National Aeronautics and Space Administration

Early Stage Technology Workshop

Astrophysics and Heliophysics

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Type II Strained Layer Superlattice (SLS) Materials for Infrared Focal Plane Array (FPA) Applications

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TECHNOLOGY DRIVES EXPLORATION

Non-Proprietary

Company/Research Overview

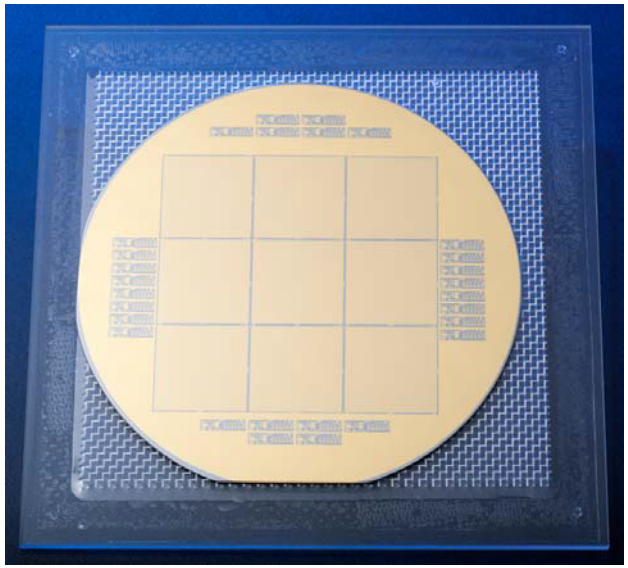
- IntelliEPI IR, Inc. is located in Richardson, TX (Suburb of Dallas)
- Founded in 2010 for advance R&D of infrared materials
- Leverage Intelligent Epitaxy Technology, Inc. (IntelliEPI) commercial III-V compound semiconductor manufacturing infrastructure
- Number of employees: 4 full time, but with access to IntelliEPI resources on as needed
- Revenue breakdown
  - Government: 85%
  - Commercial: 15%
  - Collaborators: NASA, DOE, L-3, Raytheon, QmagiQ, University of New Mexico, and Texas State San Marcos
- Type of business: C-Corp
- Woman/minority/service disabled owned: No

Overview of Technology – Contracts

- Funding Agency: NASA-JPL
  - SBIR Phase I: NNX11CF30P
  - SBIR Phase II: NNX12CA47C
  - SBIR Phase II-E: NNX14CP17C
  - SBIR Phase I NNX14CP35P
- Description: Type II Strained Layer Superlattice (SLS) Materials for Infrared Focal Plane Array (FPA) Applications
- Program Manager: Dr. David Ting (JPL)
- Current TRL level: 3-4
- Additional R&D funding: SBIR/STTR's from DOE and DOD

Overview of Technology – Successes

Prototype 1Kx1K MWIR SLS FPA



Successes:

- Delivered prototype 4-in SLS MWIR detector epi wafer to NASA-JPL for FPA fabrication
- Demonstrated high quality MWIR detector materials with good FPA performance with cut-off wavelength ~ 5 μm
- Demonstrated LWIR SLS detector materials with cut-off wavelength out to ~ 11 μm

MWIR epi-wafer grown on 4-in GaSb successfully processed into 1Kx1K FPAs with 20 um pitch by NASA-JPL.

MWIR thermal Image taken by an SLS FPA fabricated from this wafer. Camera built by NASA-JPL.

Overview of Technology – Uniqueness

What is unique about your technology?

•IR detector technology based on Sb-based materials for FPA applications → high performance and highly manufacturable

- High Quantum Efficiency (QE)
- High pixel yield
- Low dark current
- Simple optical coupling → Simplified fabrication (no-grating or prism needed)
- Large diameter GaSb substrates commercially available up to 4-in → Very large format FPA

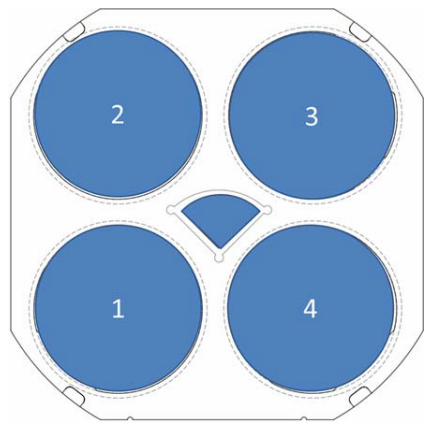
•Leverage commercial III-V compound semiconductor manufacturing infrastructure/foundry

