# Micro-Thermal analysis of liquid phenol-formaldehyde resin on wood surface

by

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# Introduction

- The durability and strength of wood based composites depend on the cured state of the binder.
- Wood can affect curing of the PF resin.
- Conventionally DSC has been used to trace the curing reaction with time. (Bulk reaction ≠ local interactions)
- It is essential to employ a technique which can identify wood species that enhances or retards curing reaction.

*Johnson & Yan, Adhesive 2005*

# μ-TA an Introduction

- μ-TA is a hybrid which combines the principles of atomic force microscopy (AFM) with thermal analysis.
- Resistive thermal probe is used instead of AFM tip.
- The thermal probe is composed of Wollaston wire which acts as a heater and sensor measuring tip movement and heat absorption on the sample surface.

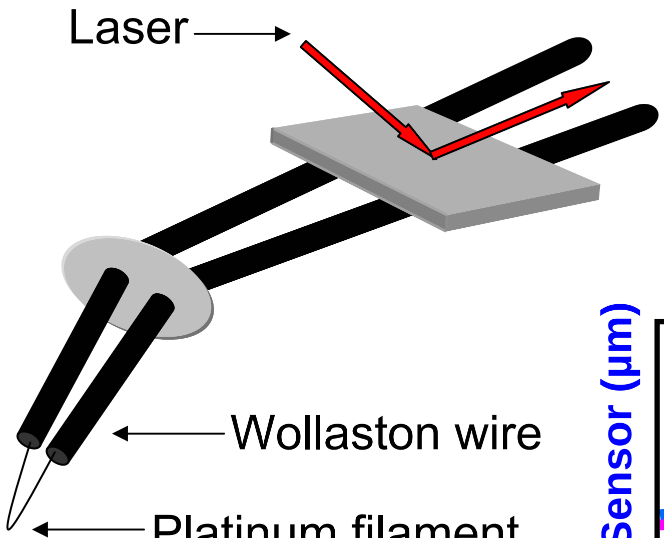
*Johnson & Yan, Adhesive 2005*

# Local Thermal Analysis (LTA)

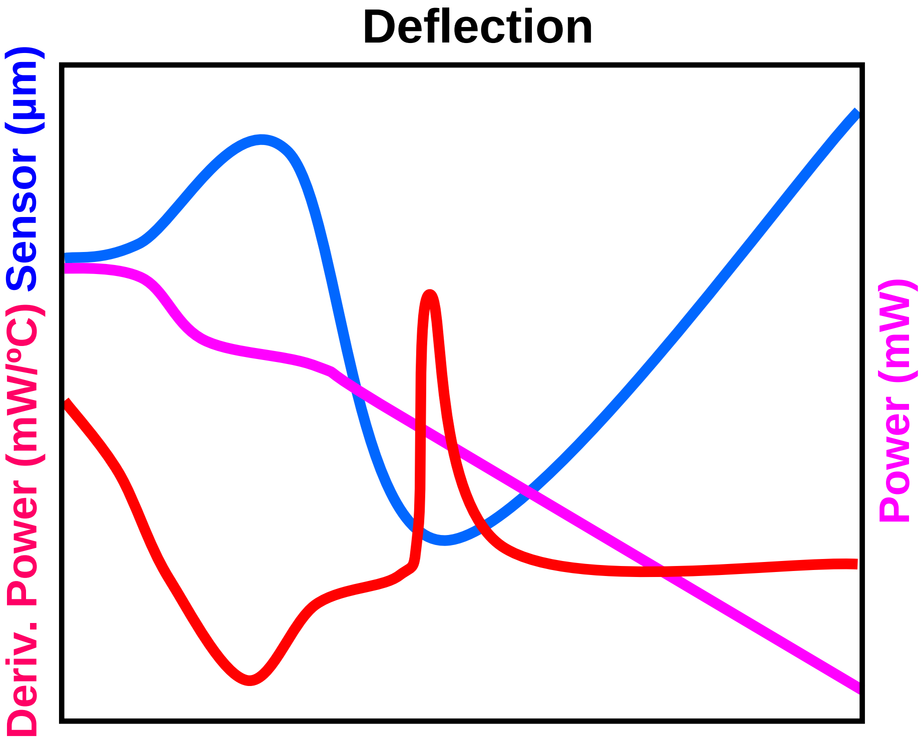
- With the application of high voltage it is possible to apply high temperature to specific regions of the sample.
- Thermal tip is placed on a particular location on the sample surface and heating is ramped at a predetermined rate.
- The probe tip sinks into the sample surface.
- The response of the tip to increasing voltage is continuously monitored in terms of the sensor response (tip vertical displacement) and power (heat absorption).

