Production InP-based MBE HBT Growth And Improvement with Real-Time Monitoring

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IntelliEPI: InP-based Production MBE HBT Development

Advantages of MBE for InP-based HBT growth

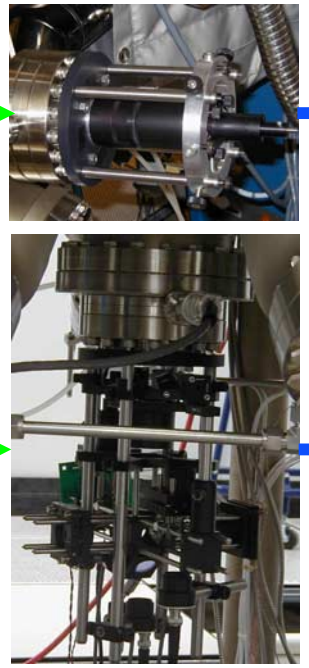
- *High p-doping to 1E20 cm-3 and high n-doping to 5E19 cm-3*
- *Excellent thickness and interface control*
- *Easy to install various sensors for real-time monitoring*
- *Low background doping*
- *Low safety overhead*

IntelliEPI's Approaches in HBT development

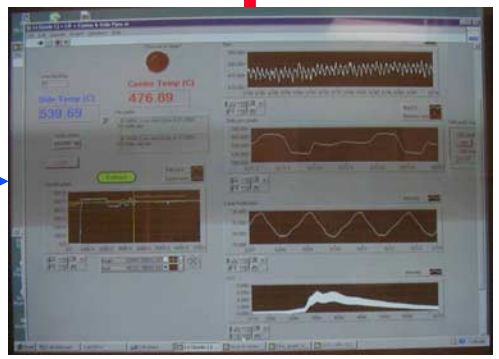
• *Used multi-wafers 4x4in production MBE systems (9x4in)*	*12/99*
• *Installed sensors to monitor composition, temp., and surface*	*01/00*
• *Demonstrated reproducible and efficient P-cell operation*	*03/00*
• *Established safety protocol in P-MBE system R&M*	*06/00*
• *Delivered volume InP-based structures to customers*	*06/00*
• *Correlated processing results with in situ data*	*12/00*
• *Improved epitaxial growth based on correlations*	*03/01*

