Low-Cost Direct Bonded Aluminum (DBA) Substrates

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Project ID #:
PM036

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Overview

Timeline

- Project start: October 2010
- Project end: September 2013
- Percent complete: 16%

Budget

- Total project funding
  - DOE 100%
- FY11: $300k
- FY12: $300k
- FY13: $300k

Barriers*

- Barriers Addressed
  - High cost per kW
  - Low energy per kg
  - Low energy density
  - Insufficient performance and lifetime
- Targets:
  - DOE VTP* 2020 target: $3.3/kW
  - DOE VTP* 2020 target: 14.1 kW/kg
  - DOE VTP* 2020 target: 13.4 kW/l
  - 15 year life

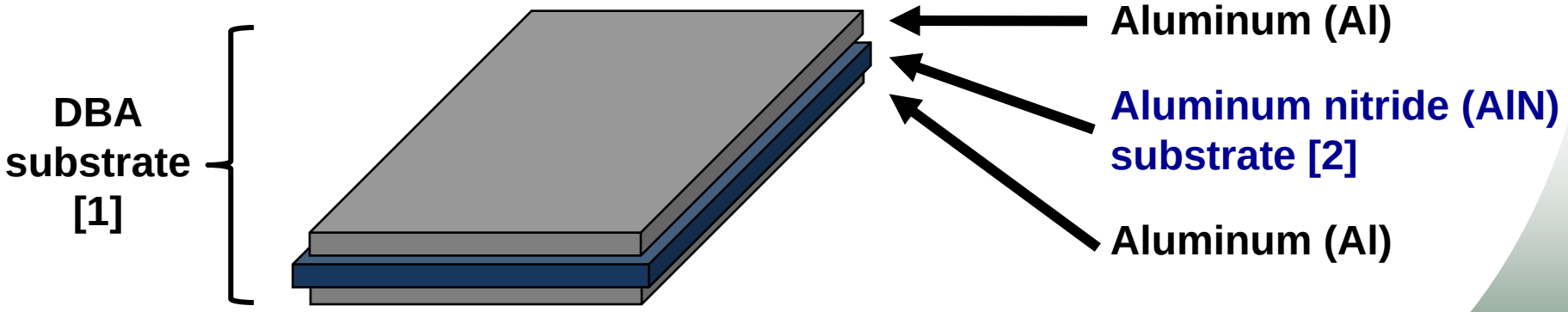
Partners

- NTRC – ORNL
- Will seek industrial collaborators in FY12

* VTP Multi-Year Program Plan 2011-2015

Objectives

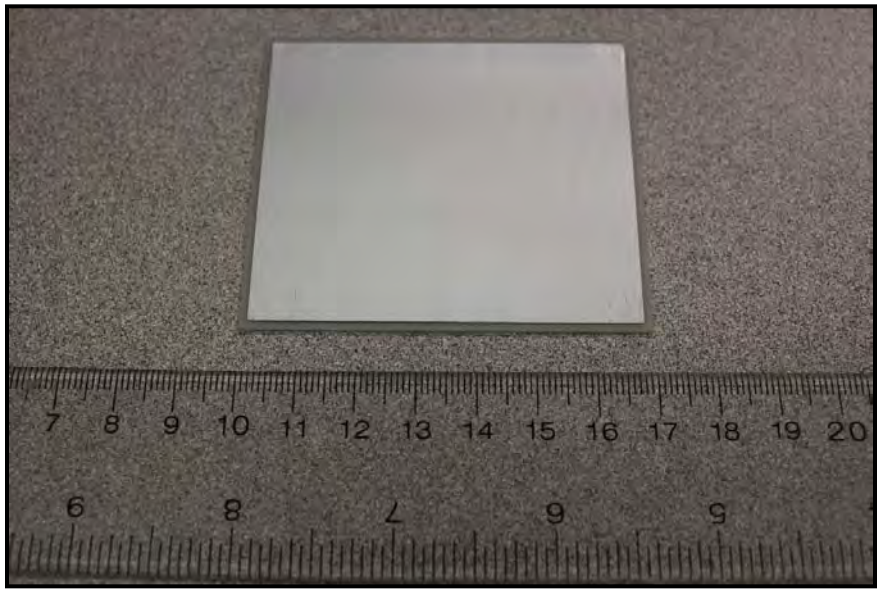
- Develop low-cost, high quality, and thermomechanically robust direct-bonded aluminum (DBA) substrates.
- Use ORNL's in-house unique processing capabilities to fabricate innovative DBA substrates using a process that is amenable for mass production and that produces high adhesive strength of the ceramic-metal interfaces.
- Consider the fabrication and use of low-cost AlN as a contributor to the low-cost.



