Short Fiber Composites

• Dispersion
  – No clumping
  – Random or uni-directional
  – Miscibility

• Adhesion
  – Responsible for stress transfer
    • Maximize fiber contribution
Mechanisms of Adhesion

• Adsorption
• Chemisorption
• Diffusion
• Electrostatic
• Mechanical Interlock
Adsorption

• Intimate intermolecular contact
  – Forces between atoms of the substrate and resin
    • Van der Waals
    • Hydrogen bonds
    • Not a covalent bond
      Need good wetting

Contact Angle Measurement

\[ \gamma_{GS} = \gamma_{LS} + \gamma_{GL} \cos \sigma \]

Surface Tension

\[ \gamma_{SV} = \gamma_{SL} + \gamma_{LV} \cos \theta \]

Chemisorption

• Creation of a strong chemical bond
  – Covalent bonding
    • Sharing electrons
  – Need wettability or sorption

Diffusion

- Inter-penetration of polymeric chains
  - Adhesion between two polymers
  - Commingling of polymer chains
  - Need mutual diffusion

Electrostatic

- Development of electrostatic forces at interface
  - Materials transfer electrons
    - Conducting materials

Mechanical Interlock

• Penetration of adhesive into voids and asperities of substrate
  – Creates an anchor within substrate
  – Need wettability
  – Correct rheology

Wood Composite Adhesion

• Primarily through mechanical interlocking
  – Thermosets (PF, UF)
    • Good adhesion
    • Low viscosity
    • Stronger affinity
  – Thermoplastics
    • High viscosity
    • No affinity

• Other potential mechanisms
  – Adsorption
  – Chemisorption
Wood-Plastic Compatibility

- Polar/Non-polar Incompatibility – Oil and Water
  - Mixing and Dispersion
    - Processing Methods (required)
    - Compatibilizers
Compatibilizers for WPC’s

• Coupling/Dispersing Agents
  – Maleic Anhydrides
  – Silanes
  – Titanates

• Coupling
  – Other polymers
    • Most polymers are not miscible
  – Fillers
    • Mainly inorganic
      – Glass, carbon, metal

• Thermoset Resins
  – Poly Diphenylmethane diisocyanates (pMDI)

Bicerano, J. 2005
Silanes

• **Monomeric Silicons**
  – Multi-functional
    • Engineered for specific composites

• **Surface Treatment**
  – Pre-treatment of fibers and fillers

• **Cross-linking mechanism**
  – Used to promote cross-linked system
    • VTMS

• **For WPC’s**
  – Research phase

Silane (Silicon-Based) Chemical

\[
\text{H (hydride)} \quad \text{(methyl)} \quad \text{CH}_3 - \text{Si} - \text{OCH}_3 \quad \text{(methoxy)} \quad \text{CH}_2\text{CH}_2\text{CH}_2\text{-NH}_2 \quad \text{(aminopropyl)}
\]
Maleic Anhydrides

- Polymer based CA
  - Grafted with matrix polymer
    - MAPP, MAPE
  - Developed for inorganics
    - Glass fiber
  - Variations
    - MW
    - Maleic content
      - Compared to grafted polymer

- Improves surface energy
  - Promotes H bonding and possibly covalent??
MA Coupled WPC’s

- Improvement in:
  - Mechanical
    - MOR
  - Physical
    - Water resistance
  - Creep?
    - Relative to increased load
MA Coupled WPC’s

- Water Resistance
  - Lowers diffusion coefficient
  - Improves durability
  - Less weathering effects

Water Sorption of HDPE-WPC’s

Soak Time (hr)

Water Sorption (%)

Soak TIme (hr)

Water Sorption of HDPE-WPC’s
Processing MA Coupled WPC’s

- MA Extrusion Influences
  - Can lower output
  - Require different lubricants
  - More difficult to run
    - Surface appearance
    - Change in rheology
      - Lower melt pressures
pMDI

• Common for traditional wood composites
  – Strong bond with wood
    • Consume water
• Concept
  – Sticks to anything

• WPC’s
  – Limited work
  – Issues
    • Low cure temp
    • Volatiles
      – Foams
      – Needs water
    • Dispersion…. 
References

• http://www.specialchem4adhesives.com