- Epi wafer produce by multi-wafer production Molecular Beam Epitaxy (MBE) reactor
- Rapid technology development transition
- Ensure stable technology platform

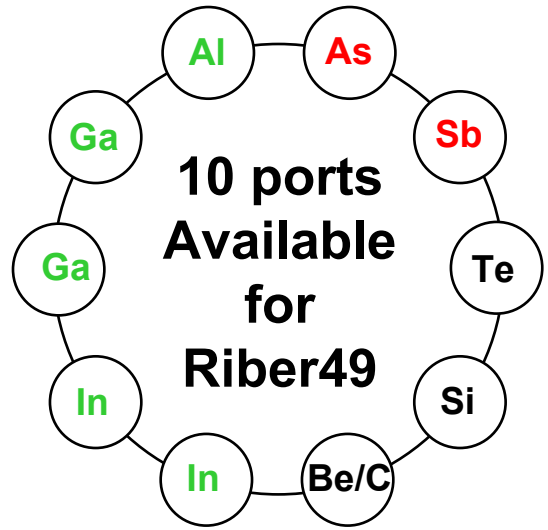
Multi-wafer Production MBE Capability for Sb-based Epitaxy Growth

- Molecular Beam Epitaxy (MBE) reactor is an ultra high vacuum chamber for crystal growth via materials co-deposition
- Riber 49 multi-wafer production MBE reactor
  - Platen: 11x2", 6x3", 4x4", and up to 1x8”
- Proprietary in-situ sensors for real-time growth monitoring
- Scale up to larger size production MBE in development with Riber 6000
  - Platen capable of supporting up to 4x6” or up to single 12”

4x4” platen



Cell Configuration



Multi-wafer production MBE reactor

IntelliEPI-IR

Non-Proprietary

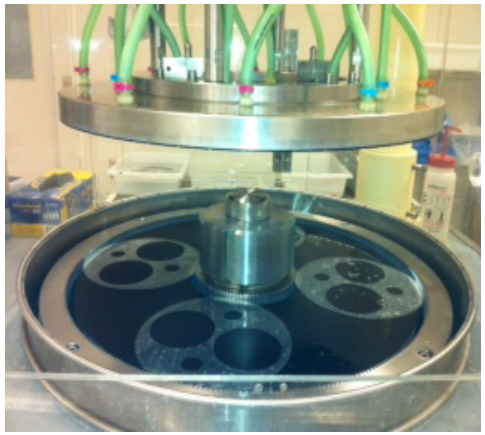
Materials Characterization Capabilities

- Class 100 clean room: (2000 ft^2)
- Characterization tools:
  - X-ray diffraction
  - PL mapping
  - Surface particle scan
  - White light reflection spectrometer
  - Hall measurement
  - Contactless resistivity mapping
  - Electro-chemical CV profiling
  - Electrical CV profiling
  - Mercury probe CV
  - Parameter analyzer
  - Wire bonder
  - Wafer flatness measurement
  - Spectral Ellipsometry
  - FT-IR PL (77K and up)
  - Dark I-V (77K and up)
  - Spectral response (77K and up)
  - Electroluminescence (77K and up)

