Bonding Similar and Dissimilar Lightweight Materials using Reactive Nanofoils

- A Concept Feasibility Study

Presenter: Mark Smith

Principal Investigator: Xin Sun

Pacific Northwest National Laboratory

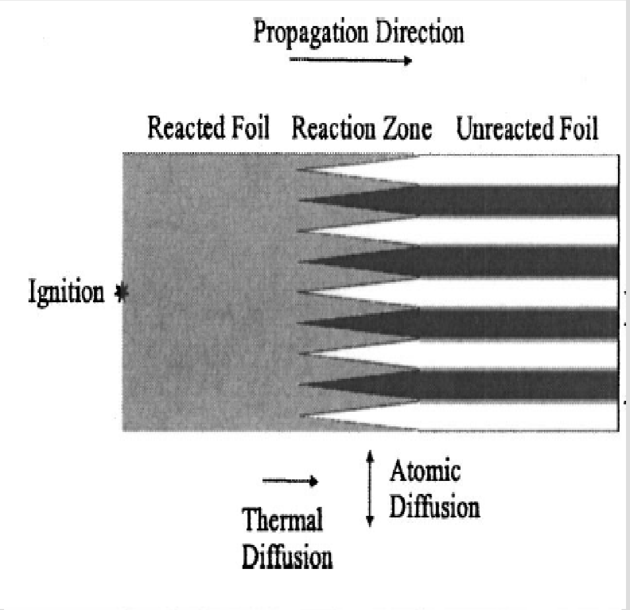
February 26, 2008

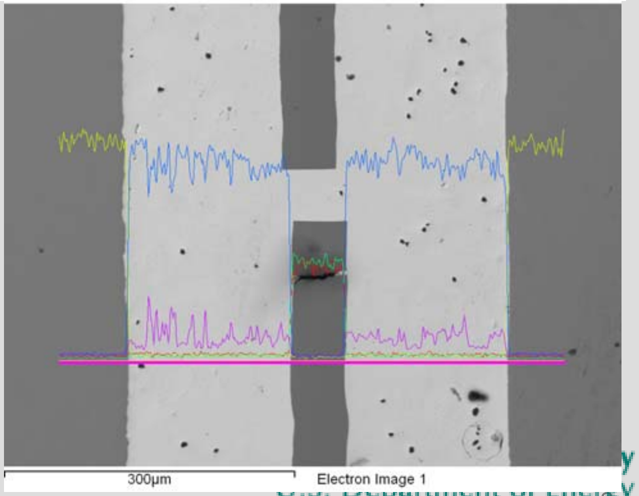
Purpose of Work

- **Ultimate Goals:**
  - Enable further vehicle weight reduction by investigating new, reliable and cost-effective joining methods for similar and dissimilar lightweight materials including metals and polymers.
- **Objectives of the Concept Feasibility Study:**
  - To provide objective bond strength evaluation for NanoFoil bond in comparison with conventional bonding methods.
  - Provide cost and cycle time analyses of using reactive NanoFoil in mass production environment.

Technical Barriers

- Drawbacks of current joining methods for metals:
  - High heat/energy input
  - Compromise/destroy the designed base material properties
- Lack of reliable and cost-effective joining methods for dissmilar metals and metals/composite/ceramic
- RNT bonding is a brand new joining technology:
  - Lack of quantitative joint performance comparisons between nanofoil bonds and conventional joining methodologies
  - Lack of cost and cycle time analyses on using reactive nanofoil bonding in mass production





Technical Approach

- Acquire or produce nanofoils of various layer thickness and lay-up
- Quantify amount of heat generation for each nanofoil lay-ups
- Braze/solder steel, Al, Mg and other dissimilar material combinations with nanofoils based on the heat input calculations of Task 2
- Examine possible microstructure modifications of base material
- Perform bond strength tests
- Compare tested bond strength with conventional adhesive bond
- Perform economic feasibility study by considering raw material cost, bond strength quality, cycle time, etc. in comparison with conventional bonding methods
- Provide technical report on findings of above 7 tasks.