IntelliEPI: Sensor-based Production MBE

Multi-wafer Production MBE System



In-situ Sensors on MBE

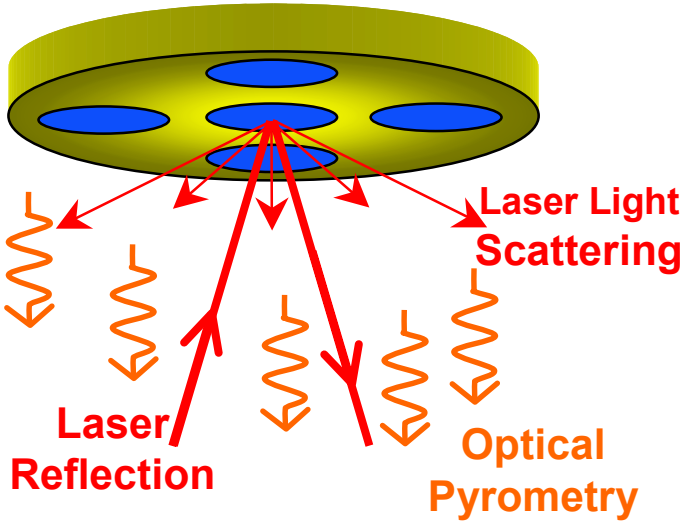


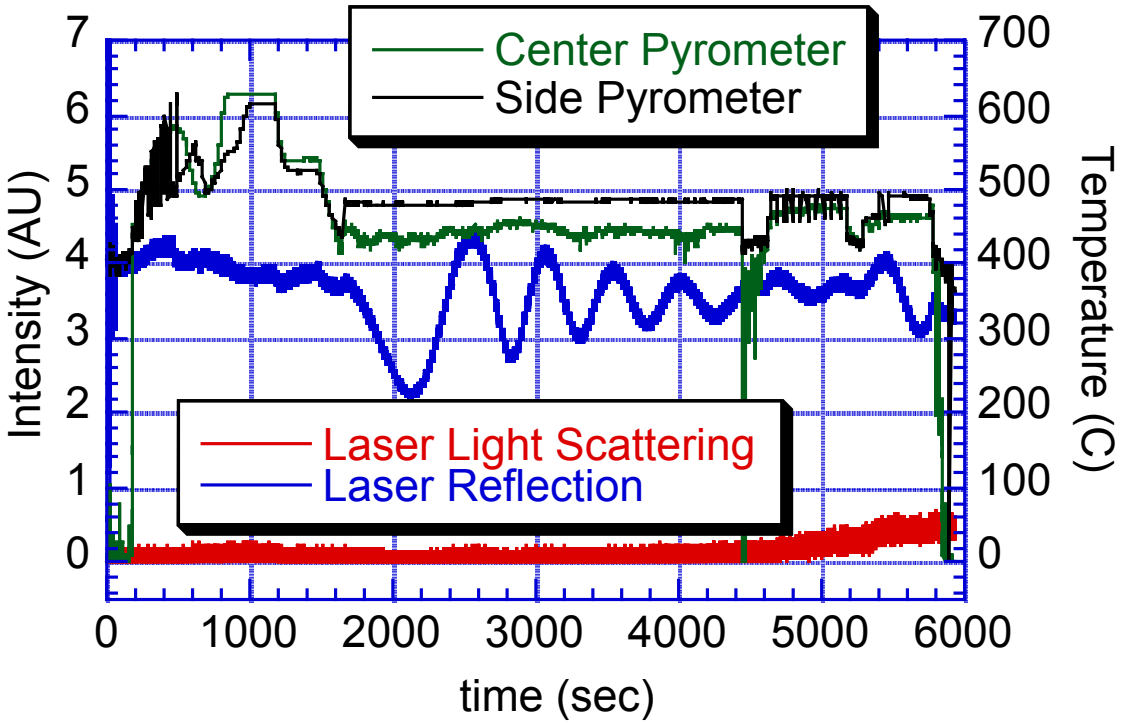
Real-time Analysis

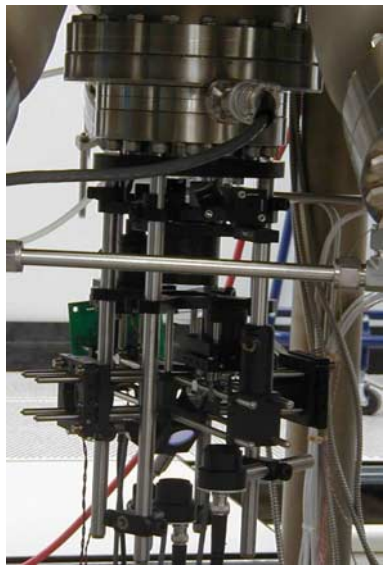
- *Real-time monitoring of MBE process using proprietary non-invasive optical measurement techniques*
- *Rapid product development cycle*
- *Value-added growth information for customers*
- *Improve yield*

