Sandia National Laboratories

Heterogeneous Integration/ Advanced Packaging

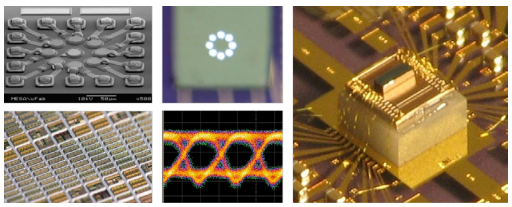
Enabling Next-Generation Electronic Microsystems

Sandia National Laboratories has developed several state-of-art heterogeneous integration capabilities to enable prototyping of high performance electronic, optoelectronic and micro-electromechanical systems (MEMS) for national security applications. Intimate integration of dissimilar materials and functions enables the use of individually optimized microelectronics, photonic devices, optical elements, and MEMS sensors/actuators to offer unprecedented functionality while improving overall component size, weight, and performance, compared to conventional packaging approaches.

Heterogeneous integration processes leverage the Sandia MESA complex, a 65,000 sq. ft. research, development and production facility with extensive silicon and compound semiconductor microfabrication tool sets. Relevant integration methods range from wafer bonding of materials to precision flip-chip assembly of devices and materials. Microsystems targeting a wide range of applications have been demonstrated, combining materials such as silicon, InP, GaAs, GaSb, GaN, AlN, diamond, and glass.

Optical Data Communications for High-Performance Computing

- GaAs- and InP-based VCSELs, modulators, photodiodes
- Dense integration onto 32-nm and 45-nm CMOS
- Silicon photonics on high-speed silicon ASIC
- Independent optimization of electronics and photonics



Si & III-V Based Sensors & Imagers

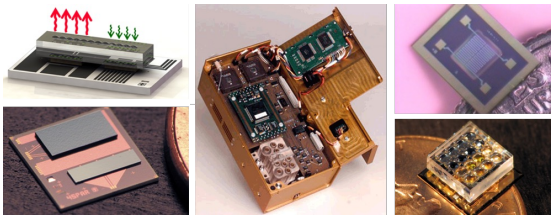
- Si (UV, visible, soft x-ray), GaAs (x-ray), GaSb (medium- and long-wave IR) detector arrays for large-format Focal Plane Arrays (FPAs)
- 10-50 µm indium bump bonding, underfill, & thinning
- Custom embedded & coated anti-reflective coatings
- <10 - 40 µm hybrid oxide-metal-bonding
- Hybridization to silicon Read-Out Integrated Circuits (ROICs) with >99.99% interconnect yield

Heterogeneous III-V/CMOS Microelectronics

- Complementary integration of GaAs and InP microelectronics
- III-V microelectronics circuitry on CMOS ASICs

MEMS-based Microsensors

- Micro-Electromechanical Systems (MEMS)-based inertial sensors integrated with custom microelectronics
- Chem and bio sensors using MEMS and Surface Acoustic Wave (SAW) devices
- Hybrid device integration with custom micro-optics

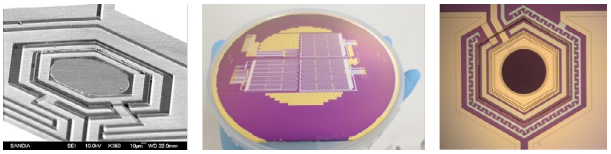


Extreme Environment Applications

- Custom RF, photonics, optics, and electronics for cryogenic interconnects
- Advanced CMOS, RF, optoelectronics, MEMS, and integration for radiation-hardness
- High-power emitters on AlN and diamond
- RF packaging for high-speed test and measurement

Microsystem-Enabled Photovoltaics

- Wafer-level bonding for multi-junction solar cells
- InGaAsP/InP and InGaP/GaAs devices on silicon
- Dielectric interfaces with III-V substrate removal
- Integration with collection optics



MESA Research | Develop | Produce

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Advanced Packaging

The development of enabling photonic/electronic microsystems requires more than the invention of new and unique devices and structures. These devices must be individually packaged and interconnected to function together as an integrated system that can communicate effectively with the external world. One must understand the application requirements to anticipate and address a number of multidisciplinary engineering challenges. To maximize chances of success, packaging, assembly, and integration should be considered as early as possible.

Sandia staff members have many decades of experience developing not only first-of-a-kind R&D devices, but also high-reliability devices for space and national defense applications, as well as commercial products. Just a sample of recent and current projects includes high-speed, high-resolution X-ray cameras, remote sensors for space deployment, a variety of quantum devices operated at cryogenic temperatures, and autonomous chemical microsensor systems. We can help evaluate a variety of packaging and integration options, anticipating and addressing manufacturability, rework, thermal management, and materials compatibility issues. Strategic partnerships within Sandia as well as with other national laboratories, universities, and private industry enable the development and implementation of advanced microsystems packaging solutions with the greatest value.

Trusted Packaging Capabilities

Seal and Encapsulation

- Hermetic ceramic packaging
  - Solder lid seal
  - Parallel seam sealing
- Glob top
- Dam and fill

Packaging and Assembly Design/ Development

- **Package design (silicon, ceramic, glass, and plastic substrates & interposers)**
- Thermal management
  - Materials selection and evaluation
- Packaging and assembly process development
- Full custom microsystems integration

Custom Packaging and Assembly

- Multi-chip modules
- **Metal diffusion bonding (Cu-Cu, Au-Au, In-In)**
  - Die-to-die, wafer-to-wafer, and die-to-wafer
- **Hybrid bonding (ultra fine-pitch oxide-metal-bonding)**
- MEMS packaging and assembly
- RF assembly
- Optoelectronic assembly
- Flex circuit assembly
- Surface mount assembly
- Rework and repackaging

Dicing

- Dicing of:
  - Si, glass, quartz, and various ceramics and organics up to 200 mm wafers
  - Thinned wafers
  - Multi-project wafers

Packaging Technologies

- ISO 9001 registered high-reliability ASIC packaging
- Hermetic ceramic and plastic high reliability packaging (all standard configurations)
- RF and optoelectronics packaging
- MEMS packaging
- Flex and surface mount assembly
- Rapid hybrid microsystems prototyping
- **Ultra-miniaturization (3-D packaging and 3-D Integration)**

Die Attach

- Manual and automated, precision die placement
- Conductive and nonconductive organic (epoxy) die attach materials
- Eutectic die attach

Wire Bonding

- Manual and automated wire bonding
- Aluminum and gold wire
  - Wedge and ball bonding
- Fine pitch (down to 50 μm)
- High wire count
- Wire bonding to ceramic, organic and metal packages

Flip Chip Assembly

- Eutectic and high Pb solders
- Au stud bumping (wafer or die)
- Plastic and ceramic substrates
- **Precision underfill**

For additional information, visit our website at:
www.sandia.gov/mesa

MICROSYSTEMS ENGINEERING, SCIENCE & APPLICATIONS

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