Epi-ready GaSb Substrate Manufacturing Capability

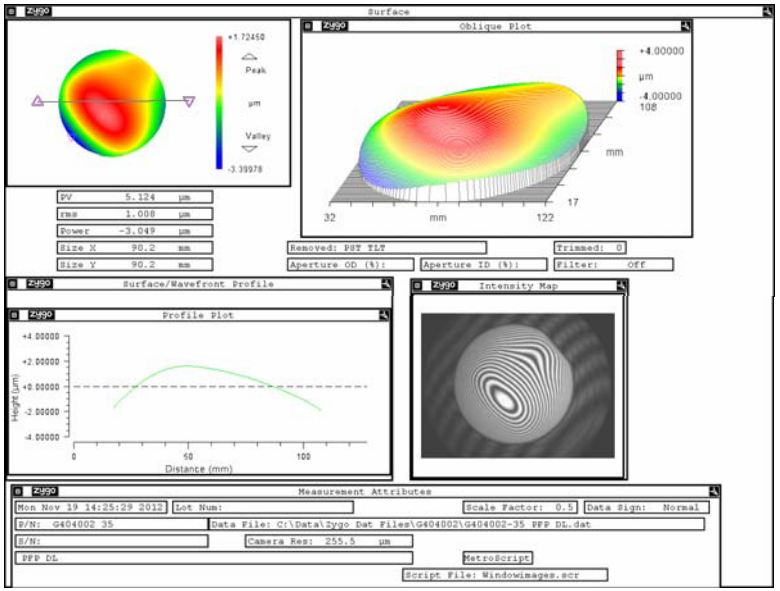
LEC crystal puller

Double side wafer polisher



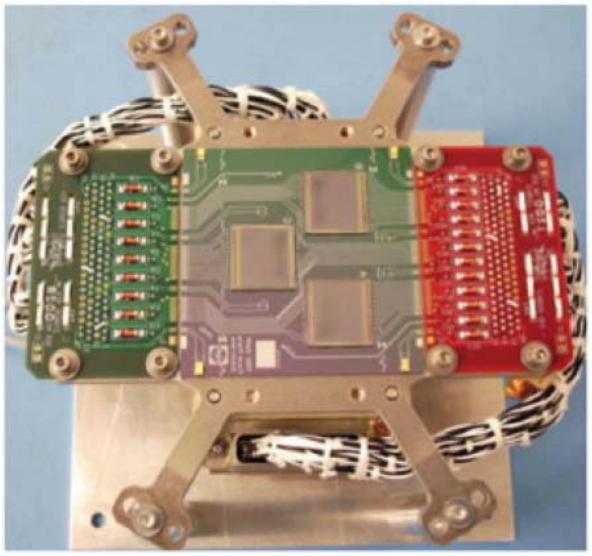
Large Diameter LEC grown GaSb ingot

Flatness map of 4" epi-ready GaSb wafer (~ 5 μm)



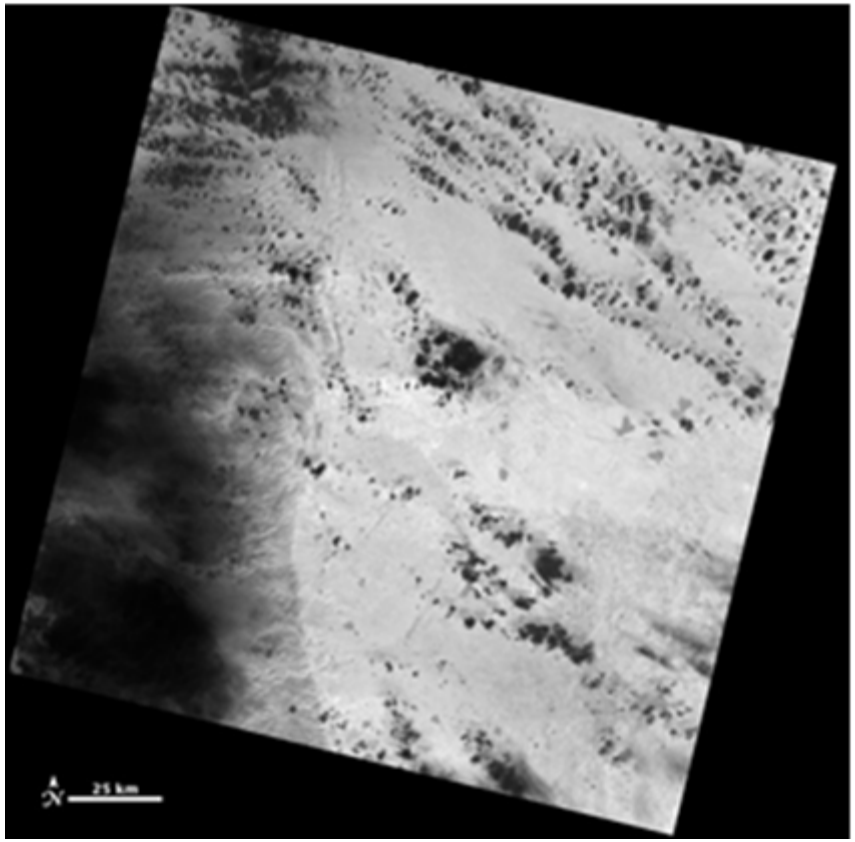
- Commercially available epi-ready GaSb wafer sizes: 2", 3", and 4"
- Wafer flatness control at ~ 5 μm level

Space Qualified Experience



TIRS Instrument with 3 staggered QWIP FPAs

Landsat Data Continuity Mission (LDCM) or LANDSAT 8 satellite with Thermal Infrared Sensor (TIRS) instrument developed by NASA-GSFC on board successfully launched on 2/11/2013. This satellite is a continuation of the Landsat satellite series. The sensor TIRS instrument uses GaAs-based QWIP technology as IR detector materials with 3 QWIP FPAs staggered in the center of the instrument. The TIRS instrument covers two spectral bands:
Band 10 TIRS 1 (10.3 - 11.3 μm)
Band 11 TIRS 2 (11.5 - 12.5 μm)