IntelliEPI: Real-time Optical Probes of Substrates

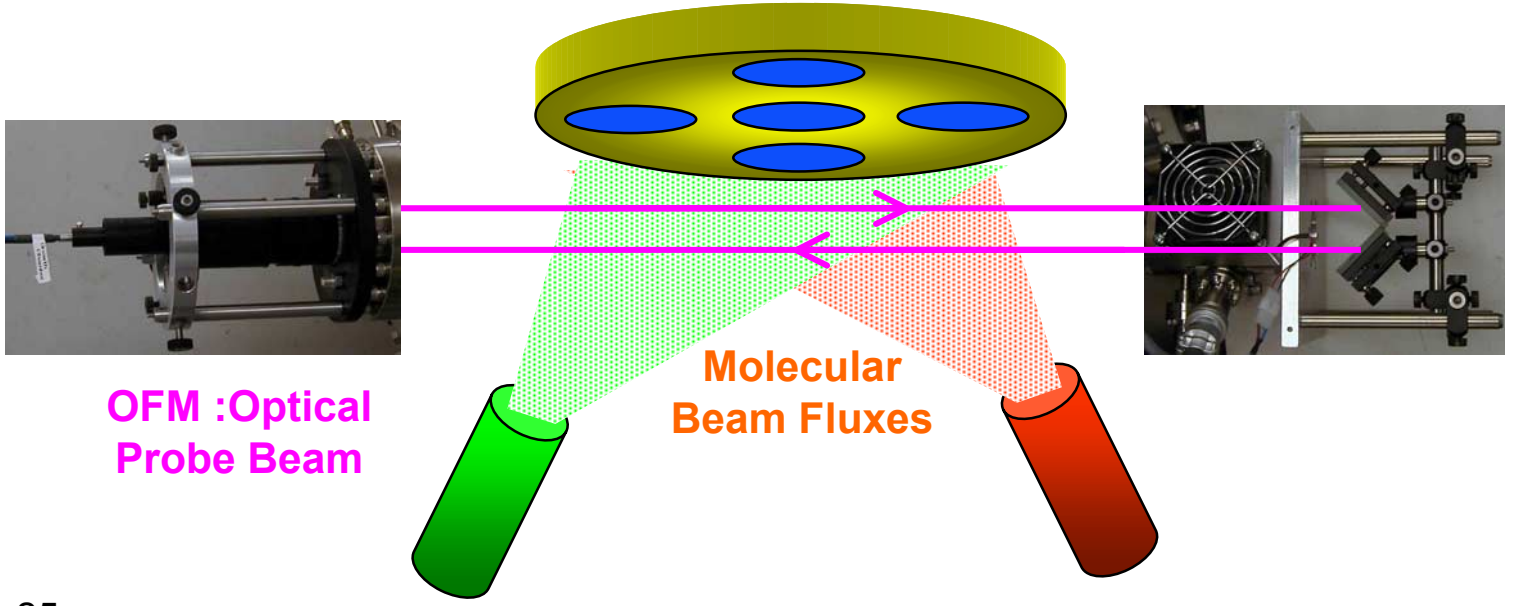
- *Optical Pyrometry and Pyrometric Interferometry*
- *Laser Reflection*
- *Laser Light Scattering*

