Low-Cost Direct Bonded Aluminum (DBA) Substrates

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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$_2$O$_3$ (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.

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.