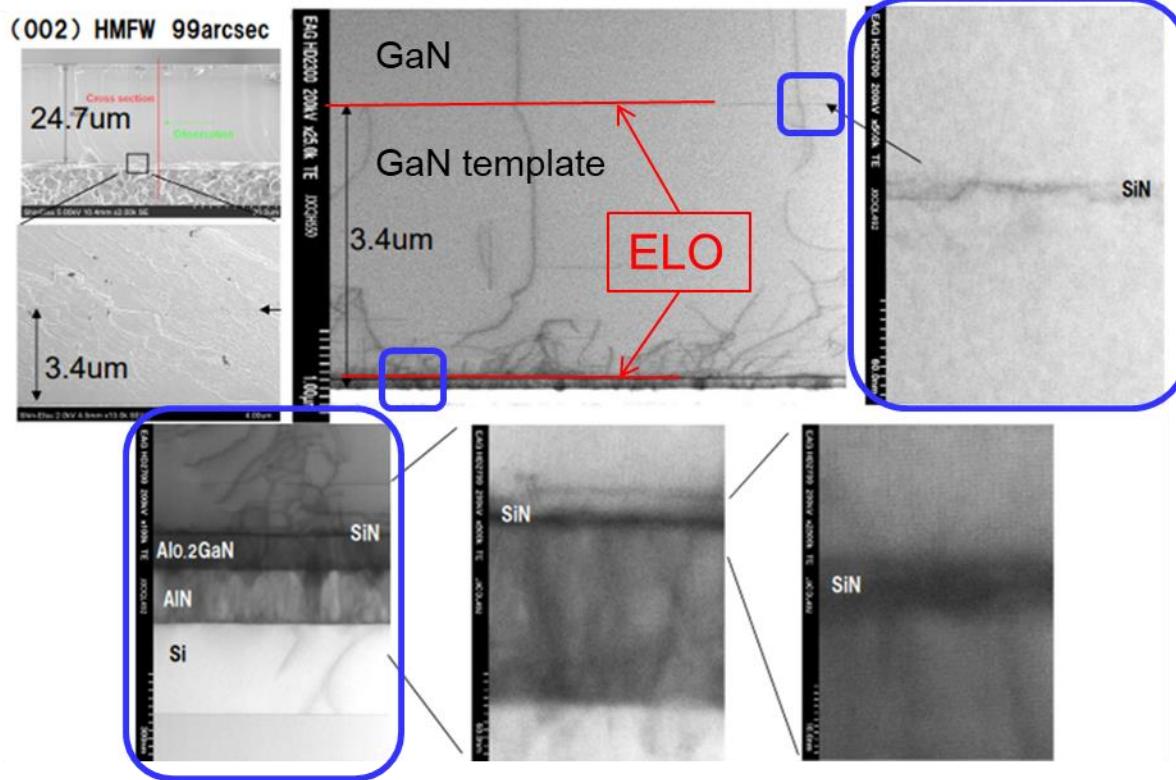




(*) HVPE (Hydride Vapor Phase Epitaxy)
for high speed deposition

GaN on QST possibilities

Feature 6. Proven with various GaN devices



Epitaxial Lateral Overgrowth (ELO) x2 significantly reduces through-going dislocations.

Low dislocation density GaN layers of up to about 5×10^{6} cm^{-2} have been obtained.

GaN on QST possibilities

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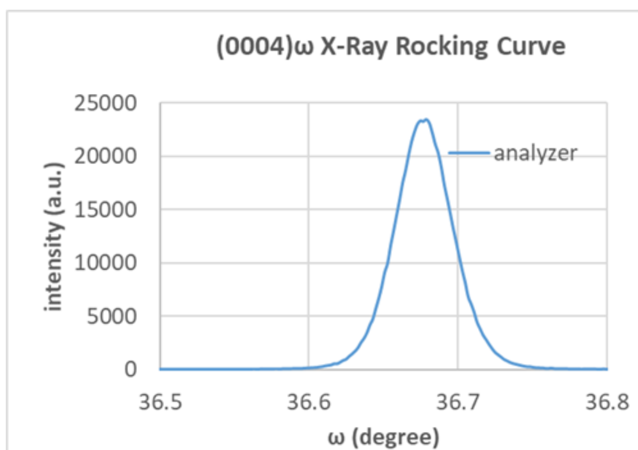
Feature 6. Proven with various GaN devices