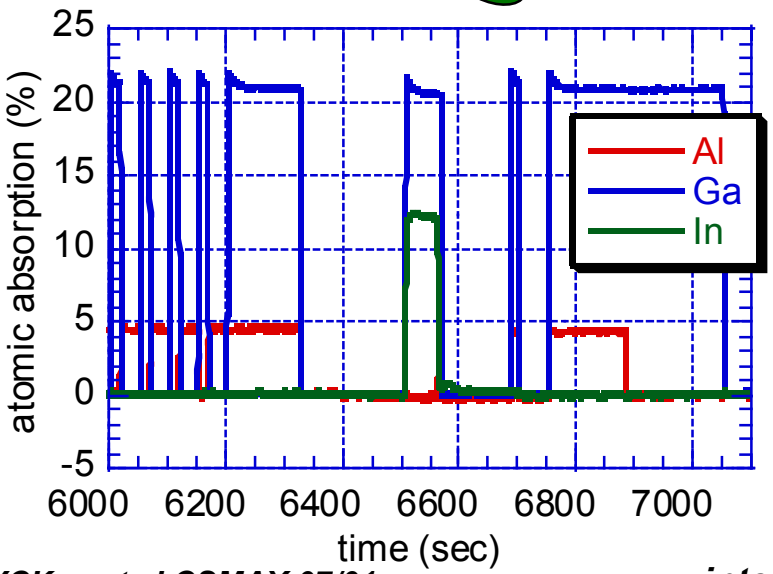






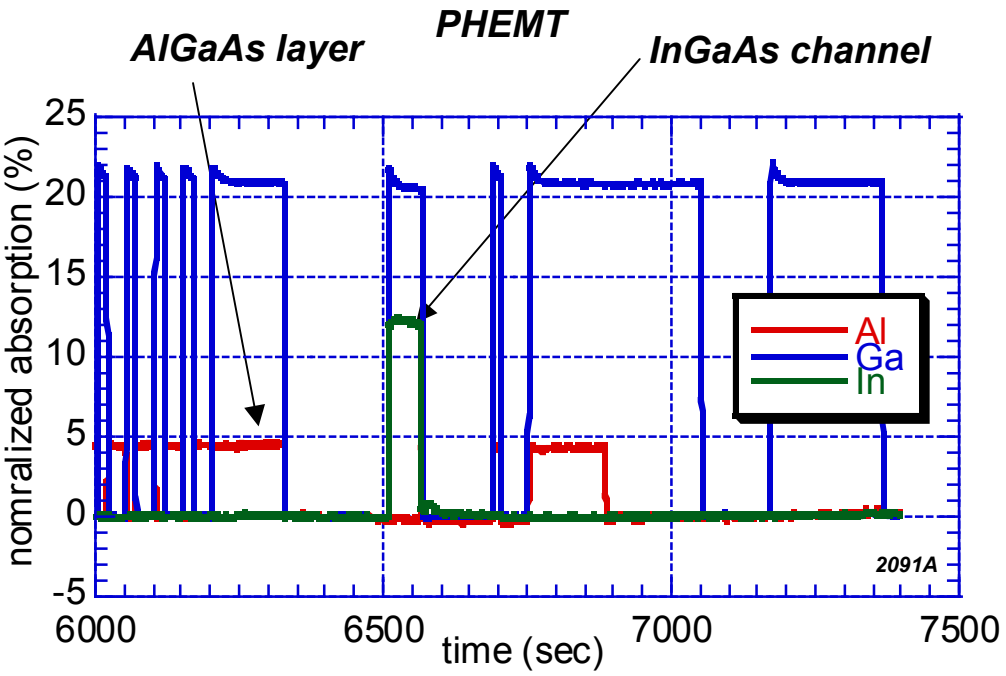
IntelliEPI: Optical-based Flux Monitor (OFM)

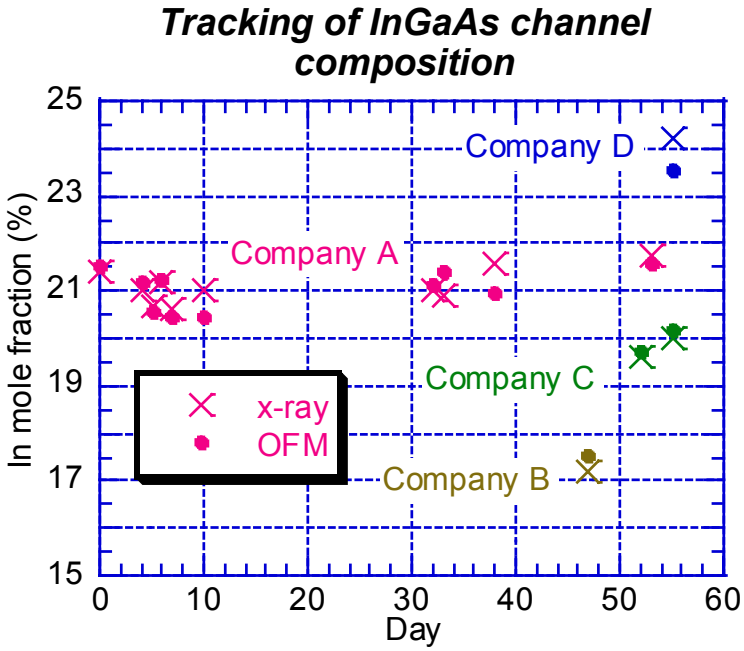




- *Optically probe atomic absorption of group III fluxes (Al, Ga, and In) simultaneously during growth.*
- *Continuous real-time measurement of molecular beam flux profile.*

