Study of Ga2O3 thin films homoepitaxially grown on (010), (-201), and (001) substrates.

V. SALLET[1], G. AMIRI[1], S. HASSANI[1], C. SARTEL[1], Z. CHI[1], J.M. CHAUVEAU[1], E. CHIKOIDZE[1].

1 : Université Paris Saclay, UVSQ, CNRS, GEMaC, 45 avenue des Etats Unis, 78000 Versailles, France

SAFEPOWER project

MORE RELIABLE ENERGY
SAFEPOWER

HORIZON-CL5-2024-D3-01

Safer and More Reliable WBG/UWBG-based MVDC Power Converters

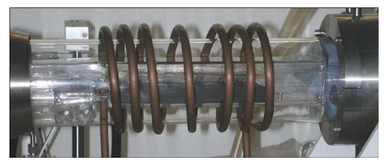
Funded by the European Union

developed thanks to these key enabling technologies:

- More efficient and reliable 3.3 kV **Silicon Carbide-base** power devices
- **6.6 kV Gallium Oxide-based** Power Devices
- Disruptive techniques for **electro-thermal power devices** analysis
- **AI-assisted converter** condition & health monitoring
- New **control strategies/architectures** for multilevel conversion

Experimental

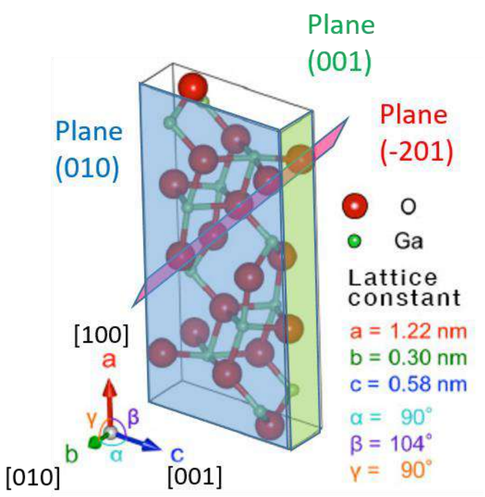
β-Ga_2O_3 epilayers were grown on (010), (-201), and (001) oriented Ga_2O_3 substrates, and R- and C- sapphire substrates by Metal-Organic Vapor Phase Epitaxy (MOVPE).



Horizontal reactor

MR Semicon MOVPE system
Low pressure 40 torr, argon, nitrogen or helium carrier gas
Growth temperature ~775°C
Precursors : Trimethylgallium (TMGa), O_2

