RFMD

UF MURI Kickoff
MURI Kickoff Agenda

• Introductions
• RFMD Background
• RFMD Technologies
• Reliability Processes and Technology Qualifications
• Reliability Issues and Examples
• Future Trends
Introductions

• Dr. Michael Fresina
  – Director, Device Engineering, Wafer Fabs
  – Responsible for new technology development, fab test engineering, characterization and reliability

• Dr. Michael Antonell
  – Senior Manager, WW FA, REL, AS
  – Responsible for failure analysis, corporate reliability lab and advanced analytical solutions
  – UF MURI liaison
RFMD at a Glance

Important Facts

• Global employees: 4,000+
• Founded in 1991
• ISO 9001 and ISO 14001 certified
• FY08 revenue: U.S. $957.6 million
• FY08 pro forma operating income: U.S. $13.5 million
• FY07 total assets: U.S. $2.121 billion
• NASDAQ: RFMD
• Website: www.rfmd.com

Mission

• To extend and leverage our leadership in RF components and compound semiconductor technologies into multiple industries.

End Markets

• Mobile handset and device
• Wireless data
• Wireless infrastructure
• Aerospace and defense
• Broadband and consumer
• General Purpose RF components
Global Reach — 4000+ Employees

- Sales and Customer Support Centers, Sales Offices
- Factory Operations
- Design Centers

RFMD
Global Operations

**Greensboro, NC:** Molecular beam epitaxial (MBE), compound semiconductor fabrication and test

**Beijing, China:** Semiconductor assembly, internal module packaging, tape and reel

**Broomfield, CO:** Aerospace and Defense assembly and test

**Brooksville, FL:** Signal source component design; MCM manufacturing and test

**Newton Aycliffe, UK:** GaAs pHEMT fabrication facility

**Nuremberg, Germany:** CATV component design and manufacturing

**Shanghai, China:** Passive component manufacturing, ETS in-sourcing, integration, and board-level and subsystem assembly
The Optimal Fit

Through Optimum Technology Matching® (OTM), RFMD engineers match the appropriate technologies to each product according to the best possible combination of price and performance.
RFMD Technology Portfolio

• External Foundries
  - Foundry responsible for qualification including reliability.
  - RFMD is sourcing established process technologies.

• Internal Technology
  - RFMD technology development and qualification.

- SiGe
- CMOS
- GaAs MESFET
- Silicon BJT
- AlGaAs HBT
- InGaP HBT
- GaAs pHEMT
- Gallium Nitride (GaN)
- GaAs BiFET
- SAW Filters
RFMD Internal Compound Semiconductor Technologies

- **AlGaAs HBT**
  - Initial process licensed & transferred from TRW
  - Be-doped base
  - 4th generation in production
  - Internal MBE epi supply

- **InGaP HBT**
  - C-doped base
  - 2nd generation in production
  - External MOCVD epi

- **GaAs pHEMT**
  - 2nd generation in production
  - Switch and PA applications
  - Internal MBE epi

- **GaAs BiFET**
  - 2nd generation in production
  - Switch and PA applications
  - Internal MBE and external MOCVD epi

- **SAW Filters**
  - 1st generation in production
  - LiTaO substrates, AlCu metal

- **GaN HEMT**
  - 1st generation in production
  - External MOCVD epi
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Reliability Testing for Technology Qualifications

- Discrete device “3-temp” lifetest
  - Usually 3+ temperatures
  - Typically multiple current densities (HBT) to determine SOA
- Early in development process depending upon risk
- Std criteria is MTTF(125) > 1E6 hours (prefer LCL)
- Migrating towards FIT predictions
  - Failures-in-time, failure rate for first N years (typ 7)
  - Considers predicted failure distribution at use condition
  - Scaled to typical application
- Also various environmental tests (ESD, THB, HAST)
Life Test Procedures

- Discrete device
- Max bias conditions, or varied to extract SOA
- Ambient temps selected for max $T_j$ typically < 300-320.
- Lower temps almost always run eventually to verify $E_A$

Self Heating

- IR
- Electrical methods
  - Yeats, Bovolon
  - $T_{sh,IR} < T_{sh,Electrical}$
  - Use IR for conservative reliability estimates

![Graph showing relationship between Tamb and $T_{sh}$](image)
Life Test Data Analysis

Figure 13. Plot of %T0 Beta at temperature vs. time
(FAB3, ambient T = 260 C)

Figure 14. Probability plot for HBT6 life data
(all data, at temperature)
Typical Failure Analysis

- **Pre- & post electrical baseline**
- **Non-destructive**
  - Visual
  - PEM
  - SEM
  - High Res x-ray
- **Destructive**
  - FIB
  - “de-processing”
  - Laser isolation

More important when we are not meeting reliability requirements!
Example: HBT Reliability Issues

- **Failure modes generally assumed:**
  - Be-diffusion
  - REDG
  - Both very difficult to identify/verify

- **Excess unpassivated base surface** increased surface recombination and REDG leading to early beta wearout.
Example: FET Reliability

• **Ohmic degradation**
  – Changes to access resistance

• **Gate sinking**
  – Metal-semiconductor interaction
    • Gate leakage
    • Barrier height changes
  – Intermetallic mixing
Future Trends: Technology and Reliability

• Technology
  – More integrated processes (multiple active devices on same substrate)
  – Smaller devices
  – Higher density circuits

• Reliability Testing
  – Production screening (WLR?)
  – More V&I acceleration to compliment temp acceleration
  – Step stress test

• Failure Analysis
  – $T_{sh}$ measurements
  – p-n junctions location, defects, and doping non-homogeneities
  – Chemical/physical analysis of intermetallics and interdiffusion products