IntelliEPI: OFM Flux Profile for Real-time Analysis

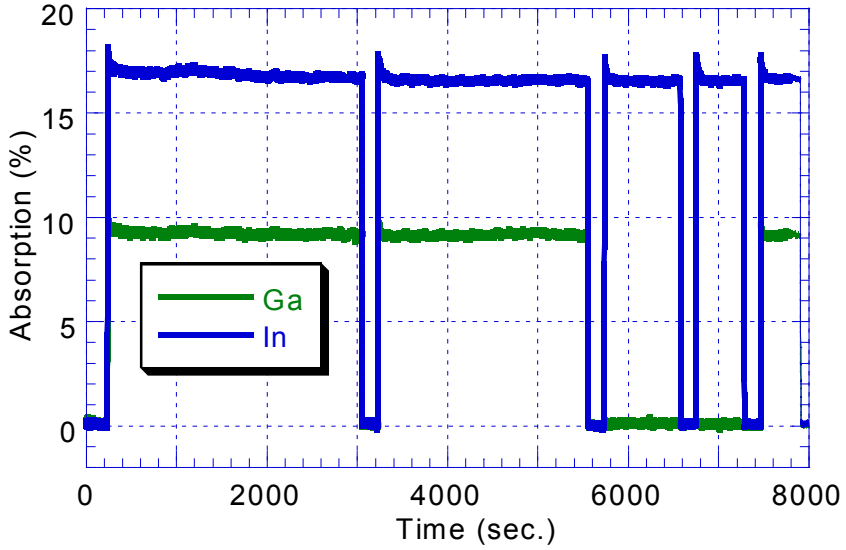




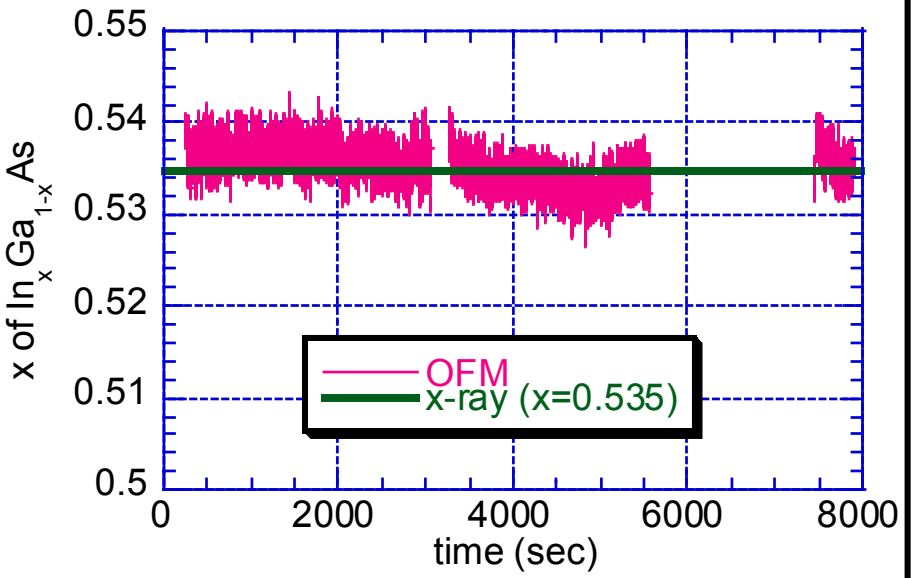
- ***Determine AlGaAs and InGaAs composition from group III flux ratio.***
- ***Real-time growth rate measurement.***
- ***Quantitative measurement of flux transient.***

IntelliEPI: Group III Flux Profile of HBT Growth

OFM flux measured during growth every 0.1 sec.