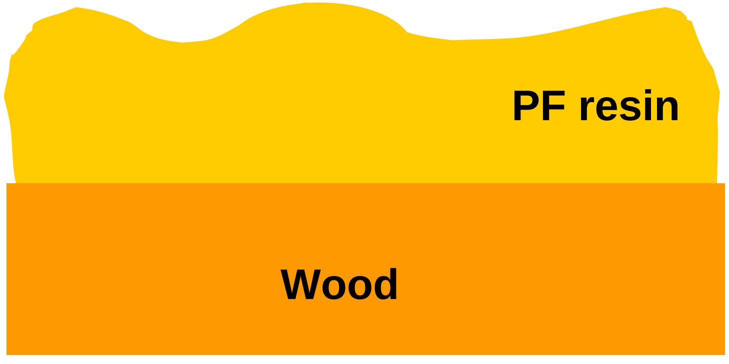
*Johnson & Yan, Adhesive 2005*

# Local Thermal Analysis (LTA) Methodology



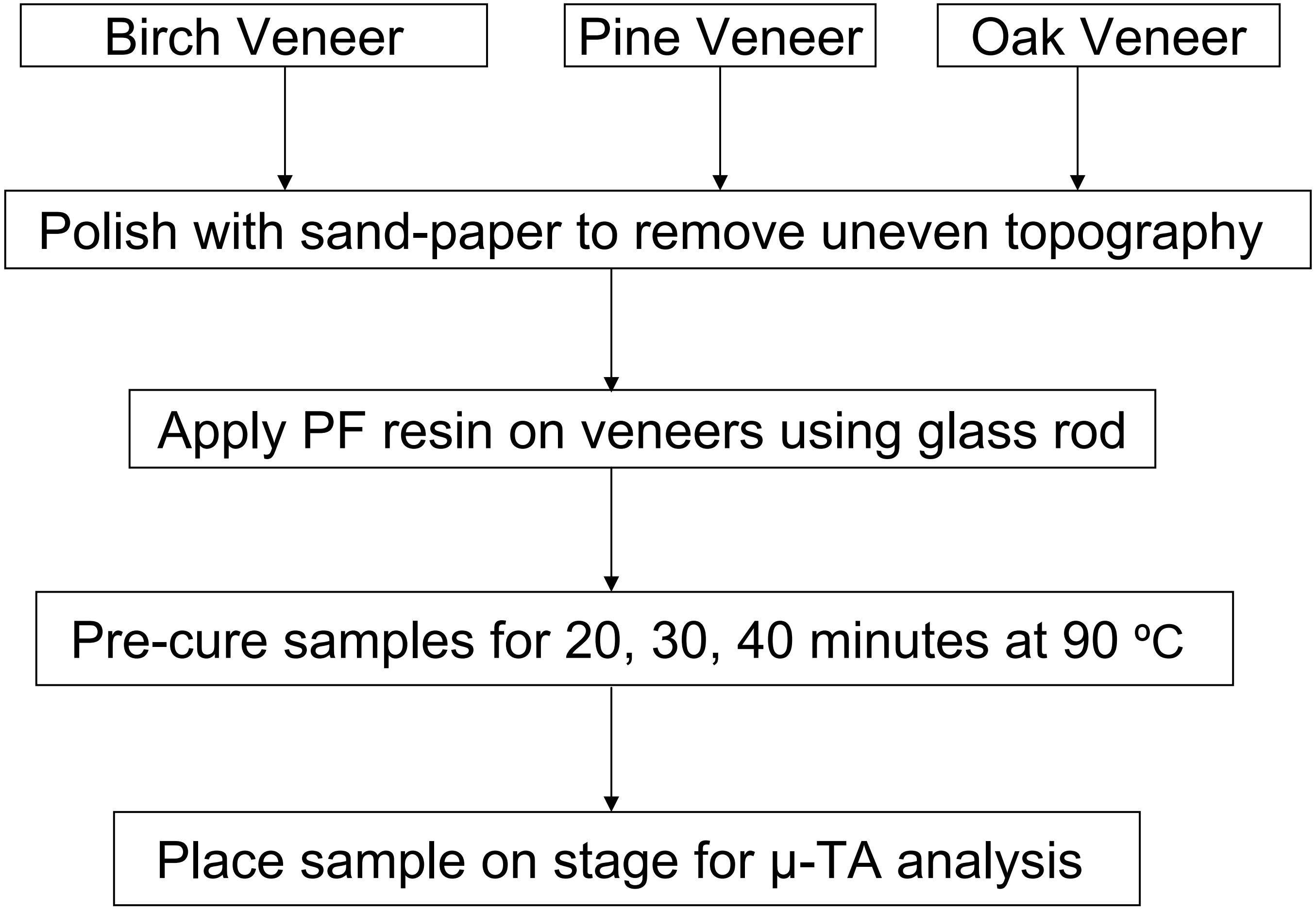

Heating rate = 25 ºC/Second