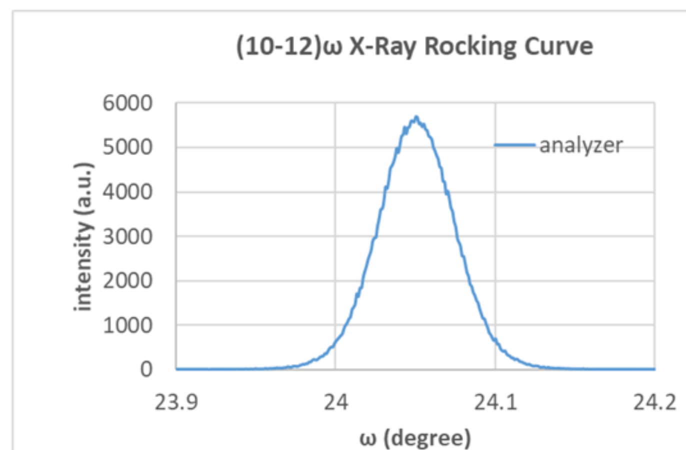
Kyma's GaN/QST XRD

We are now ready to take a new step toward vertical devices.

	FWHM(°)	FWHM(arcsec)
GaN(0004)	0.044	159
GaN(10-12)	0.054	196

XRD results are quite good for GaN epitaxial layer on Si seed crystal





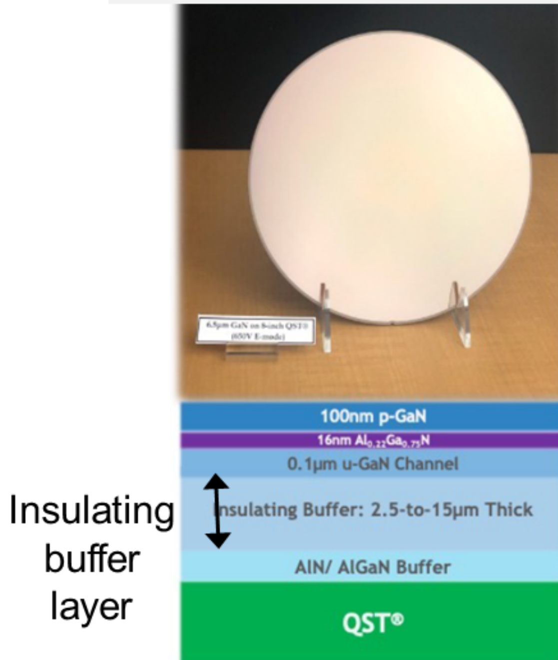
GaN on QST possibilities

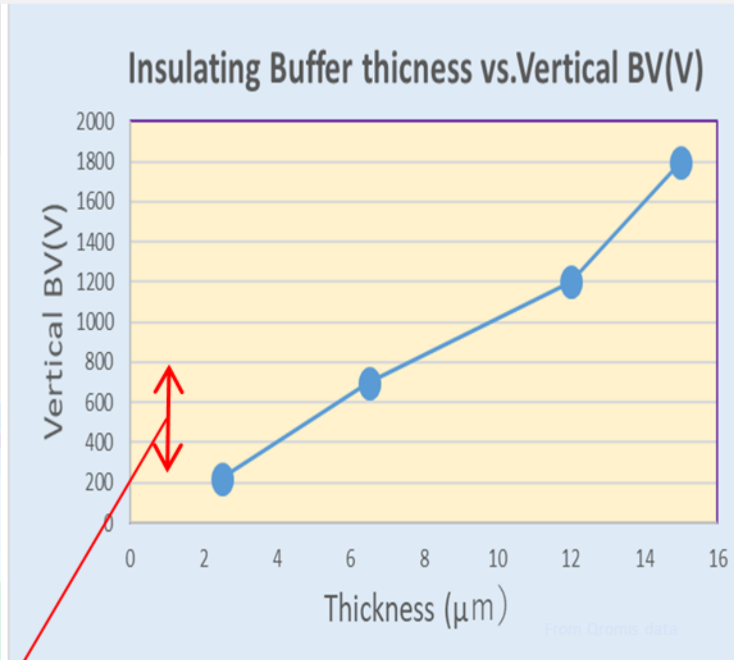
Feature 6. Proven with various GaN devices