β-Ga2O3 structure

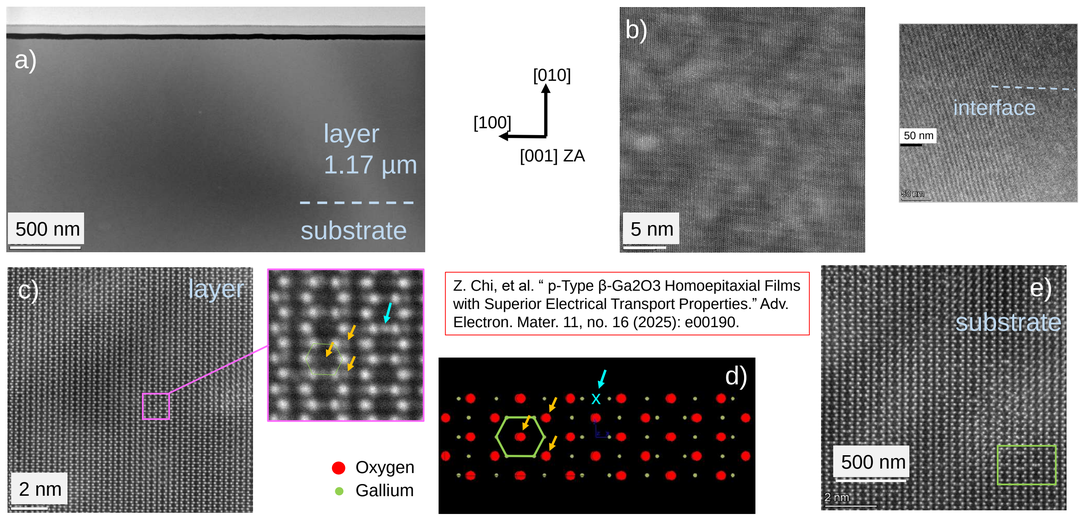


Wide bandgap semiconductor suitable for power electronics

Materials parameters	Si	GaAs	4H-SiC	GaN	Diamond	β-Ga_2O_3
Bandgap, E_g (eV)	1.1	1.43	3.25	3.4	5.5	4.85
Dielectric constant, ε	11.8	12.9	9.7	9	5.5	10
Breakdown field, E_C (MV/cm)	0.3	0.4	2.5	3.3	10	8
Electron mobility, μ (cm^2/Vs)	1480	8400	1000	1250	2000	300
Saturation velocity, v_s (10^7 cm/s)	1	1.2	2	2.5	1	1.8-2
Thermal conductivity λ (W/cm K)	1.5	0.5	4.9	2.3	20	0.1–0.3
Figures of merit relative to Si						
Johnson = $E_c^2 \cdot V_s^2/4\pi^2$	1	1.8	278	1089	1110	2844
Baliga = $\varepsilon \cdot \mu \cdot E_c^3$	1	14.7	317	846	24 660	3214
Combined = $\lambda \cdot \varepsilon \cdot \mu \cdot V_s \cdot E_c^2$	1	3.7	248.6	353.8	9331	37
Baliga high frequency = $\mu \cdot E_c^2$	1	10.1	46.3	100.8	1501	142.2
Keyes = $\lambda \cdot [(c \cdot V_s)/(4\pi \cdot \varepsilon)]^{1/2}$	1	0.3	3.6	1.8	41.5	0.2
Huang HCAFOM, $\varepsilon \mu^{0.5} E_C^2$	1	5	48	85	619	279

(010) homoepitaxy – published result (previous work)

STEM : thanks to A. Perez, B. Mundet, B. Ballesteros, J. Santiso,Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC, Barcelona Institute of Science and Technology (BIST), Barcelona, Spain

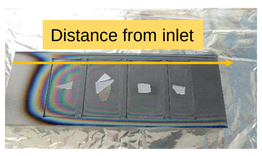


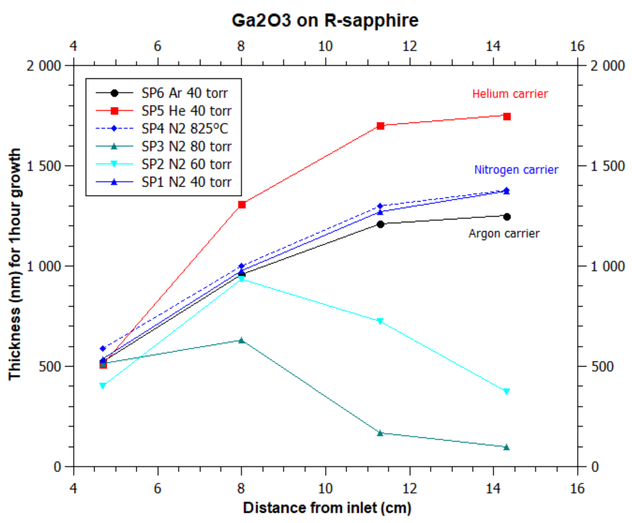
Z. Chi, et al. " p-Type β-Ga2O3 Homoepitaxial Films with Superior Electrical Transport Properties." Adv. Electron. Mater. 11, no. 16 (2025): e00190.

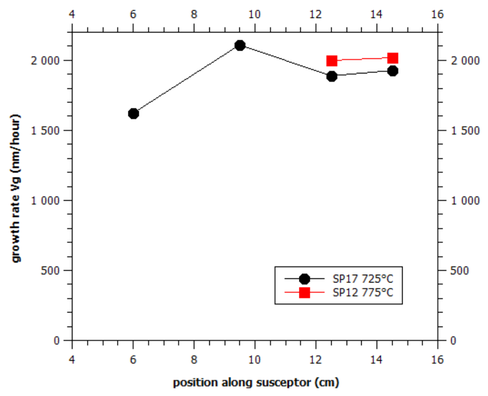
Homoepitaxial growth on (010) occurs without generation of extended defects or dislocations. For this (010) orientation, STEM was performed across [001] zone axis and we remark the occurrence of additional contrasts between two Ga1 atomic columns, as indicated by the blue arrow in the figure(d), which we attributed to columns of interstitial Ga, as suggested in ref. Bhuiyan et al, Appl. Phys. Lett. 115, 120602 (2019). Orange arrows indicate the expected locations of O atoms,