*Johnson & Yan, Adhesive 2005*

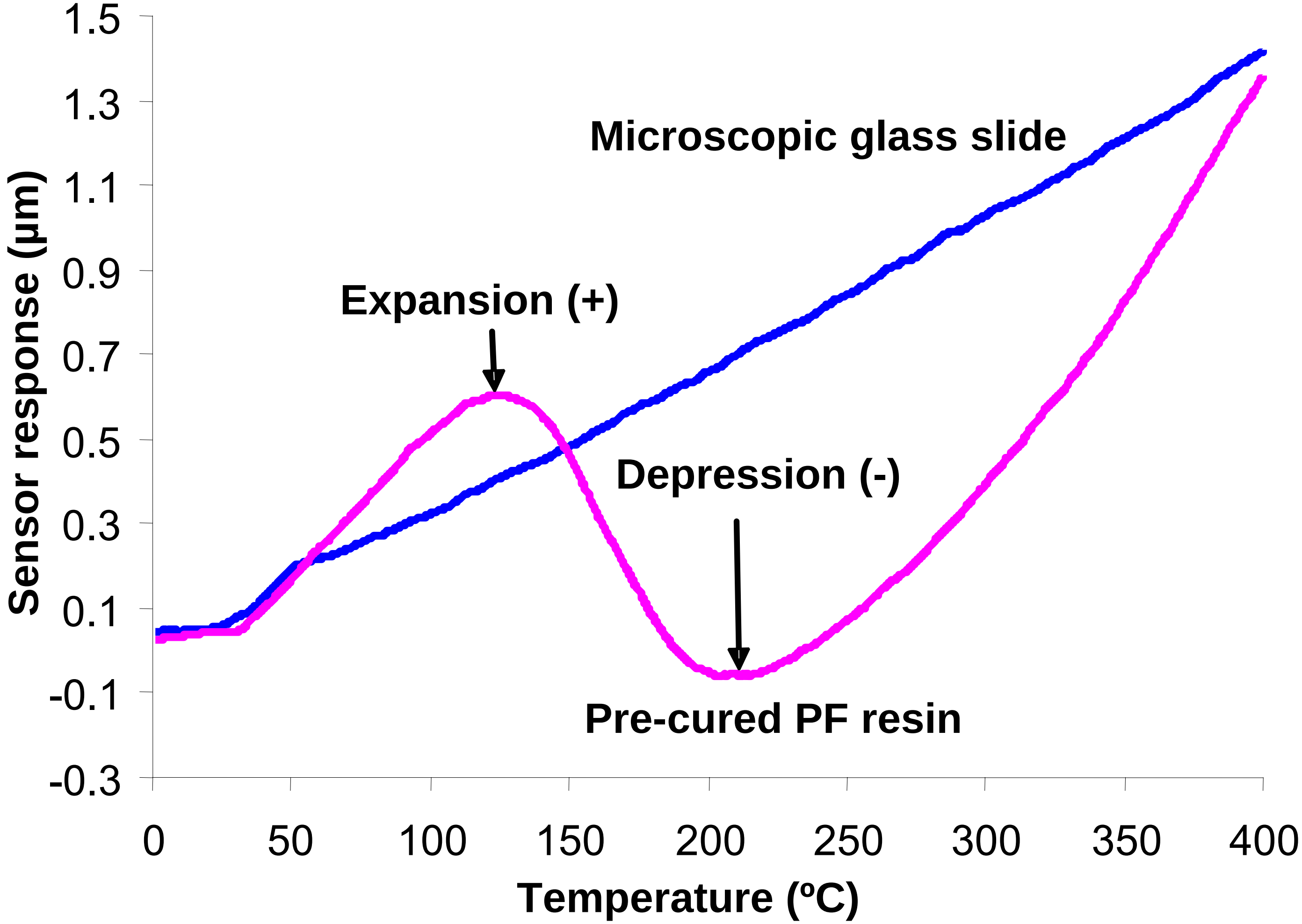
# Experimental Procedure




Cure temperature was set to 90 ºC to obtain optimum cure state to prevent sticking of resin onto the probe.

