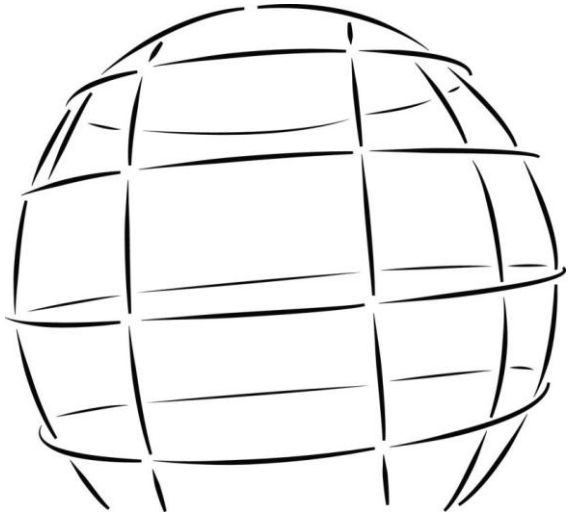
Dow Automotive Systems

Adhesive Solutions for Vehicle Lightweighting



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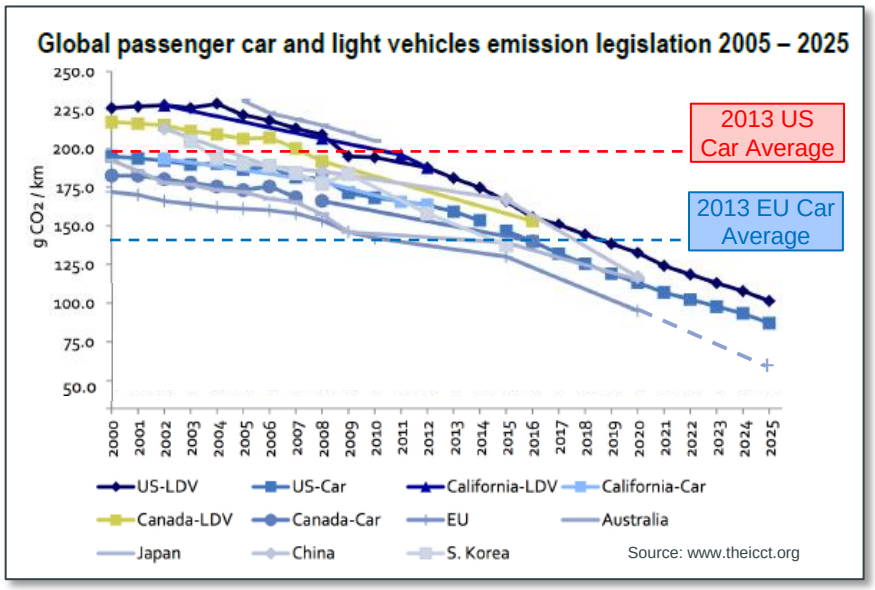
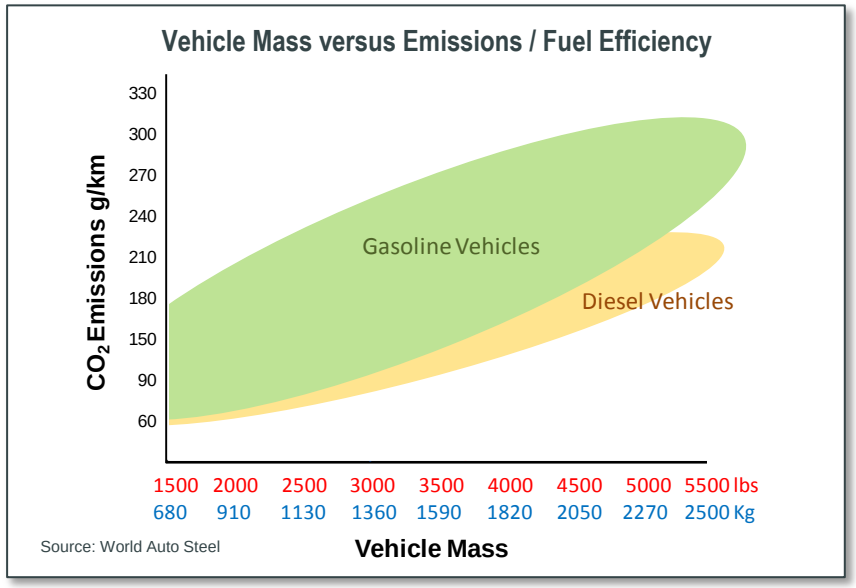
Dowautomotive.com

Why Mass Reduction?