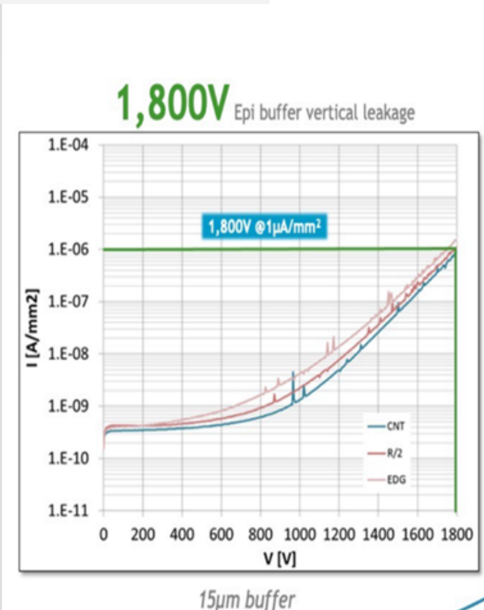
QST's horizontal GaN power devices

Provided by Qromis

Insulating buffer layer of 15μm allows for 1800v breakdown voltage







Current GaN device
600-800V range

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GaN on QST possibilities

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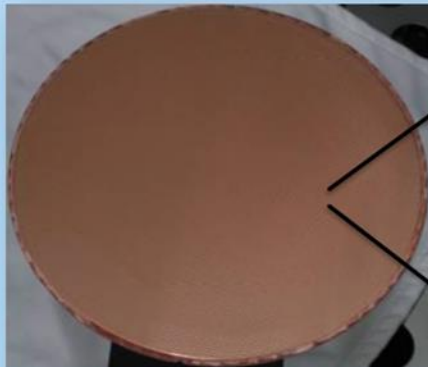
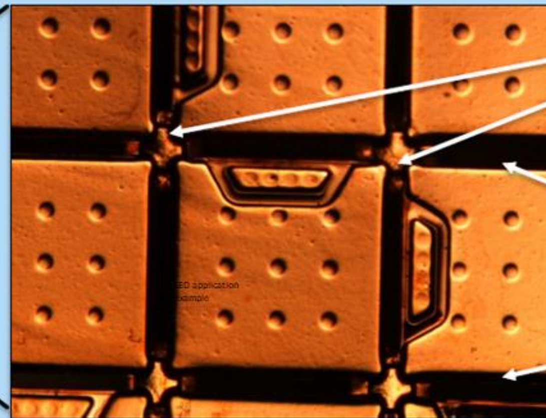
Feature 6. Proven with various GaN devices

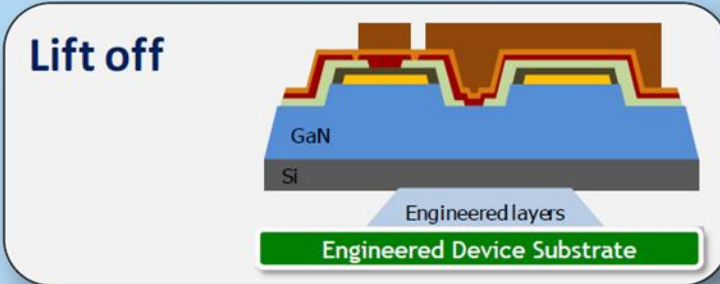
QST's LED application

Provided by Qromis

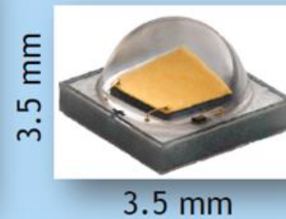


Cu Mesh Formation for Substrate Separation Process





Packaged LED Emitter (Retro Technology)



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GaN on QST Summary

3. Summary

Features of QST

1. **High quality & thick film GaN**
   → Realizes high device characteristics
2. **Simplify the buffer layer**
   → Buffer layer thinner than GaN/Si
3. **Standard Substrate thickness**
   → Standard semiconductor equipment can be utilized.
4. **large diameter possibility**
   → Reduce the cost of conventional vertical GaN to less than 1/10
5. **Compatibility with CFB**
   → Improve cost competitiveness through **Substrate recycling!**
6. **GaN device proven**
   → Various devices such as LED, POWER, RF, etc.

QST x CFB Co-creation value

On an insulating QST substrate

"Semi-vertical GaN" has been proven

↓

GaN function layer transfer

by CFB®

↓

“Vertical conductivity” = “Vertical GaN”

feasible

(*) compatible with

lateral HEMT or LED