

# **History, Success and Lessons of Development and Commercialization of Formaldehyde-free Wood Adhesives**

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# Wood-based Composites and Wood Adhesives

## Wood composites

- ❖ Consisting of woody materials and non-wood materials
- ❖ Traditional wood composites (woody materials and adhesives)
  - Plywood
  - Oriented strandboard (OSB)
  - Particleboard
  - Medium density fiberboard (MDF)

**Wood adhesives: urea-formaldehyde resins**

**Petrochemicals and carcinogenic formaldehyde**

# Green wood adhesives from renewable resources

- Our new wood adhesives
  - ❖ Formaldehyde-free
  - ❖ Environmentally friendly
  - ❖ From renewable natural resources
  - ❖ Adhesive properties comparable to PF and UF resins (**narrow operation windows: long potlife at room temp, but have to be cured at 100-130 °C in minutes, e.g. 6 min hot press time for making 11/16" panel**)
  - ❖ Cost-competitive to PF and UF resins

# Mussels glue



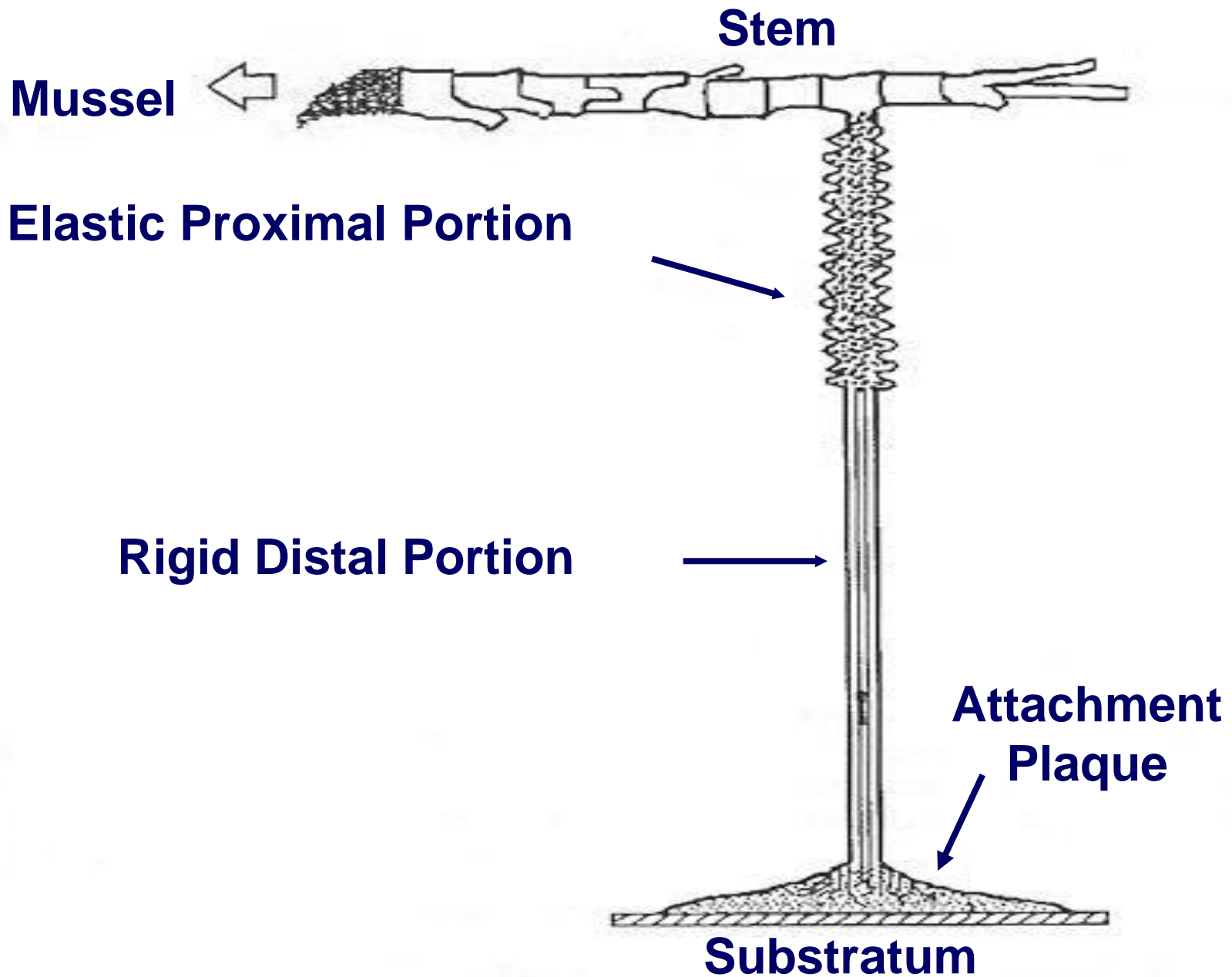
# Mussels Stick



adopted from <http://www.accessexcellence.org/WN/SUA11/collagen997.html>



JUN 5 2006



# Marine adhesive protein (MAP)

MAP-1: rich in DOPA and lysine

MAP-2: rich in DOPA and cystine

MAP-3: small peptides

Ala-Lys-Pro-Ser-(Tyr/DOPA)-Hyp-Hyp-Thr-DOPA-Lys





# Soy protein

- **The soybean consists of about 40% protein, 21% fat, 34% carbohydrate, and 4.9% ash.**
- **Glutamic acid and aspartic acid account for about 1/3 of amino acids in soy protein**