Powertrain improvements alone cannot achieve the fleet fuel efficiency/emissions targets

- Mass reduction is vital for car makers to avoid fuel efficiency or emissions legislated penalties
  - 10% mass reduction = +6-8% fuel efficiency including secondary mass (and cost) reduction of powertrain / chassis





Why Adhesives?

Alternative, lighter weight materials of construction will be required

Adhesives are an enabler for joining dissimilar materials

Decreasing Density of Materials

Coefficient of Linear Expansion α of Substrates at 20° C, µm/m/° C	
Steel	11-13
Aluminum	21-23
Magnesium	26
Continuous CFC	0
CFC Molding Compound (CLTE influenced by fiber content, fiber length and orientation)	5-20

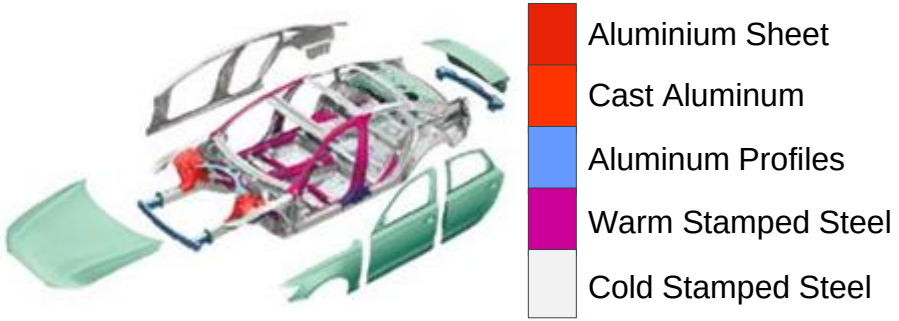
Why Adhesives?

- **A challenge** for lightweight material implementation in vehicles is **effective joining technologies especially for dissimilar, lightweight substrates** such as high strength steel, aluminum, magnesium and composites.
- **Epoxy and polyurethane structural adhesives** are an **enabling technology for dissimilar material assembly,** where traditional joining techniques such as welding and riveting are limited in their applicability.

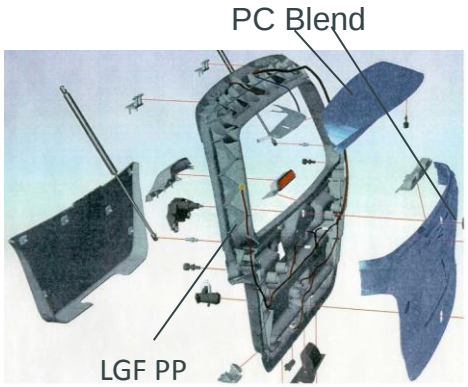
Full Body Bonding

CFRP Structure

Module Bonding



Multi-Material Use



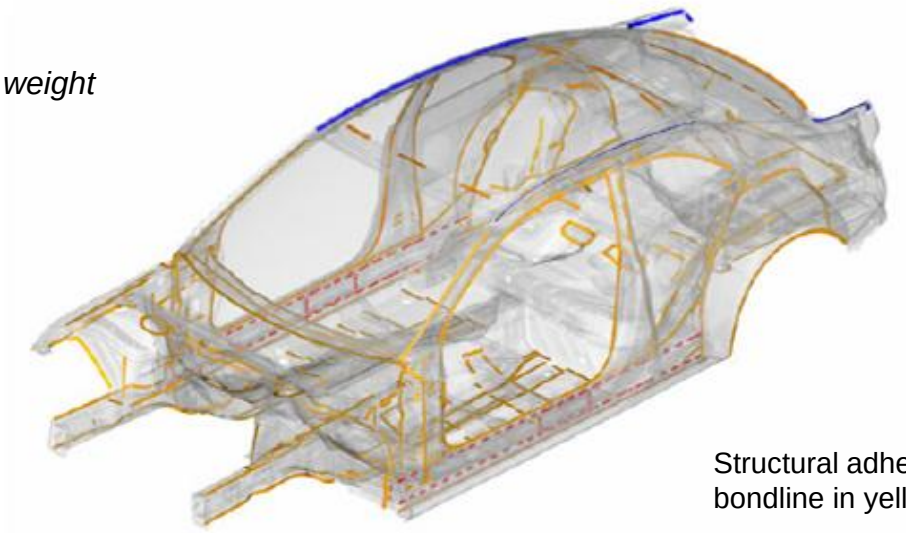
Light Weight Closures

Why Adhesives?