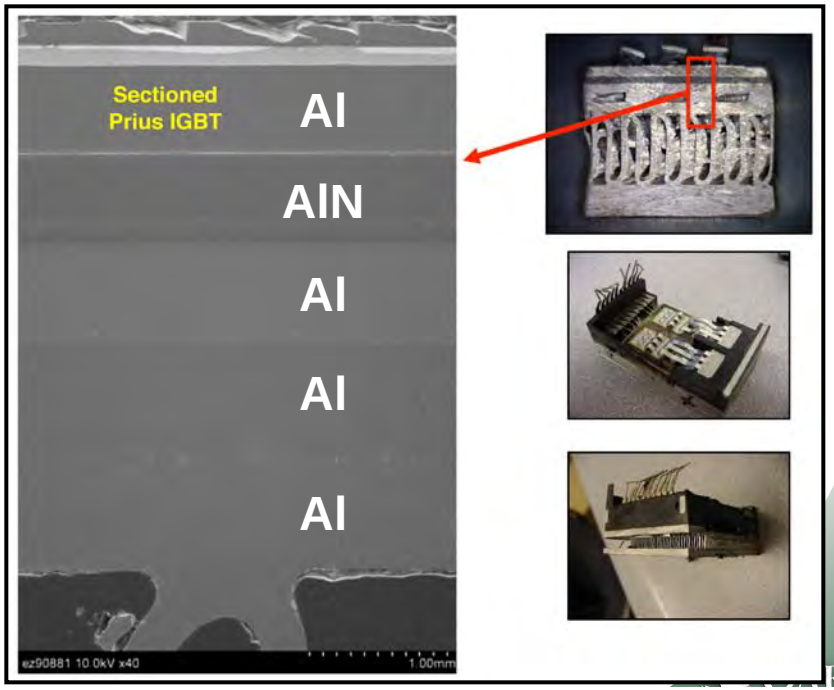
Milestones

- ✓ **FY11 - 1: Survey conventional and alternative processing methods to directly bond Al to Al_2O_3 (and AlN).**
- ✓ **FY11 - 2: Down-select processing method most likely to produce high strength bonding between Al and ceramic.**

Example of a commercial DBA (with AlN) substrate



Example of Al to AlN bonding in 2010 Prius IGBT



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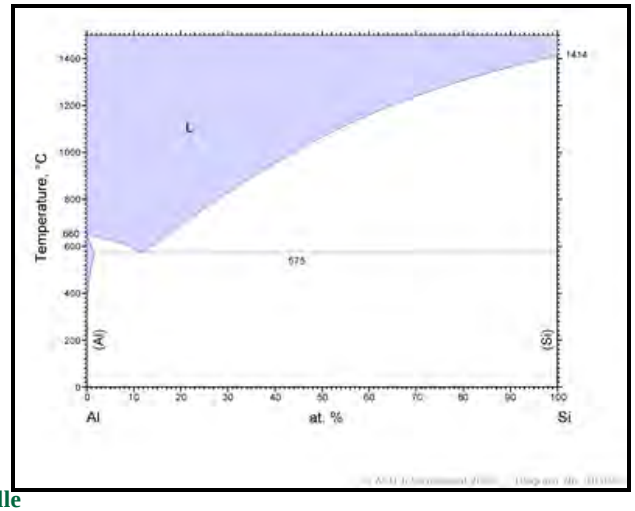
Technical Approach

- Study patent and open literature for DBA fabrication.
- Identify alternative processing method to fabricate large-sized DBA substrates that has potential for low-cost manufacture. This is the first primary step in creating availability of low-cost DBA substrates.
- Develop method to fabricate low-cost AlN substrates. The use of a low-cost AlN immediately results in lower-cost DBA substrates.
- Benchmark existing commercial DBA substrates for eventual comparison against DBA substrates fabricated in this project. Also benchmark select commercially available direct bonded copper (DBC) substrates.
- Develop test method(s) to measure interfacial shear strengths of Al-ceramic interface.

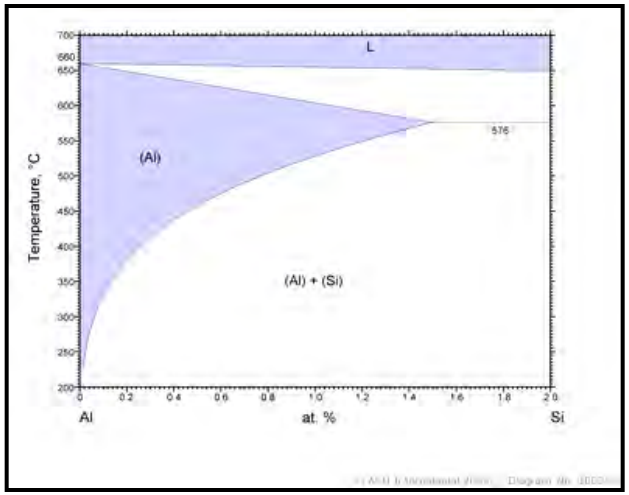
Technical Accomplishments

- **Literature survey ongoing (phase diagrams, existing patents, aluminum-ceramic bonding)**
- **Acquiring commercial DBA and DBC substrates for microstructural, shear strength, thermal conductivity, coefficient of thermal expansion, and thermal cycling benchmarking.**
- **Considering alternative low-cost means to fabricate AlN substrates (for later inclusion in DBA substrates).**

The phase diagrams of Al alloys are under consideration



Udovskii, et al., 1995.



Fuefel, et al., 1997.

Future Work

- **Develop low-cost, high quality, and thermomechanically robust direct-bonded aluminum (DBA) substrates.**
- **Use ORNL's in-house unique processing capabilities to fabricate innovative DBA substrates using a process that is amenable for mass production and that produces high adhesive strength of the ceramic-metal interfaces.**
- **Consider the fabrication and use of low-cost AlN as a contributor to the low-cost.**

Summary

- Identifying alternative processing method(s) to fabricate DBA substrates having potential for low-cost manufacture.
- Benchmarking commercial DBA substrates to better understand bonding character of Al-ceramic interface.
- Developing method to quantify shear strength of Al-ceramic interface.
- Developing method to fabricate low-cost AlN for use in the DBA substrates.