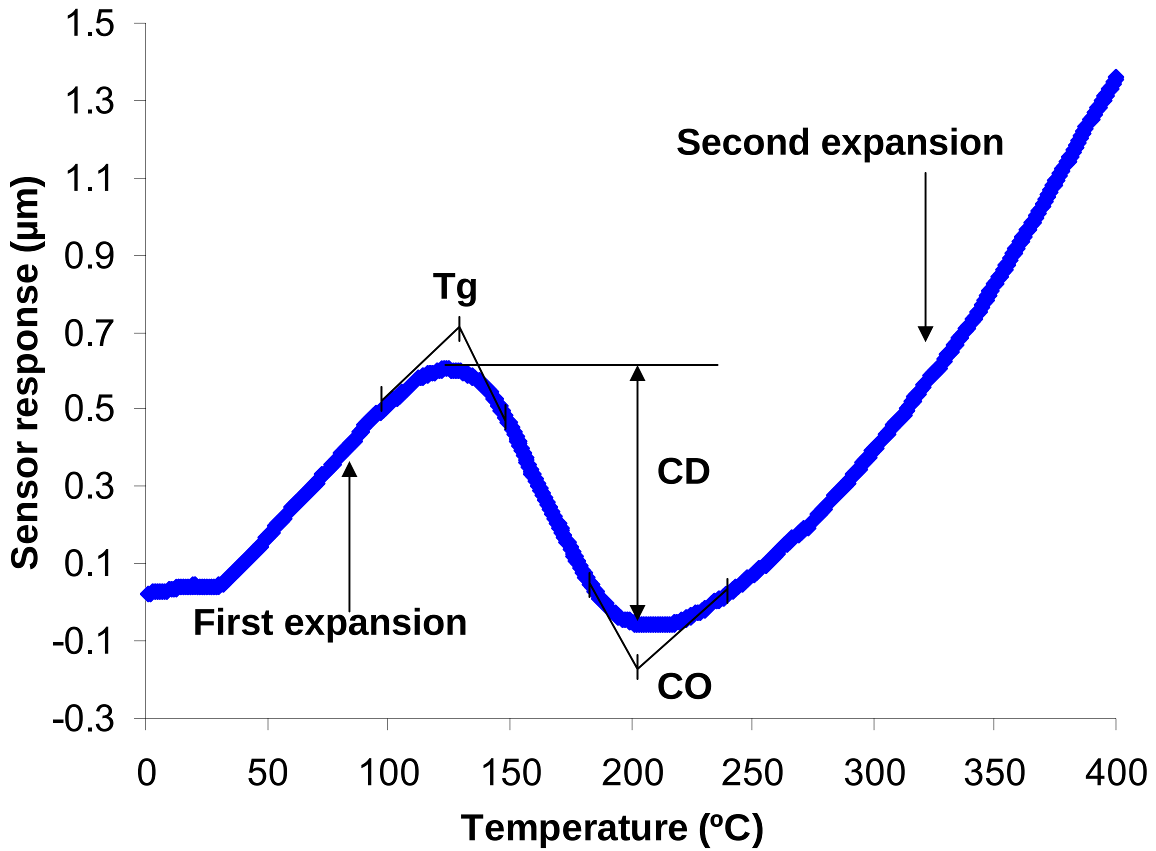
*Johnson & Yan, Adhesive 2005*

# Comparison of LTA results on glass plate and Pre-cured PF resin at 90 ºC for 30 minutes




Glass – Linear