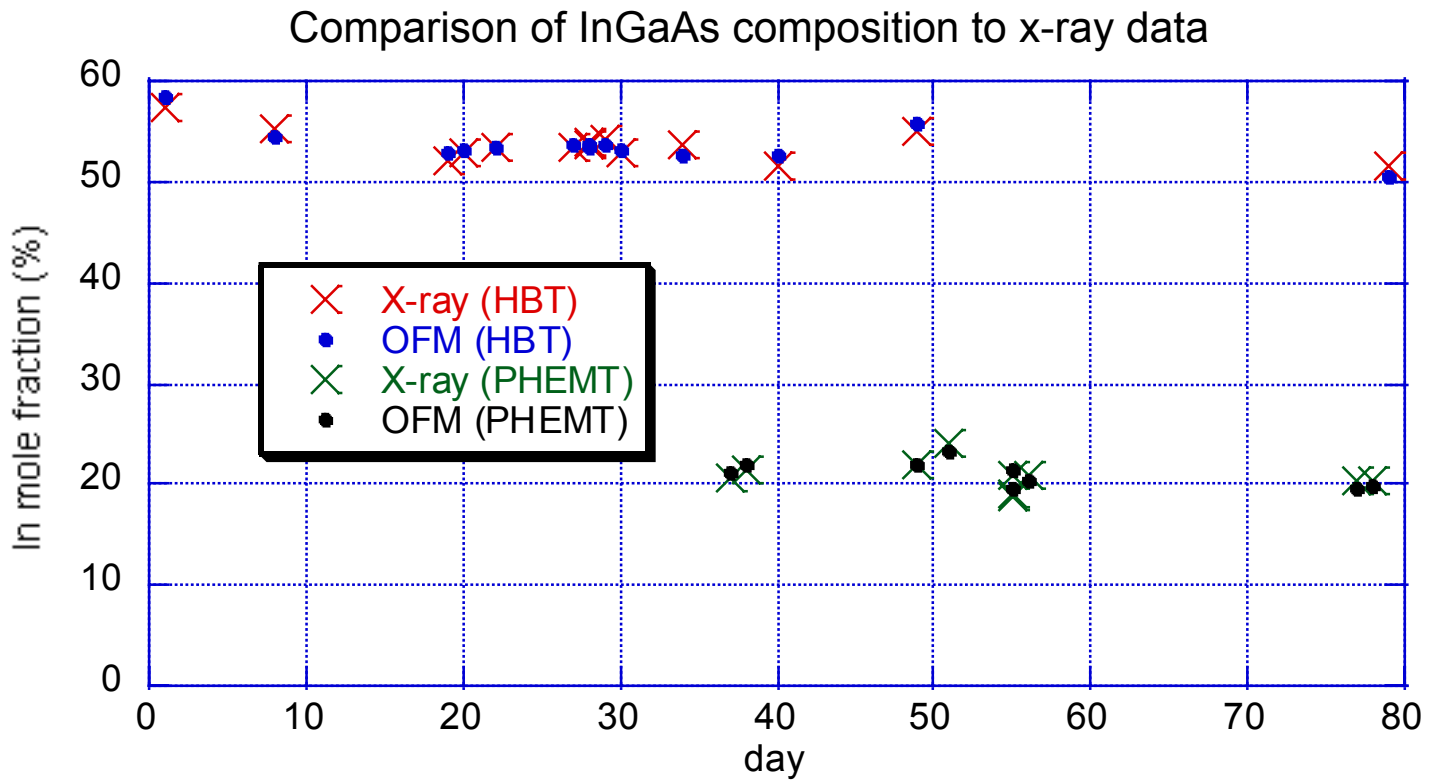


Comparison of InGaAs composition to post growth x-ray analysis.



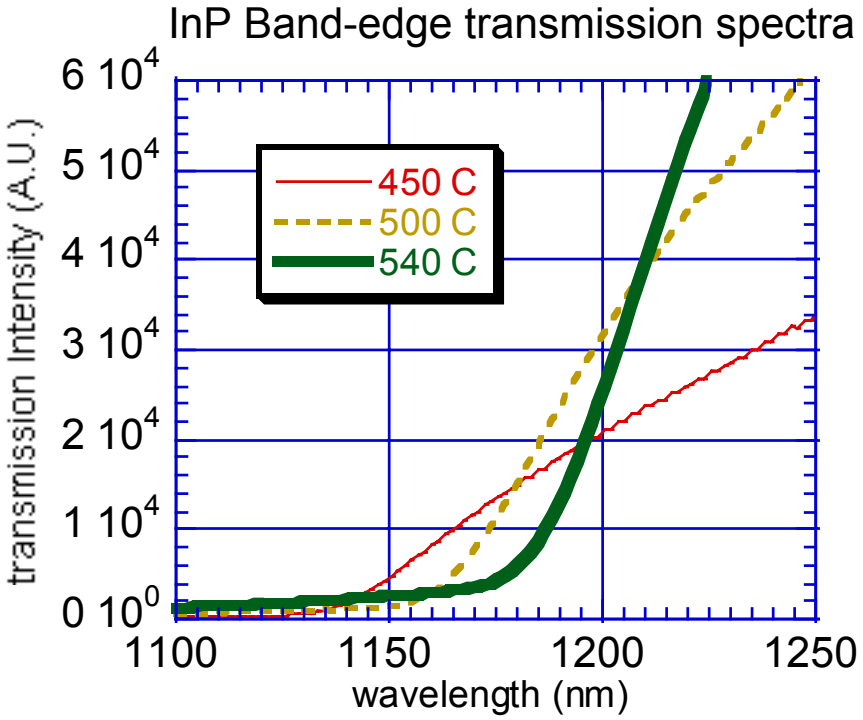
- *Real-time monitoring of growth rate and composition.*
- *InP/InGaAs HBT on InP substrate.*

