Topics Covered

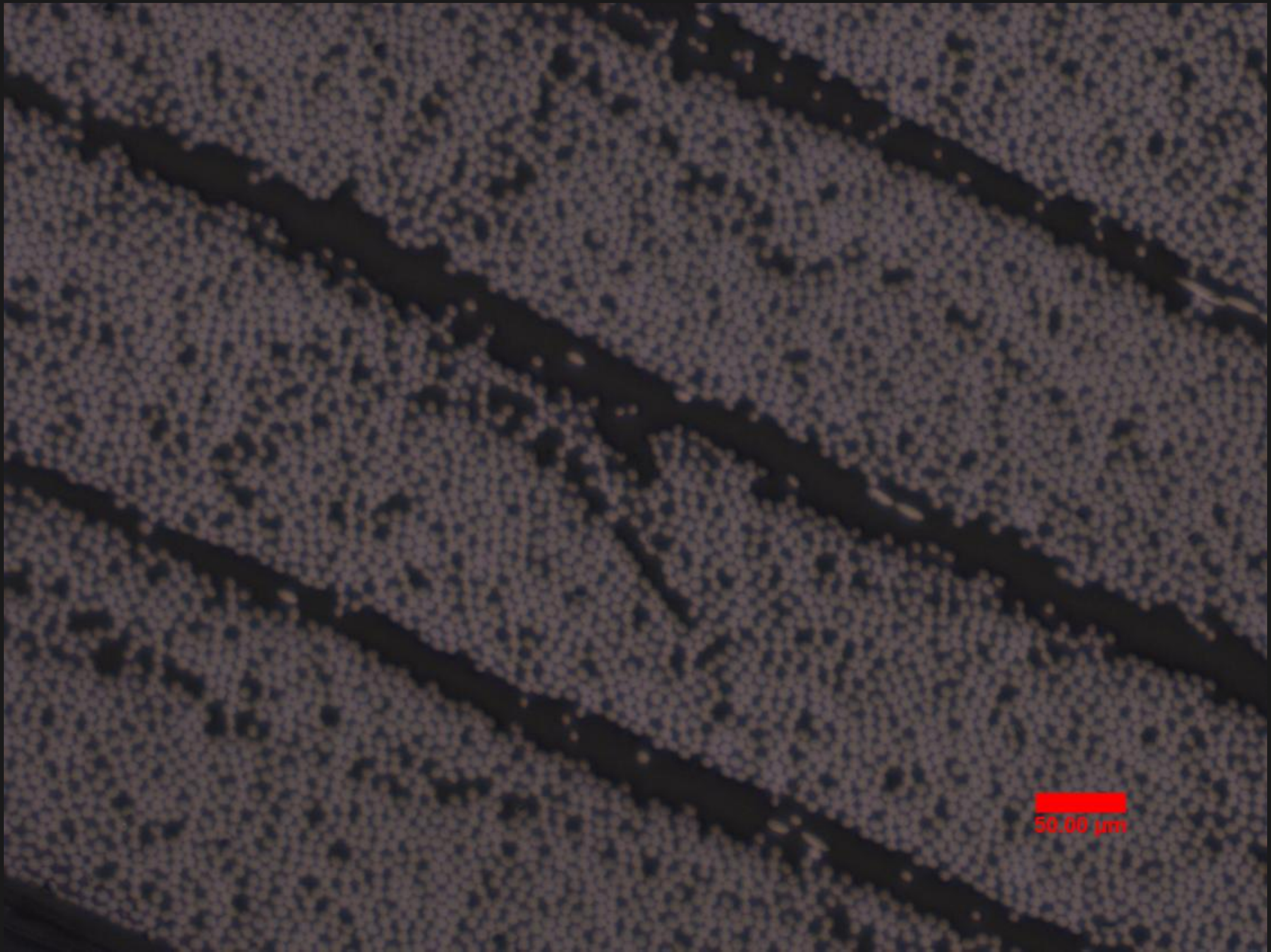
- Types of Composite Materials
- Properties of Composite Materials
- Composite Manufacturing Processes
- Design, Manufacturing and Testing of the Composite MLB Helmet

Examples of Composite Sporting Goods

- Arrows
  - Increase stiffness to decrease energy loss
- Baseball and Softball bats
  - Durability, performance, sweet spot size, handle flex
- Hockey Sticks
  - Reduce weight, adjust flex or kick point
- Fishing rods
  - Lighter, increase sensitivity and adjust flex profile
- Tennis Rackets
  - Reduce weight, increase sweet spot

A composite material is a combination of two or more materials differing in form or composition that retains their identities.

