Design Of A Double Pane Transparent Wood Window

Team Fabricating Transparent Wood

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Motivation

- Reduce the amount of planned energy consumption to meet energy performance requirements set by U.S. DoE
- Residential and commercial buildings consume 40% of the country's primary energy from heating, cooling, and lighting
- From this usage, buildings account for 30% of global CO_2 emissions

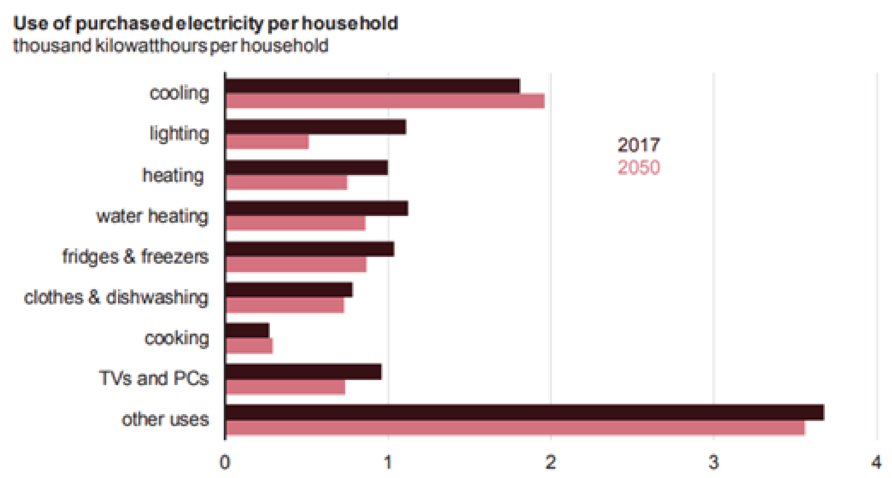

Figure 1. Purchased electricity per household in 2017 and projected use for 2050 in kWh

- Transparent wood provides:
  → Unique interactions with light
  → High impact energy absorption that eliminates safety issues associated with glass
  → Newer, energy efficient alternative to glass

Previous Work

- Previous methods for improving the energy efficiency of glass windows include: multiple panes, films, and glazes
- Li et al. (2016) were the first to fabricate high haze transparent wood (R-wood and L-wood)
- High haze wood is anisotropic thermally, optically, and mechanically
- Different polymers have been tested for infiltration to create the composite

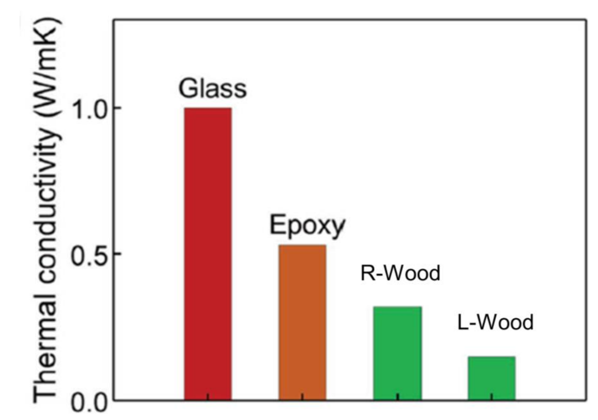

Figure 2. Thermal conductivity of glass compared with epoxy and two cuts of wood (Li et al., 2016)

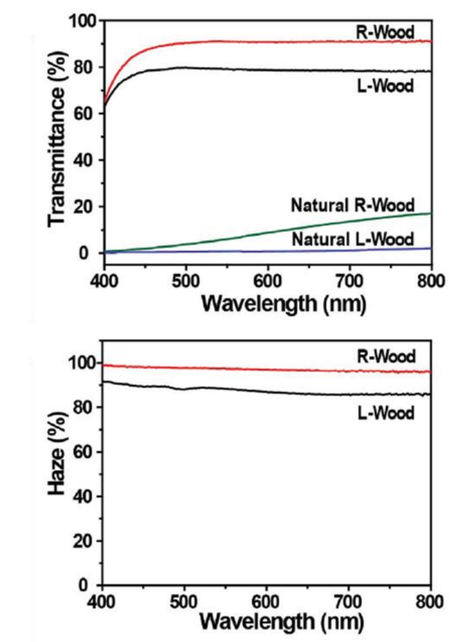

Figure 3. Transmittance (top) and Haze (bottom) versus wavelengths for high haze wood (Zhu et al., 2016)

Technical Approach

Generalized Fabrication of Transparent Wood (Li et al., 2016):

Cut sample → Delignification* → Solvent Exchange → Epoxy Infiltration

*Delignification methodology changes for samples greater/less than 1.5 mm

Property Data Analysis:

- Flexural Strength from three-point bend test
- Heat flow from thermal conductivity testing
- Wavelength dependence of transmittance and haze from UV-VIS-IR spectrophotometry
- Translate sample properties to prototype performance

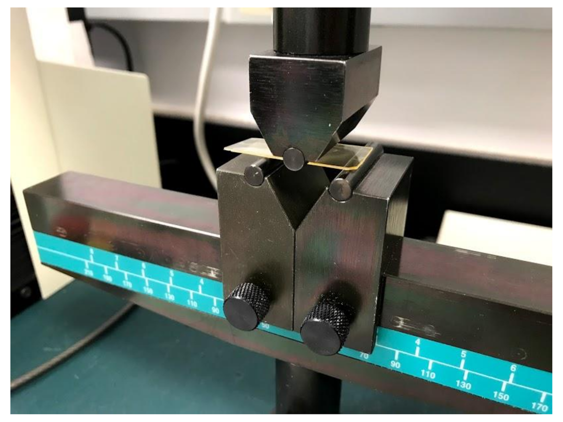

Figure 4. 3-point bend test apparatus

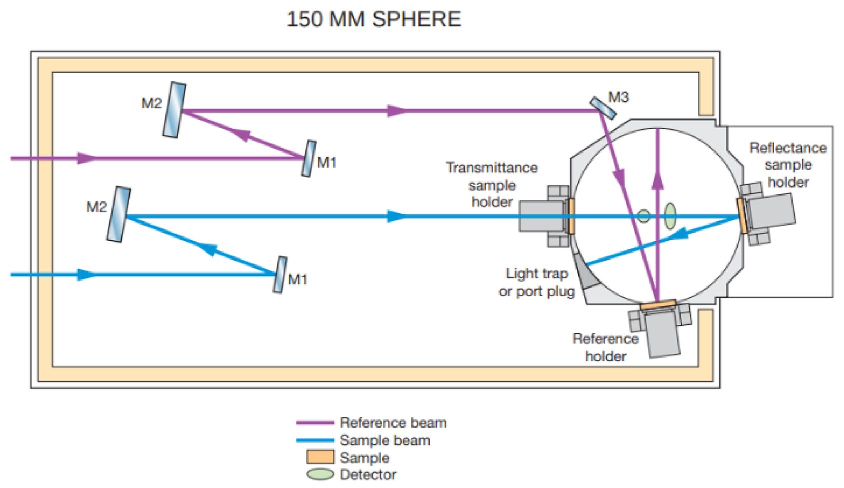

Figure 5. UV-VIS-IR spectrophotometer with integrating sphere schematic

Results of Calculations & Measurements

- L-wood chosen for both high and low haze components due to physical stability, better thermal resistivity, lower possible haze, and acceptable transmittance and flexural strength
- Beer-Lambert Law for transmittance: $\%T = 100\frac{I}{I_0} = e^{-ebc}$
- Heat flux – Fourier's Law: $\dot{Q}_{net} = \frac{\lambda}{t}A\Delta T - (IA\tau)$
- Flexural strength: $\sigma_f = \frac{3PL}{2bt^2}$

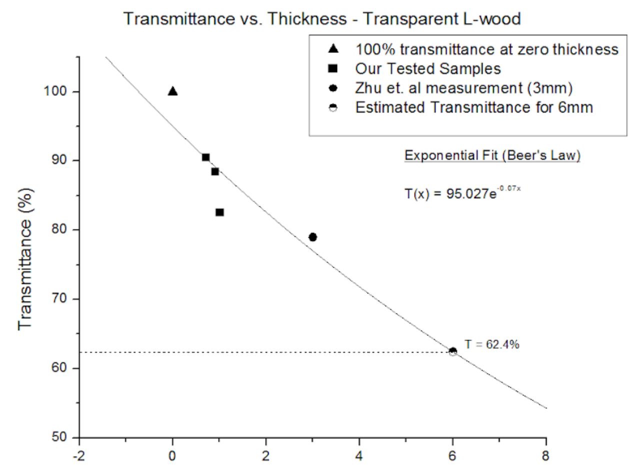

Figure 6. Transmittance versus thickness for transparent L-wood fit to Beer's Law