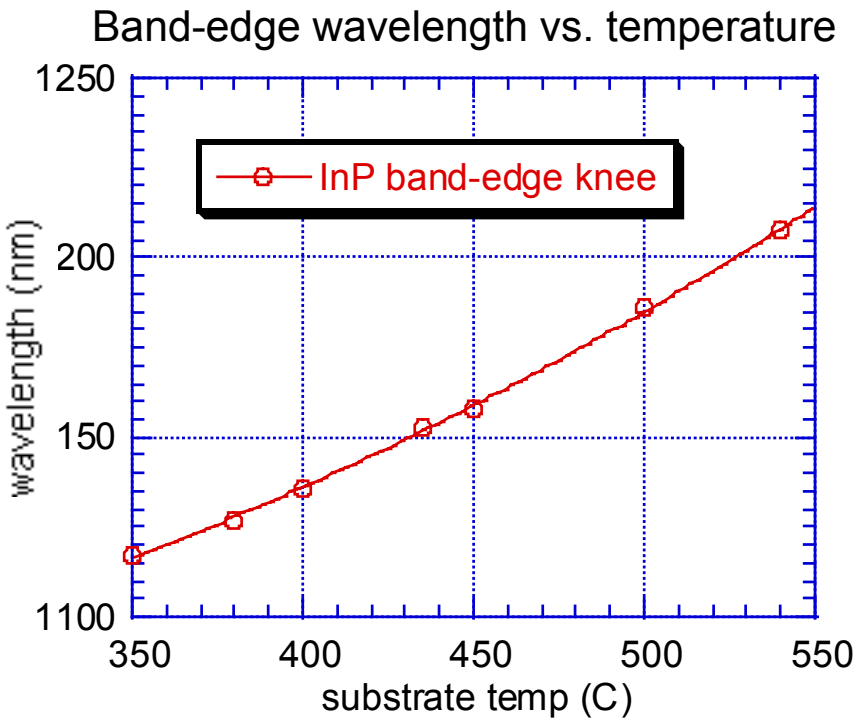
Intelli*EPI*: InGaAs composition vs. runs



- ***OFM real-time monitoring of InGaAs composition during growth.***
- ***Compositional accuracy better than ±1%.***

IntelliEPI: Band-edge Temperature Measurement





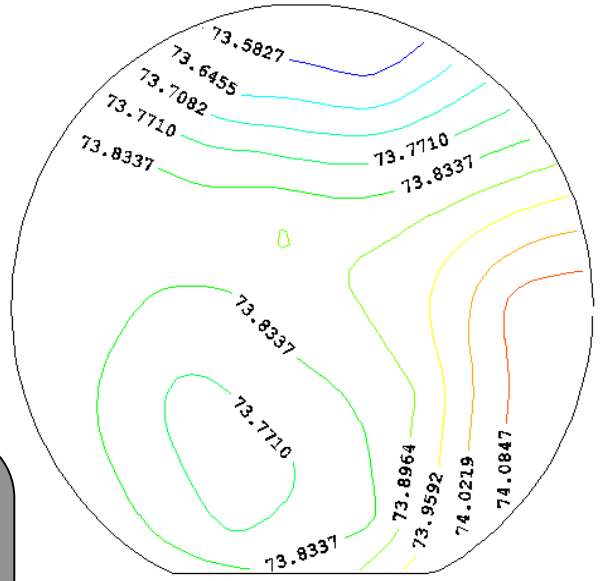
- ***Determine substrate temperature by monitoring shift in substrate band gap as a function of temperature.***
- ***Measurement range extends to substrate temperature well below the operating range of optical pyrometer.***

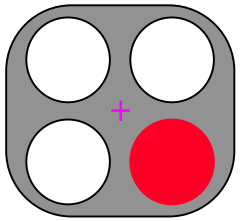
IntelliEPI: InP HBTs - Carbon Doping using CBr4

IntelliEPI has successfully developed carbon doping capability using CBr4 gas source

- *Reproducible InGaAs carbon doping up to 1E20 cm-3*
- *Excellent InGaAs material quality (mobility and x-ray FWHM)*
- *No memory effects*
- *Doping sensitive to growth temp and comp.*
- *Across 4in wafer uniformity (<0.2%)*
- *GaAs carbon doping up to 1E20 cm-3*