100x



Why Composites

- Anisotropic nature of composites – design to a direction or loading condition
- Good strength to weight ratio
- Versatile manufacturing processes
- Large amount of material combinations
- Aesthetics

Typical Components of the Composite

- Binder (Resin or Matrix)
  - Epoxy (Thermoset)

	Density (g/cc)	Modulus (Msi)	Tensile Strength (Ksi)	Elongation (%)	Cost ($/lb)
Epoxy	1.20	0.30 – 0.50	1.0 - 14	2 – 30	$5 - $20

- Reinforcement (Fiber)
  - Fiber Glass
  - Aramid
  - Carbon

	Density (g/cc)	Modulus (Msi)	Tensile Strength (Ksi)	Elongation (%)	Cost ($/lb)
E Glass	2.54	11	500	4.8	$ 1.00
Aramid	1.44	19	550	2.8	$ 18.00
Carbon	1.78	33 - 85	500 - 850	0.7 – 2.1	$13 - $100

Fiber Forms

- Continuous tow
  - Different yields (bundle size, g/1000m)
- Braid “socks”
  - Different diameter and thickness
- Woven
  - Different types for: processing, thickness, and aesthetics
- Prepreg – fiber with uncured resin
  - Unidirectional or woven
  - Very consistent: resin content and thickness

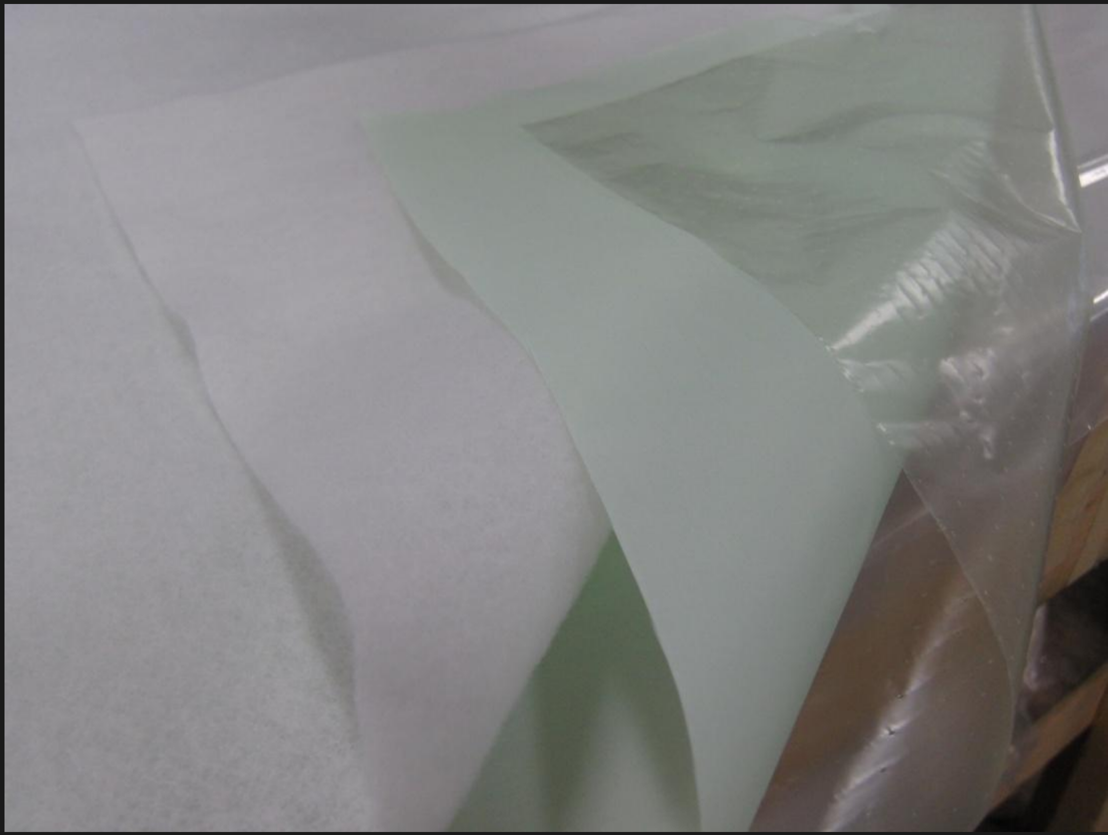
Cured Composite Properties

- Apply rule of mixtures for composite properties
- (Volume Fraction fiber)*(Property fiber) + (Volume Fraction resin)*(Property resin) = Property of the Composite
- Strength (0.5 * 500) + (0.5 * 10) = 255

	Density (g/cc)	Modulus (Msi)	Strength (Ksi)	Cost ($/lb)
Carbon Epoxy	1.55	16.50 – 40	250 - 450	$9.00 - $50
E Glass Epoxy	1.87	5.50	255	$ 3.00
Aramid Epoxy	1.33	9.50	280	$ 11.50
7075 – T6 Aluminum	2.82	10.0	86	$ 16.00
4150 Steel	7.89	30.0	280	$ 3.00

