



Barium Titanate (BTO) on 12" (300 mm) silicon

Proven performance for next-generation photonics

Production oxide MBE from DCA Instruments – FOUP-to-FOUP automation, wafer-to-wafer reproducibility and high-quality epitaxial BTO on a proven, reliable platform.

2019

first production oxide MBE
for 300 mm

>100

BTO wafers on 300 mm, 3 σ
lattice ~0.1 %

< ± 2 °C

wafer-temperature
uniformity, 8"/12"

24/7

automated FOUP-to-FOUP
batch processing

THE OPPORTUNITY

Why BTO: a strong Pockels material made for silicon

Fully CMOS compatible

Epitaxial BTO on Si via an MBE-grown SrTiO_3 seed; integration steps common in CMOS back-end-of-line; monolithically integrated in a 300 mm SiPh foundry process with 95 % functional yield.

Smaller modulators, denser arrays

~ 923 pm/V Pockels coefficient. 1.75 mm phase shifters reach 105 GHz; four modulators on a 5.1×3.5 mm² die; 350 μm phase shifters for a full π shift.

Field-driven, low power

No carrier injection – lower drive voltage and energy per bit; 560 nW per π static power, no thermal crosstalk.

BEYOND DATA COM – ONE MATERIAL, MANY APPLICATIONS

Non-volatile memory

- Optical states held with no holding power
- Multilevel phase shifters, 16 levels shown

Programmable photonics

- 116-actuator BTO gate array
- ~ 80 ns switching; filters, routing, 4×4 transforms

Quantum photonics

- Low-loss switches (0.33 dB-V)
- Pockels effect retained at 4 K (~ 200 pm/V)

Robust operation

- Modulation above bulk Curie point (tested to 130 °C)
- No degradation after 250 °C exposure

WHY MBE

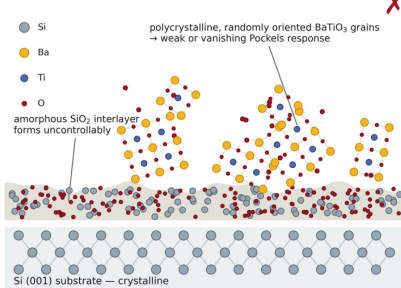
The enabling step: an MBE-grown SrTiO_3 seed layer

Why molecular beam epitaxy is indispensable

BaTiO_3 will not grow as an ordered crystal on bare silicon — an MBE-grown SrTiO_3 seed layer, just a few atomic layers thick, presents the perovskite template on which single-crystal BaTiO_3 can form.

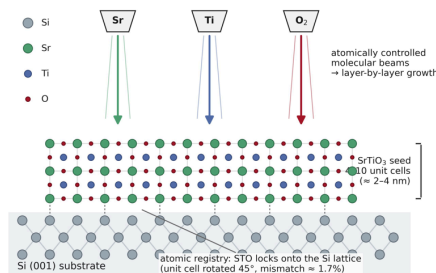
1 BTO directly on bare silicon

no template → no epitaxial order



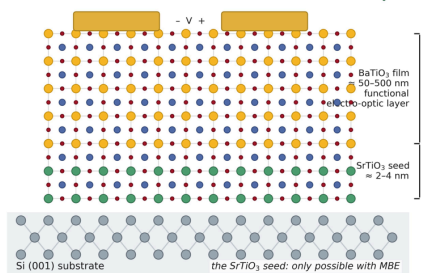
2 The MBE solution: SrTiO_3 template

a seed just a few atomic layers thick locks into registry with silicon ultra-high vacuum ($\approx 10^{-10}$ mbar)



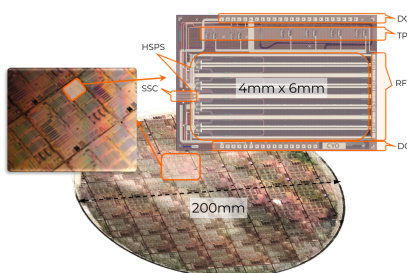
3 Result: single-crystal BaTiO_3 on silicon

one crystal lattice from substrate to device — not to scale device layer: electrodes / waveguide (modulator, switch, transducer)



Without an MBE-grown SrTiO_3 seed layer, high-quality epitaxial BTO films on silicon cannot be

achieved. The few-atomic-layer seed locks into registry with the silicon and provides the template for single-crystal BTO – sputtered and hybrid-MBE BTO also build on it.



Fully processed 200 mm BTO-on-silicon-photonics wafer, integrated at wafer level, with a reticle and a dual-polarisation IQ modulator die (4×6 mm²). Epitaxial BTO grown on DCA metal-oxide MBE systems.

Sources: Abel et al., Nat. Mater. 18, 42 (2019); Alexander et al., Nature 641, 876 (2025); Qiu et al., OFC 2026; Geler-Kremer et al., Nat. Photon. 16, 491 (2022); Catalá-Lahoz et al., Nat. Photon. 20, 932 (2026); Eltes et al., Nat. Mater. (2020), doi:10.1038/s41563-020-0725-5; Messner et al., J. Lightwave Technol. 37, 281 (2019).