expansion, PF resin – Sinusoidal behavior

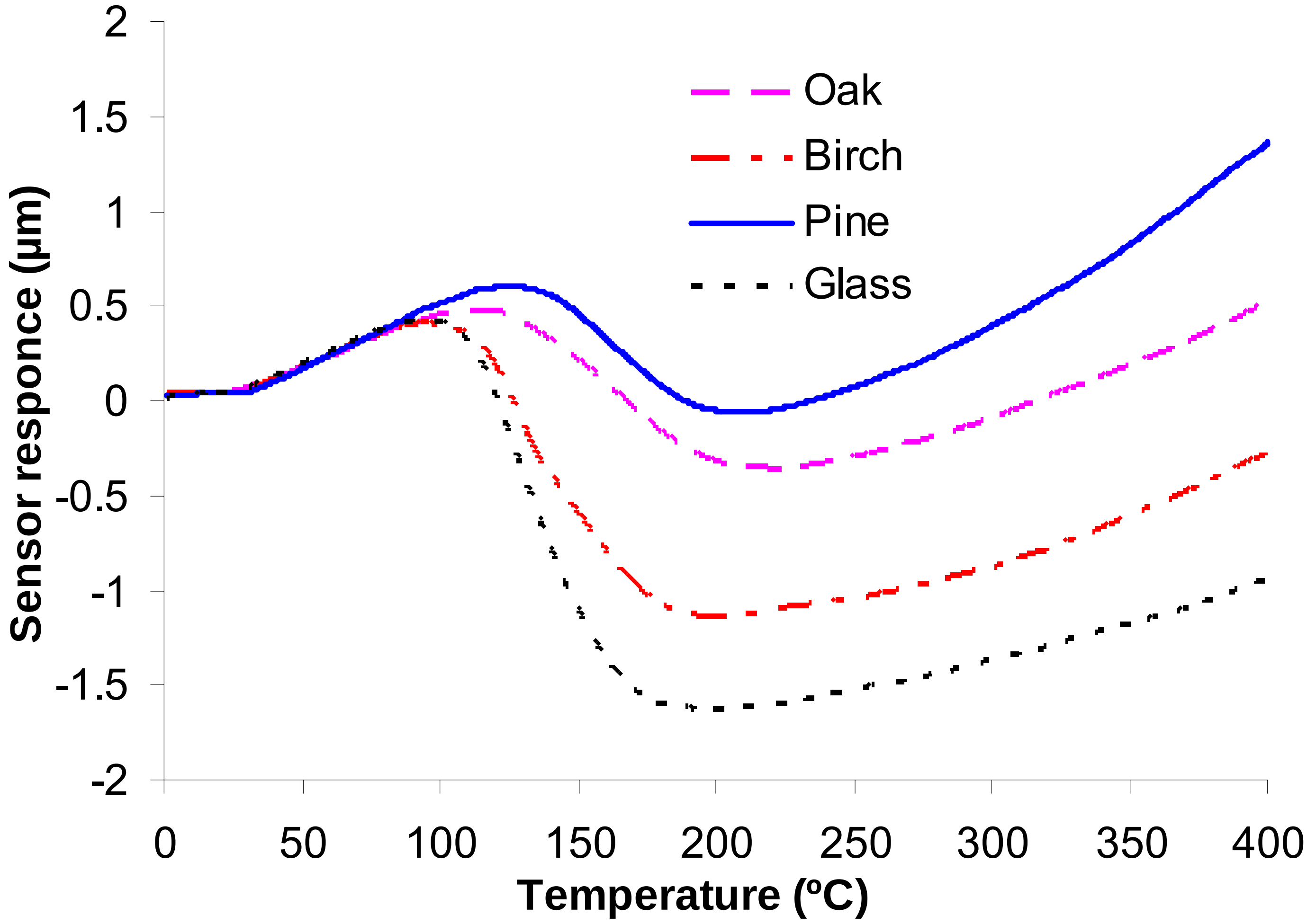
# Analysis of Sensor Response




**Tg** – Glass transition temperature
**CD** – Cantilever Deflection