- Other benefits of structural adhesives:
  - **Increased load bearing capability, static and dynamic stiffness**
  - Leads **to improved safety and crash behavior, reduced vibrations and noise, optimized ride, driving and handling characteristics and extending the vehicle life span** and long-term value via higher durability

- The value of lightweight is even more pronounced **in electric vehicles** as a way to offset the additional battery load (up to 900Lbs) and to extend the vehicle range.

  - *Break the trend of increasing body weight*
  - *Multi-material use in body shop*
  - *Bonding full aluminium vehicles*



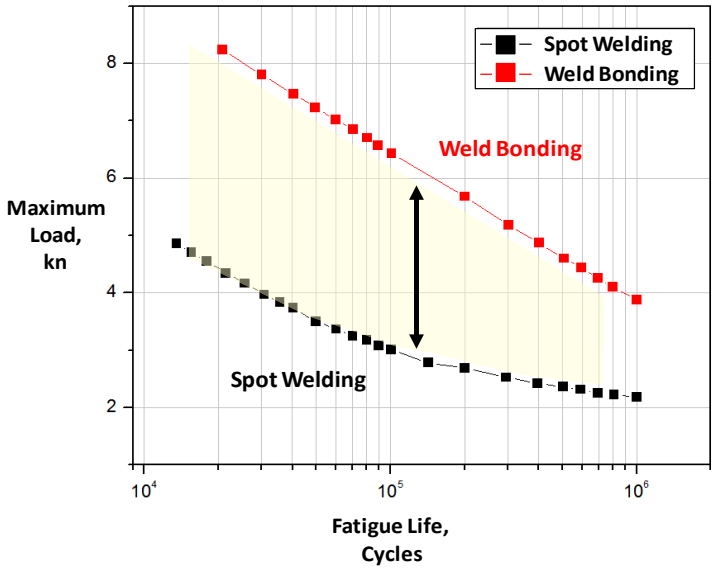
Structural adhesive bondline in yellow

Structural Adhesives Make a Difference

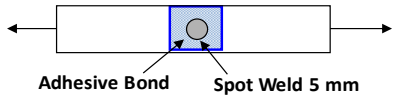
In applications of structural adhesives where designers are optimizing for weight reduction, evidence suggests that **0.6 to 1.1 kg of mass can be reduced for every meter of structural adhesive applied.**

Why are Structural Adhesives Effective?

- Reduce stresses in bonded joints, which improves vehicle durability
- Enables down gauging of steel, which reduces weight
- Higher loads can be sustained, which improves crash and safety performance



- **Spot Welding**: Standard joining technique
- **Weld Bonding:** Adhesive bonding with welding secondary attachment



- Increased load-carrying capability allows down gauged substrate for weight reduction

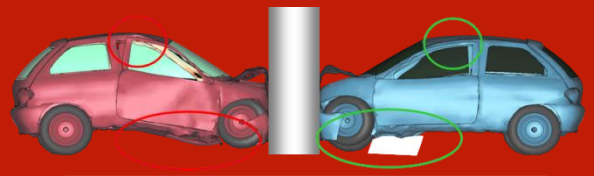
Challenges for Lightweight Vehicles with Dissimilar Material Joining

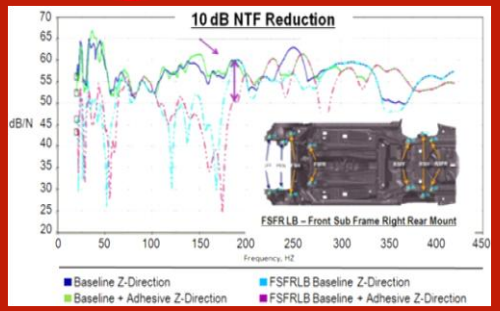
Joining

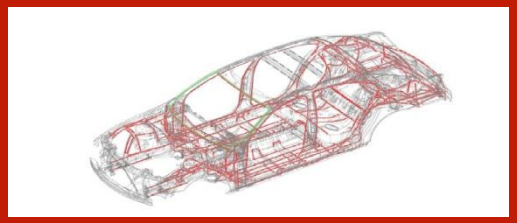
- Thinner substrates
- Dissimilar Materials
- Earlier in manufacturing process
- Challenges:
  - Coefficient of linear expansion differences
  - Residual stresses
  - Component distortion due to thermal and mechanical loads
  - Impact of residual stresses on adhesion performance
- Strength, fatigue/durability, and corrosion
- Galvanic corrosion
- Hybrid joining (secondary attachment)

Performance

- Safety
- NVH performance
- Ride, handling comfort
- Fuel economy







Current and next generation adhesives facilitate solutions

Why Dow Automotive Systems?