WHY DCA

Every BTO route on one flexible, fully automated platform

Solid-source MBE

Highest controllability

- Ti from DCA HTEC high-temperature effusion cell or e-beam
- Excellent material quality

Hybrid MBE

Faster growth

- Ti from DCA MOPI metal-organic precursor injector
- V_{rf} and propagation loss comparable to other growth methods

UHV sputtering

Higher throughput

- DCA APEX-L linear magnetron for 8" to 12"
- Simpler processing on an MBE seed

AUTOMATED

Fully automated, FOUP-to-FOUP – and scalable

FOUP + EFEM	Load lock	Robot (CDC)	M1000 MBE #1	M1000 MBE #2	Storage
dual FOUP ports wafer ID & flip	10 / 25 wafers degas 200 °C	automated 300 mm UHV transfer	STO seed and/or BTO epitaxy	second growth module, same robot	10 / 25 wafers in UHV

Scalable cluster: one robot handler serves multiple growth modules (e.g. dual M1000 MBE chambers); additional CDCs extend the cluster tool to up to four M1000 growth chambers.



DCA M1000 production oxide MBE with automated transfer system and integrated EFEM.

DCA MOSAIC runs the whole sequence

- Automated FOUP loading, wafer ID and flipping
- UHV transfer, wafer tracking and full process history
- Growth recipes with closed-loop flux feedback
- Real-time interlocks: vacuum, motion, cooling, power
- 24/7 batch processing with ultra-low particle loading
- SECS/GEM compatible – seamless foundry integration

25,000

robot transfer cycles tested – all within the safe limit

< ±2 °C

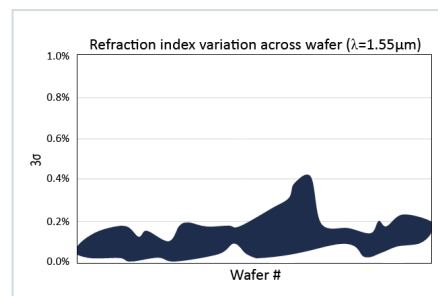
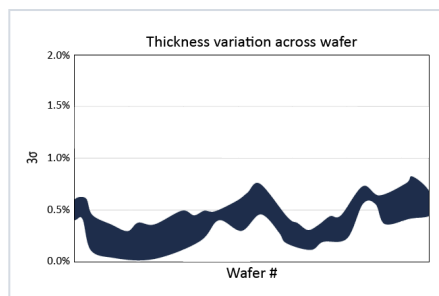
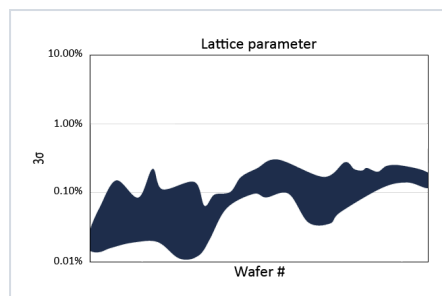
wafer-temperature uniformity, 8" and 12"

40+

automated transfer systems installed

DELIVERING OUTPUT

>100 BTO wafers on 300 mm – 3 σ statistics



~0.1 %

3 σ lattice-parameter variation (Ba/Ti stoichiometry)

< 1 %

3 σ thickness variation, films >150 nm

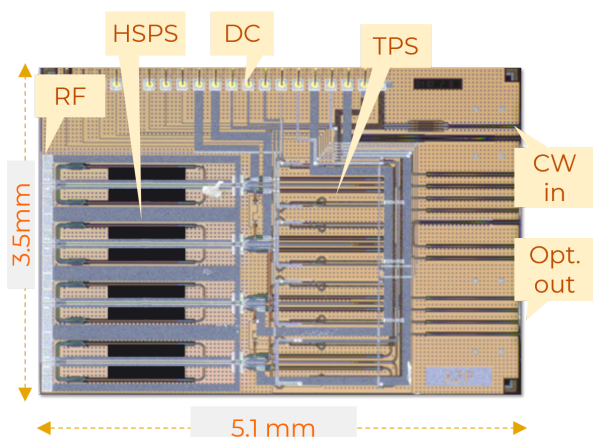
< 0.2 %

typical 3 σ refractive-index variation at 1.55 μ m

Across the 300 mm wafer, lattice parameter stays within ± 0.2 % and refractive index within ± 0.4 % from centre to edge. 12" wafers double device throughput vs 8".

PROVEN RESULTS

A record-setting 1.6 Tb/s chip on DCA-grown BTO



1.6 Tb/s

net, 4×448 Gb/s PAM4 over 2 km

105 GHz

6 dB EO bandwidth, 1.75 mm modulator

85 °C

consistent from 20 to 85 °C, all 4 channels

1 Tb/s/ λ

net, BTO DP-IQ modulator

Four-channel BTO/SiPh transmitter, 5.1×3.5 mm² (OFC 2026).

Lumiphase AG

Switzerland · device maker

- MBE-grown BTO in 200 and 300 mm SiPh flows
- OFC 2026 record devices on DCA-grown epitaxy

PsiQuantum

USA · quantum computing

- Platform built in a 300 mm foundry fab
- 95 % functional BTO device yield

La Luce Cristallina

USA · wafer supplier

- Sells 200 mm BTO and STO-on-Si wafers
- DCA MBE (STO seed) + DCA UHV sputtering



Talk to us about BTO production on 200 / 300 mm

Dr Sabina Hatch, Sales Director · sabina.hatch@dca.fi · www.dca.fi

Sources: Qiu et al., OFC 2026 (McGill / Ciena / Lumiphase); Alexander et al., Nature 641, 876 (2025); Posadas & Demkov, ICMBE 2026.