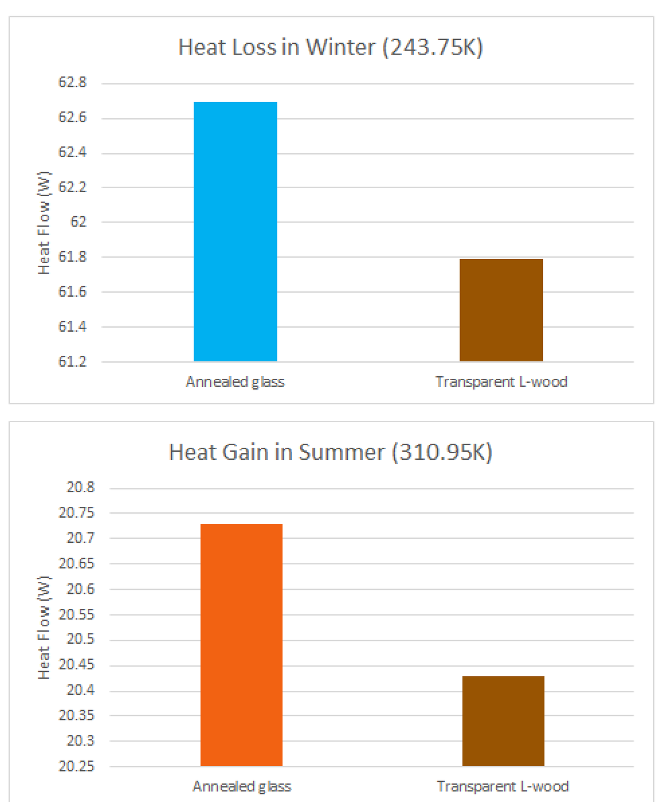

Figure 7. Comparison of heat loss in winter (top) and heat gain in summer (bottom)

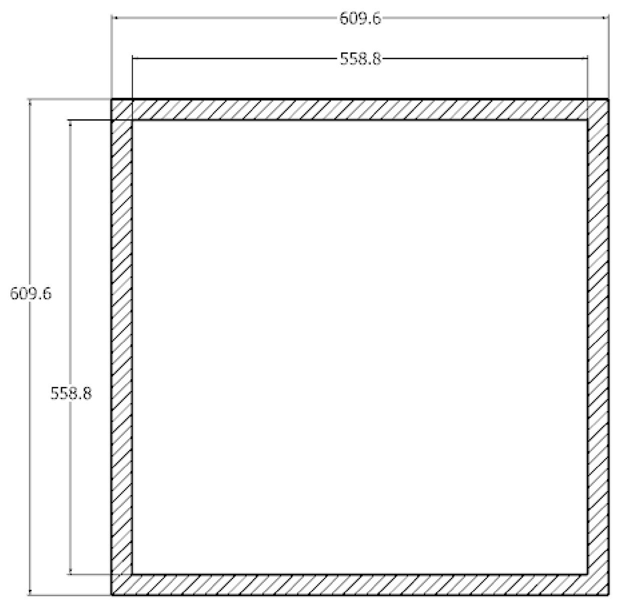

Figure 8. Front face frame of window design [mm]

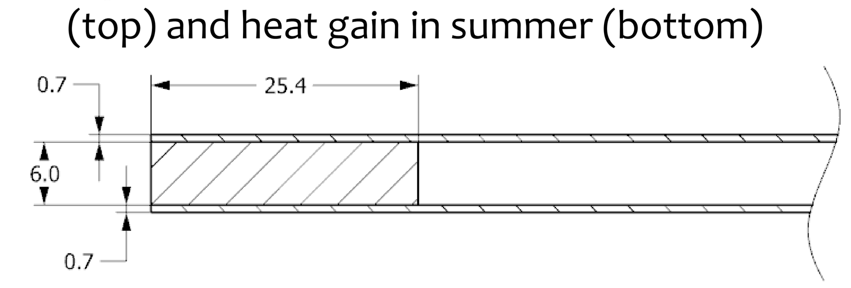

Figure 9. Side view of window design showing sandwiched panes [mm]

Design Goals

- Fabricate a novel transparent wood window that combines high and low haze wood to transition from a laboratory technology to a market product
- Match or improve upon performance (optical, thermal, mechanical) of current glass windows on market
- Identify and confirm property trends with grain orientation and thickness
- Minimize overall thermal conductivity
- Maximize overall optical transmission
- Minimize haze in low haze wood, maximize haze in high haze wood → hybrid
- Understanding trends between size, orientation, and properties, and being able to incorporate that knowledge into the design for desired performance

Conclusions

- Low haze grain orientation and thickness trends agreed with those of high haze grain orientation and thickness
- Estimated properties of overall window prototype based on properties of individual components for comparison with glass windows
- Transparent wood technology is young with limitations, but understanding of weaknesses will focus research for improvement
- Feasibility will rely on scalability of processing and sourcing

Next Steps

Continued Research

- Diagonal (D)-wood
- Processing focus for scale-up size and quantity; consistency
- Epoxy alternatives in regards to sustainability and non-yellowing properties
- Sourcing and recyclability

Product Launch

- Target market: younger couples in the Northeast region
- Pricing: $300
- Government incentives
- Economies of scale

Acknowledgements

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"We pledge on our honor that we have not given nor received any unauthorized assistance on this assignment."

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