# **Timelines for development and commercialization of formaldehyde-free soy-based adhesives**

- **Provisional application filed on May 13, 2002 and a patent issued in 2006**
- **Presented the findings at Forest Products Society meeting in June 2003**
- **Began commercialization work from late 2003**
- **Full conversion of the first plywood plant in late 2004**

# Efforts for Development of a PAE Alternative at OSU since 2008

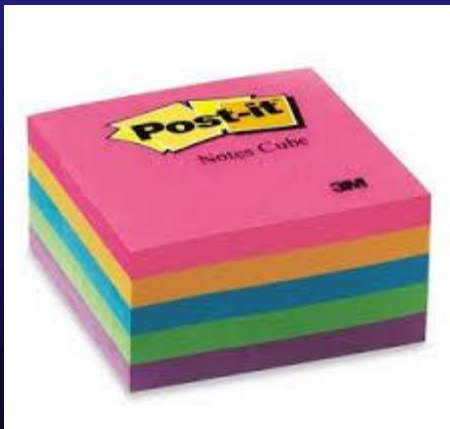
- **A curing agent (polyepoxide) from glycerol or other poly-ols and epichlorohydrin**
- **A curing agent from glycerol and ammonia**
  - Epichlorohydrin can be derived from glycerol
  - **Reaction of epichlorohydrin and ammonia generates an effective curing agent**
- **The soy-(curing agent) adhesive worked very well for interior plywood (Jang et al, Int. J. Adhesion & Adhesives, 2011, 31: 754-759).**

# Keys for the Success

- **Strong support from open-minded industry leaders**
- **Willing to learn new things from outside talents.**
- **Be perseverant**
- **Don't yield on internal and external pressures**

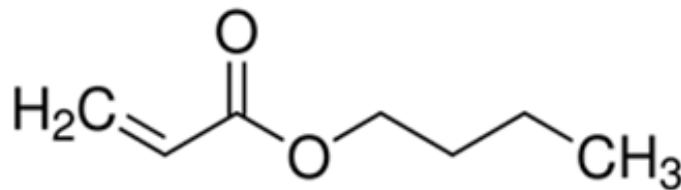
# Pressure sensitive adhesives (PSAs)

- Self-adhesive materials
- Bond instantaneously under a light pressure
- No need of water, solvents, heat or radiation
- Tapes, labels, and miscellaneous products

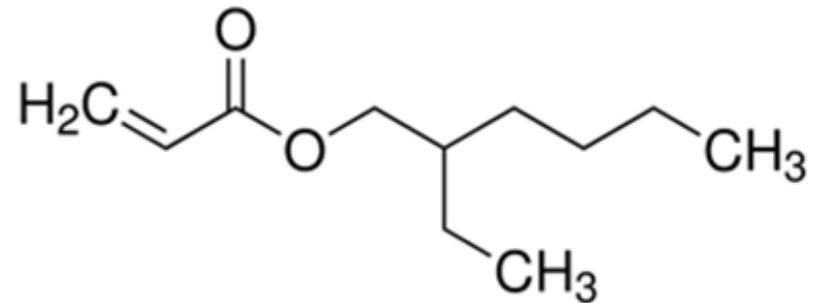


# Base polymers for commercial PSAs

- Natural rubber
- Polyacrylates



***n*-butyl acrylate**



**2-ethylhexyl acrylate**

- Styrenic block copolymers (SBCs)
  - ❖ polystyrene-polybutadiene-polystyrene (S-B-S)
  - ❖ polystyrene-polyisoprene-polystyrene (S-I-S)
- Silicone

# Our Approaches

- Have discovered a new class of polymers that can be used for PSAs
- **Five patents pending: three parallel PSA technologies**
- One of the PSA technologies has been licensed by a big company
- **Solely based on renewable materials, no organic solvents or toxic chemicals required, very novel and simple process, and very cost-competitive to existing PSAs**

# Styrene-free Unsaturated Polyester resins from renewable materials

- Existing unsaturated polyester resins
  - ❖ Used for boats, sink/shower tubs, automobiles, airplanes, water-cooling towers...
  - ❖ Issues: petrochemical-based, about 40-60% styrene (reasonably anticipated human carcinogen)
- Recent breakthrough: renewable-material-based replacement of styrene