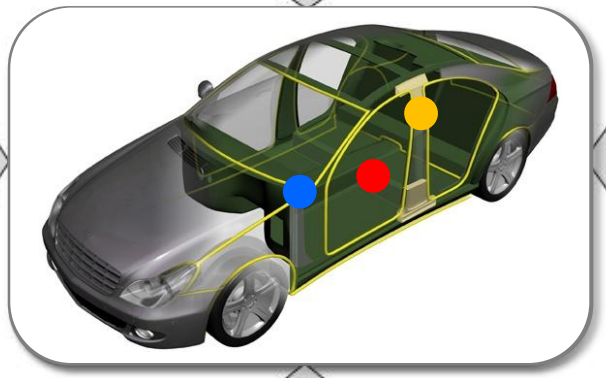
VORAFORCE™
resin matrix systems

- Optimization of interface between carbon fiber and resin
- Ability to create carbon fiber systems tailored for automotive composite applications

- Tailored substrate surface chemistry for optimal performance
- Materials design and joint engineering to manage interrelationship between different substrates
- Down-engineering of composite components by leveraging adhesive joint
- Solutions for body shop or trim shop assembly

BETAMATE™ and BETAFORCE™
structural adhesives

- Adhesive bonding of cavity sections reinforced with structural foam
- Continuous bond-line contains structural foam within the cavity



DowAksa AKSACA™
carbon fiber and derivatives

- Potential to reduce level of carbon fiber in the composite by leveraging reinforcement contribution of structural foam
- Acoustical contribution of foam in composite body

BETAFOAM™
structural foam

Aluminum Bonding

Consideration for bonding Aluminum:

- Types of aluminum parts (sheet, extrusions, castings)
- Surface treatments
- Oxide layer formation, untreated aluminum
- Strength, fatigue/durability, and corrosion
- Galvanic corrosion
- Welding considerations of aluminum

Dow BETAMATE structural adhesives are the enabling joining technology on:

- 2012 Motor Trend Car of the year (Tesla Model S)
- 2013 Motor Trend Car of the year (GM Corvette Stingray)
- 2014 PACE award winner PACCAR (Kenworth T680 and Peterbilt 579)

…and we are proud to be the BETAMATE structural adhesive supplier on the 2015 FORD F-150

Composite Bonding: New Vehicle Approaches

- **Composites** are gaining traction in automotive production due to their **weight-saving potential**, yet they remain difficult to join.
- **Adhesives offer a reliable alternative** to traditional mechanical and thermal processes, which cannot be applied to these lightweight materials.
- Advanced bonding solutions such as **polyurethane structural adhesives enable a continuous bond line and cohesive joining** of surfaces.

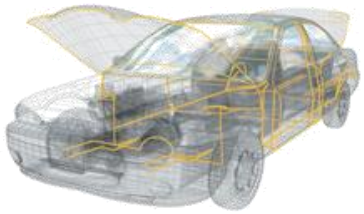
- **Dow Automotive Systems supplied BMW for the carbon fiber compartment of the BMW i3** with an individual joining solution basing on PU adhesives.
- This PU structural adhesive has been **individually designed and optimized for BMW's process requirements.**

Future Structural Adhesives Bonding Applications – BETAMATE™

BETAMATE™ Epoxy Technology

Hybrid Technology and New Chemistries

Move assembly to body shop for large lightweight panels (roofs) and e-coat capable composites.



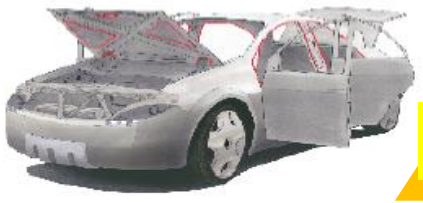
Assembly

Steel, AHSS

SUBSTRATE

Aluminum

Composites, Plastics



Structural Metal Bonding

Summary

Structural Adhesives enable vehicle light weight strategies by

- Bonding **dissimilar materials** including **carbon fiber reinforced composite materials** to many light weight substrates
- Managing **thermal expansion differences** with dissimilar materials
- **Facilitating down-gauging** and/or **down-grading** of steel for **cost and weight reduction**

The continuous bond line provides **improved load transfer** between sheet metal parts, resulting in **improved stress distributions**

Adhesives **enable dissimilar material joining** when traditional joining methods cannot be used and **addresses galvanic corrosion** concerns

Benefits include

- Bond many substrates, including metals and composites without priming
- Increase body stiffness (NVH), improves crash performance
- Increase vehicle body durability
- Compatible with other mechanical and thermal joining techniques

THANK YOU

FOR YOUR ATTENTION!

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