Accomplishment

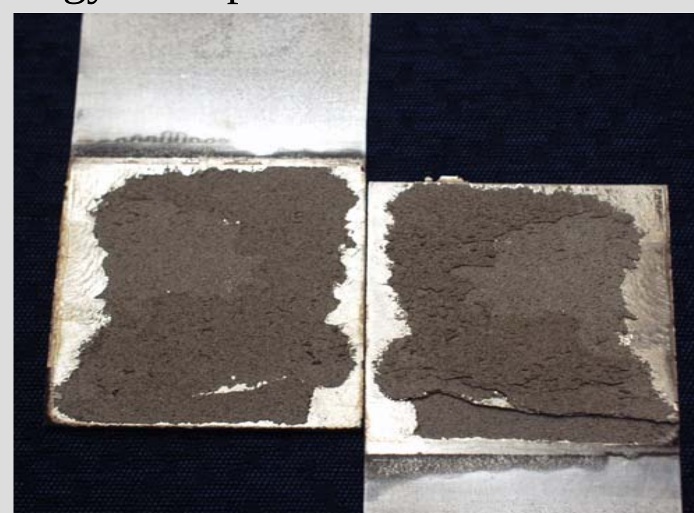
- 1.4mm SAE1008/1.4mm SAE1008 solder joint:
  - 96.5Sn-3.5Ag pre-applied to bond surface on a hot plate using flux
  - Failed in base material
  - Very strong bond, nominal strength > 10.6MPa
  - Very small strength variation: testing base material
  - High energy absorption

- 2mm AA5182-O/2mm AA5182-O solder joint:
  - 96.5Sn-3.5Ag pre-applied to samples on a hot plate using mechanical agitation
  - Cohesive failure at bond surface
  - Nominal bond strength: 6.3MPa – 9.5MPa
  - Large strength variation
  - Sample bent, ductile bond failure: energy absorption

Accomplishment

- 2mm AA5182-O/2mm AZ31 solder joint :
  - Al: 96.5Sn-3.5Ag pre-applied to samples on a hot plate using mechanical agitation
  - Mg: Samples vapor metallized with Ti/ Incusil braze, Incusil = 61.5Ag-23.5Cu-15In
  - Adhesive failure at bond surface
  - Nominal bond strength: 2.86MPa – 4.9MPa
  - Large strength variation
  - No sample bending, very brittle bond, minimal energy absorption

- 2mm AA5182-O/2mm AA5182-O braze joint:
  - Samples metallized with 95Ni-5Al via thermal spray (wire arc spray)
  - NanoFoil coated with thin braze (Incusil) layers.
  - Braze on NanoFoil melts and sticks to Ni coating.
  - Cohesive failure at bond surface
  - Nominal bond strength: 7.5MPa-8.02MPa
  - Small strength variation
  - Sample bent, ductile bond failure: energy absorption



Accomplishment

- Bond strength comparison with adhesion bonding:
  - Cohesive failure at bond surface
  - Nominal bond strength: 7.2MPa
  - Sample bent, ductile bond failure: energy absorption

- Developed cost model for nanofoil:
  - Initial capital cost and depreciation
    - Strongly depends on line speed and deposition rate
  - Operations cost
  - Foil thickness optimization
  - Raw material cost

Activities for Next Fiscal Year

- Strength improvement for Mg/Al bond
- Explore metal/polymer bonding with nanofoil
- Explore alternative interlayer materials
- Further refine cost model
  - Explore process envelope
  - Deposition rate

Technology Transfer

- Maintained close interactions with OEM, Tier 1 suppliers and nanofoil supplier:
  - Materials Tech Team Joining subcommittee
  - MFERD joining team
  - Reactive Nano Technologies (RNT)
  - MAGNA
- Publishing and presenting research results in Sheet Metals Welding Conference XIII, May 2008.

Summary

- Potential for petroleum displacement
  - This project provides objective bond strength evaluations and cost analyses on reactive nanofoil bonding to enable joining of dissimilar lightweight materials in vehicle applications – Enabler for lightweighting
- Technical Accomplishments
  - On target with project objective and timeline
- Technology transfer
  - Continue close interactions with the nanofoil manufacture and OEM, supplier joining experts
- Plans for next year
  - Continue development work in joining dissimilar metals and metals/composite
  - Refine cost modeling

Publications and Presentations

1. Strength Evaluation of Reactive Nano-Foil Bonded Joints for Automotive Applications, Xin Sun and Alan Duckham, to be presented at and to be in the *Proceedings of the XIII Sheet Metal Welding Conference*, May 2008. Detroit, MI.
2. Bonding Similar and Dissimilar Lightweight Materials using Reactive Nanofoils, Xin Sun, *invited presentation at the MFERD Joining Team Meeting*, Feb. 4, 2008. Southfield, MI.