Growth rate studies

Ga2O3 layers on R- oriented sapphire







Variation with growth temperature Tg :

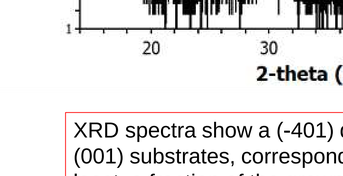
- no change in Vg between 725°C and 775°C

Growth rates are typically 2-3 µm/h, and up to 4µm/h can be achieved

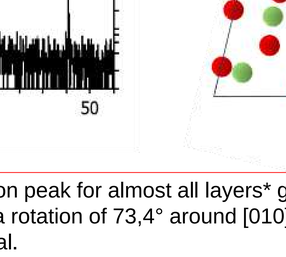
Since O2 flows are high (750-3000 sccm), total flux is not constant and consequently the growth rate varies as a function of TMGa partial pressure (in Pa), and not TMGa flow (in µmol/min)

(-201) and (001) homoepitaxy

(001) Ga2O3 Sn doped substrate supplied by NCT (Japan), both sides polished

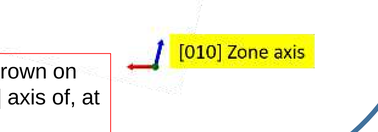


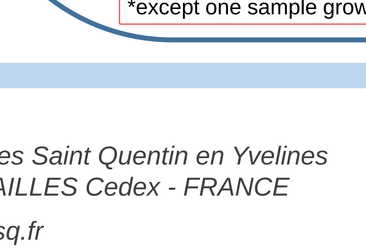
SP9 500 nm

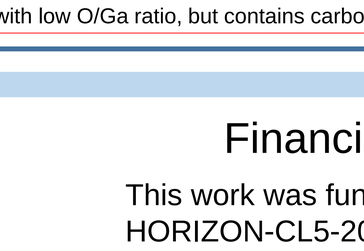


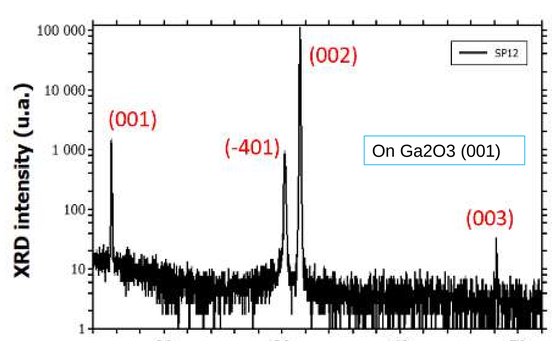
AFM image (Brukker ICON)

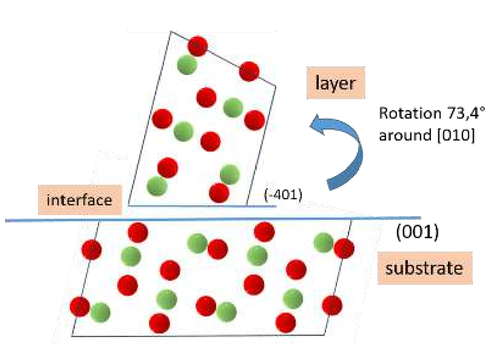
Ra = 0,215 nm











XRD spectra show a (-401) diffraction peak for almost all layers* grown on (001) substrates, corresponding to a rotation of 73,4° around [010] axis of, at least, a fraction of the grown material.
*except one sample grown with low O/Ga ratio, but contains carbon

UNIVERSITÉ DE VERSAILLES ST-QUENTIN-EN-YVELINES
université PARIS-SACLAY
cnrs
GEMaC Groupe d'Etude de la Matière Condensée

UMR8635 CNRS - Université de Versailles Saint Quentin en Yvelines
45, av des Etats Unis - 78035 VERSAILLES Cedex - FRANCE

www.gemac.uvsq.fr

Financial supports

This work was funded by the European project HORIZON-CL5-2024-D3-01 SAFEPOWER