**CO** – Cure onset

*Johnson & Yan, Adhesive 2005*

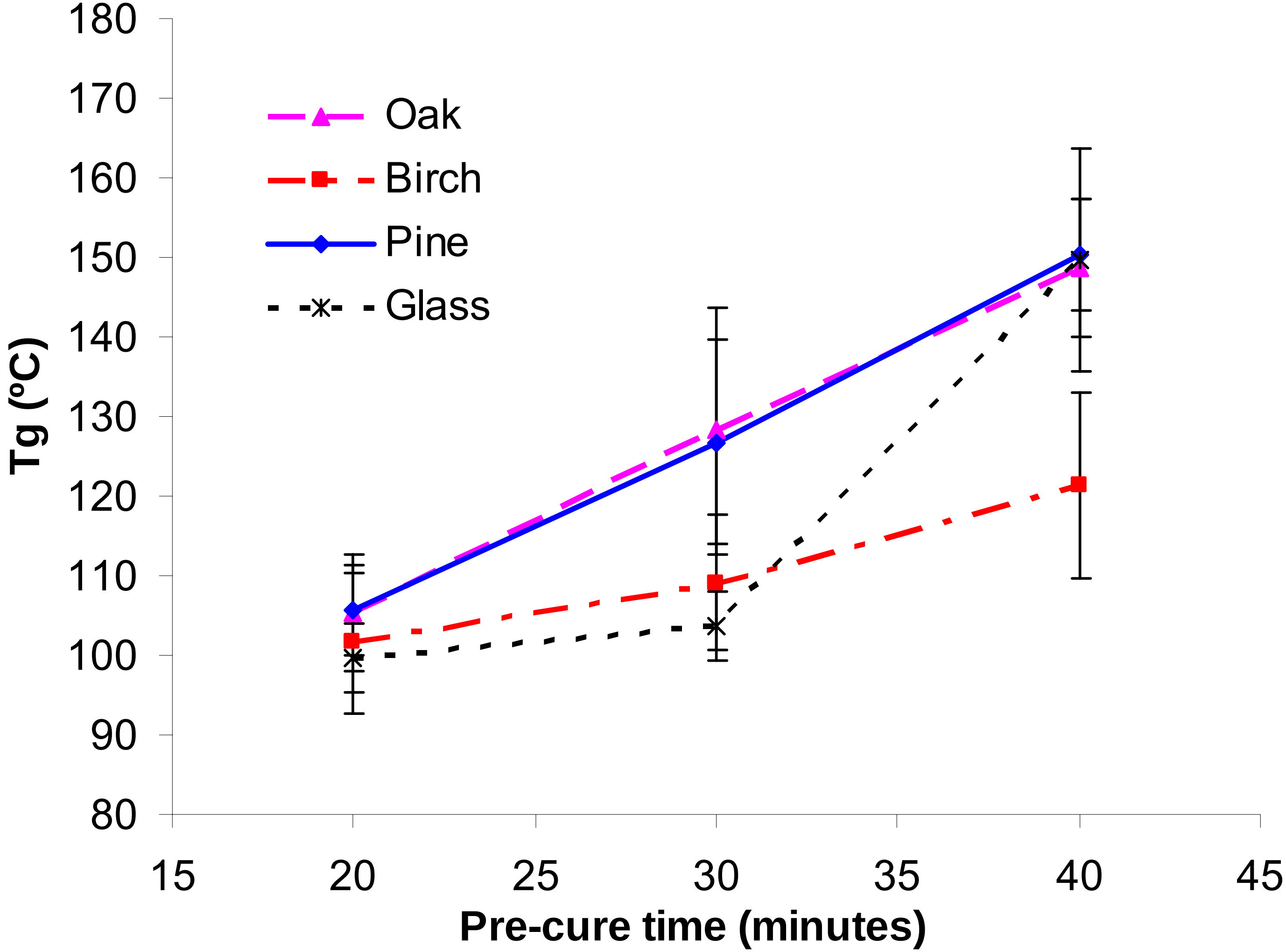
# LTA analysis of PF resin on different substrates pre-cured at 90 ºC for 30 minutes