Wet lay-up Vacuum bag

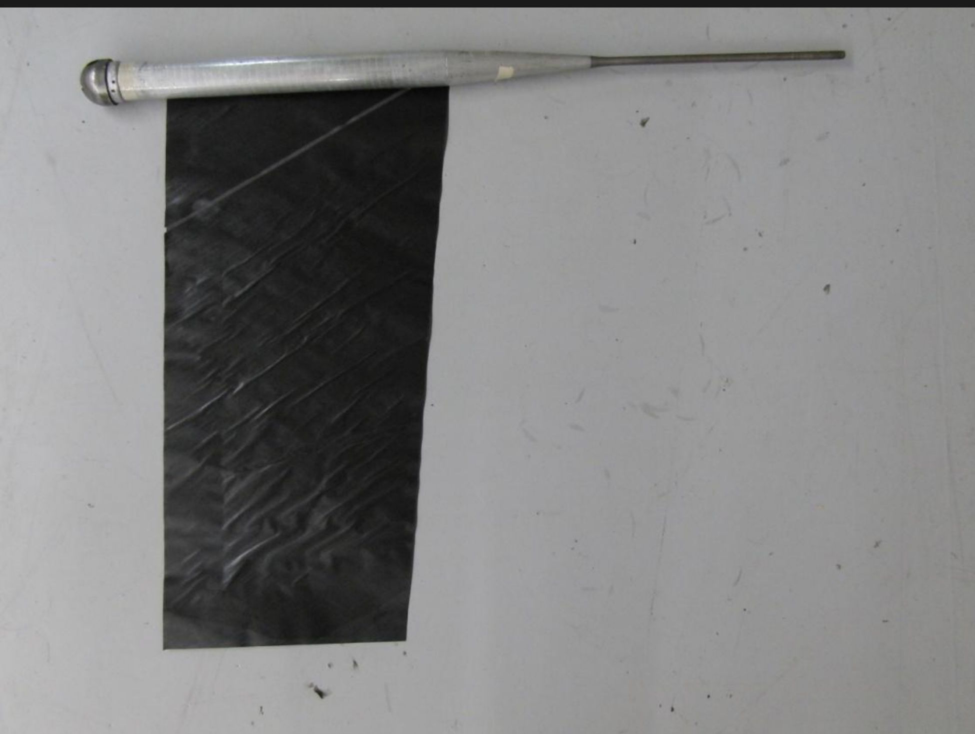
- Cut woven material
- Wet out pattern
- Lay on release film
- Lay on bleeder cloth
- Lay on bag and seal
- Pull vacuum while resin cures



Resin Transfer Molding

Filament Winding

Roll Wrap



Bladder Molding

- Bladder molding - Pressure from the inside
  - Prepreg material is applied over a bladder
  - Preform is placed in a mold, bladder is inflated
  - Heat is applied to cure

Process Comparison

- Wet lay-up – Canoes, helmets
  - Good exterior finish, complex shapes, low cost
- Resin transfer molding – bats, canoe paddles
  - Good consistency, mid part cost and equipment investment
- Filament winding – bats, golf shafts
  - Lower material cost, multiple parts, high equipment investment
- Roll wrap – arrows, fishing rods, golf shafts, bats
  - Tubular parts, good consistency
- Bladder molding – bike frames, tennis rackets, golf shafts
  - Good exterior finish, higher part cost

100 MPH Composite MLB Helmet

- Timeline
  - First discussed the project fall of 2010
    - Had a big and heavy ABS helmet that passed
    - Goal: 30% lighter and 15% smaller
    - Stiffness seemed to help lower SI
  - First mold in house January 2011
  - First part tested March 2011 and passed
  - Did not get another to pass for 2 months
  - Presented new design to MLB in June 2011
  - Set up production and running November 2011

Determine Materials and Process

- Wet Lay-up Vacuum bag was chosen
  - Need for good exterior finish
  - Complex shape
    - Multiple piece mold to be able to remove the part
- Carbon fiber was chosen
  - Maximize stiffness
  - Minimize weight
  - Started with standard “off the shelf” woven carbon
- Epoxy resin was chosen
  - Good pot life
  - Ease of use
  - Very durable/tough system

Issues

- Weave did not conform to the complex shape
  - Developed a “looser” weave to be more pliable
  - Developed a thick material to reduce the number of patterns
- Surface finish was very poor
  - Started testing standard spray gel coats (polystyrene)
    - Too much smell
  - Development our own epoxy gel coat
    - Tougher and production friendly
- Difficult to get consistent vacuum
  - Development a box to put the mold with a reusable silicone bag
- Cycle time was too long
  - Tried different resin but nothing was as durability as the first resin
  - Started heating the box to decrease cure time

Helmet Lay-up

- Assemble Mold
- Apply gel coat
- Apply resin to weave
- Lay in weave
- Lay in peel ply
- Lay in perforated film
- Lay in bleeder cloth
- Seal bag
- Pull vacuum and heat

Left half of mold

Molded Helmet

- Remove from mold
- Trim perimeter
- Cut holes
- Sand
- Paint
- Insert pads
- Apply decals

Head Form to measure Peak "G" force and Severity Index

Future of Composites in Sporting Goods

- Helmets – lighter, dual ear
- More nano technology
- More cost effective non-destructive testing
- Lower cost materials and processes to make them more available to everyone

Summary

- With the anisotropic nature of composite a person can design the stiffness or strength in the direction or plane that is the most beneficial for a specific product
- Large amount of design options with different fibers, resins and fiber content enables a person to mix and match materials and processes for a given application