IntelliEPI: CBr4 Carbon Doping of P-type InGaAs

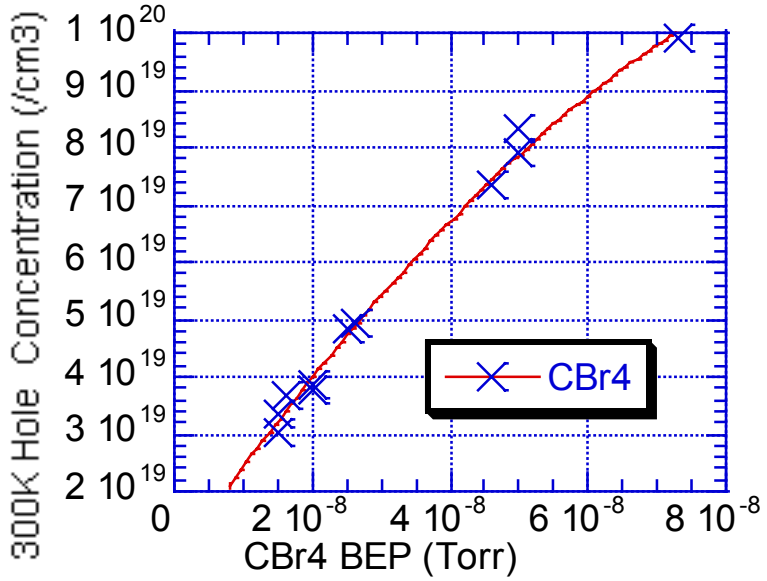


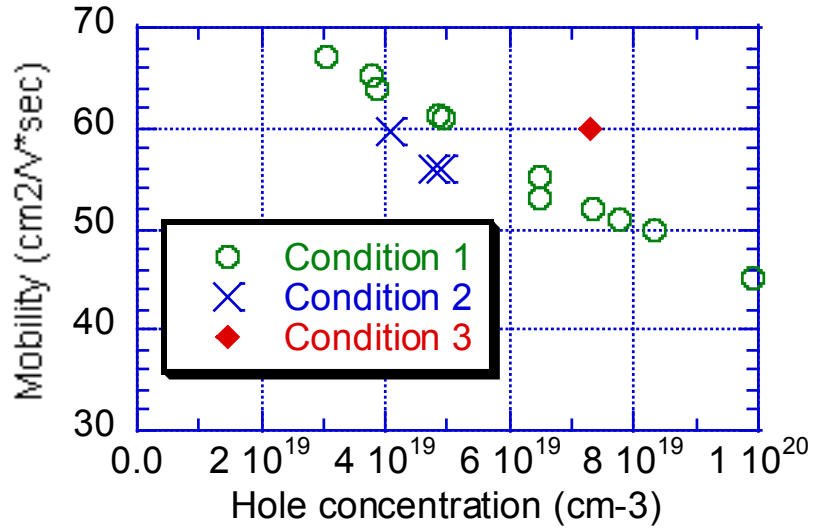


Statistical Summary

Number of Test Points	36
Average Value	73.8482
Maximum Value	74.1416
Minimum Value	73.521
Sample Spread (%)	0.84
Std Dev Value	0.1379
Wafer Uniformity Value (%)	0.19

Magnetoresistance measurement using Lehighton shows the resistivity across 4" wafer grown from a 4x4 MBE system. The film thickness and the hole mobility is 350 nm and 60 cm^2/Vs, respectively.





Intelli*EPI*: Summary

- ***Establish monthly production >150 wafers/mo to customers in US, Japan, Korea, Europe, and Taiwan***
- ***Multi-sensor pyrometry/reflectivity: measures growth rate in real-time***
- ***Optical-based Flux Monitor: instantaneous composition measurement of group III fluxes***
- ***Band-edge absorption:***
  - Absolute substrate temperature measurement
  - Operate down to low temperature range, critical for InP
- ***Carbon doping up to 1E20 cm-3 with excellent uniformity***
- ***Excellent uniformity across wafer platen***
- ***All multi-wafer runs; no single wafer runs***
- ***Correlation of processing results and in-situ measurements results is the most powerful tools for IntelliEPI. It will help both IntelliEPI and our customers in yield/production improvements***