First thermal image taken by TIRS Instrument

- TIRS instrument team for LANDSAT 8 satellite led by NASA-GSFC and built in collaboration with ARL and QmagiQ
- The FPAs selected for this mission was fabricated by QmagiQ using our QWIP epi materials

IR FPA Technology Comparison

	Operating temperature	MWIR response	LWIR response	Manufacturability	Cost	Prospect for large format	Availability of large diameter substrate
Si micro-bolometer	Un-cooled	Poor	Poor	Excellent	Low	Excellent	Excellent
MCT	Cooled	Excellent	Excellent	Poor	High	Very poor	Poor
InSb	Cooled	Good	N/A	Very good	Medium	Very good	Good
GaAs-QWIP	Cooled	Good	Good	Excellent	Medium	Excellent	Excellent
GaSb-based SLS	Cooled	Very good	Very good	Good	Medium	Excellent	Very good

- For HOT-MW, Type II materials has demonstrated higher operating temperature (up to 150K) compared to InSb (~ 80K)
- Type II SLS offers both performance and manufacturability especially for large format FPA applications
- Domestically supplied GaSb substrate commercially available up to 4-in for large format or manufacturing needs

Target Technology Market Applications

NASA applications

- High performance infrared detector materials platform for NASA earth, planetary science, & astrophysics missions
- Europa Jupiter System Mission (EJSM)
- Hyperspectral InfraRed Imager (HyspIRI)
- Next generation Thermal Infrared Sensor (TIRS) for Landsat satellite

Non-NASA applications

- Defense thermal imaging/night vision/FLIR for vehicles and perimeter surveillance, & missile defense
- Trace chemicals based on sensing unique emission including hyperspectral imaging
- Bio-medical applications such as tumor identification
- Environmental and industrial such as gas sensing

Technology Development Strategy

Challenge: IR detector epitaxy materials based on Type II SLS technology for FPA application still in development

- High barrier to entry for FPA fabrication house without epi expertise—niche specialty trade
- For commercialization, technology transition from R&D to manufacturing needs to be effective and scalable

Solution: Establish baseline device/structure library in conjunction with epi wafer foundry

- Enable customers to have access to detector epi capability without having to develop costly internal epi capability
- Epi development directly with multi-wafer production MBE → Rapid technology transition from R&D to commercialization
- Possibility to scale up to larger production MBE reactor for larger capacity needs or larger size substrate

Business Development Strategy

Thermal image taken by QmagiQ 2 generation 640x512 SLS camera

Operating at 77K

λ(cut-off): 9-10 μm

Epi development funded by SBIR

Early engagement with key customers/FPA fabrication partners

- Ensure compatibility of IR detector materials technology development with customers' processes
- Leverage customer marketing capability and distribution channels to maximize business opportunities
- Pursue external funding opportunities together with strategic partners
  - Leverage SBIR for joint technology/product development with customers

Current Development Status of Technology

Current status by spectral band

- MWIR (3 – 5 μm) Demonstrated large format FPA, closest to commercialization
- LWIR (8 – 12 μm): Demonstrated cut-off wavelength to ~ 11 μm, FPA verification on-going
- VLWIR (> 12 μm cut-off): Need further development to demonstrate high QE for hyperspectral applications
- Multi- or dual-band (SW/MW, MW/MW, MW/LW, & LW/LW): Need further development

What will it cost to advance this technology? (ROM cost)

- Single band development: Need ~ $0.5M to $1M to optimize epi materials for each band, and more for VLWIR
- Multi- or dual-band: Need ~$1M to $2M depending on the applications

Why should NASA, Industry, and other government agencies invest in this technology?

- Enable next generation high-performance IR imaging technology
- Potential technology to support NASA future missions/needs such as EJSM, HyspIRI, & next generation TIRS instrument
  - High performance
  - Lower cost alternative to HgCdTe technology
  - Large format FPA possible with 4-in GaSb substrate commercially available
- Technology platform for other applications in defense, environmental monitoring, industrial, and bio-medical

Summary of Key Points

- Expertise in MBE growth of IR detector wafer based on type II SLS materials system
- SLS detector technology offers several advantages
  - High performance
  - Manufacturable by leveraging commercial III-V compound semiconductor
  - Large format FPA possible with availability of large diameter substrate
- Experience with flight qualified deliverable

Manufacturing & facility capabilities

- Epi foundry based on multi-wafer production MBE growth capability with larger reactor platform for scale up
- Extensive in-house materials/device testing capability
- Domestic epi-ready GaSb manufacturing line with up to 4-in commercially available

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