Difference in sensor response attributes to different cure behavior.

*Johnson & Yan, Adhesive 2005*

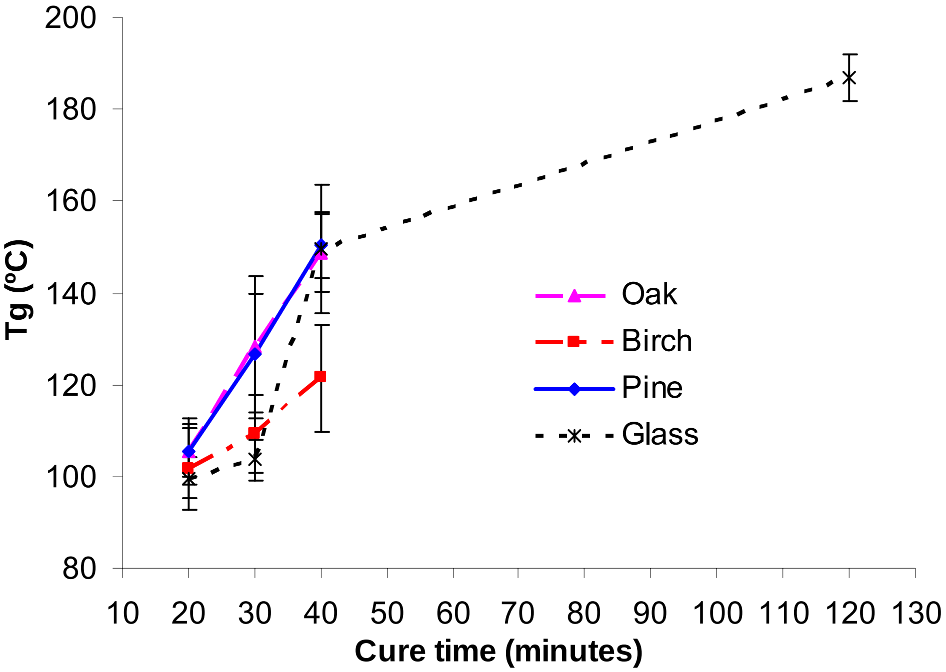
# $T_g$ of PF on different substrates pre-cured at 90ºC

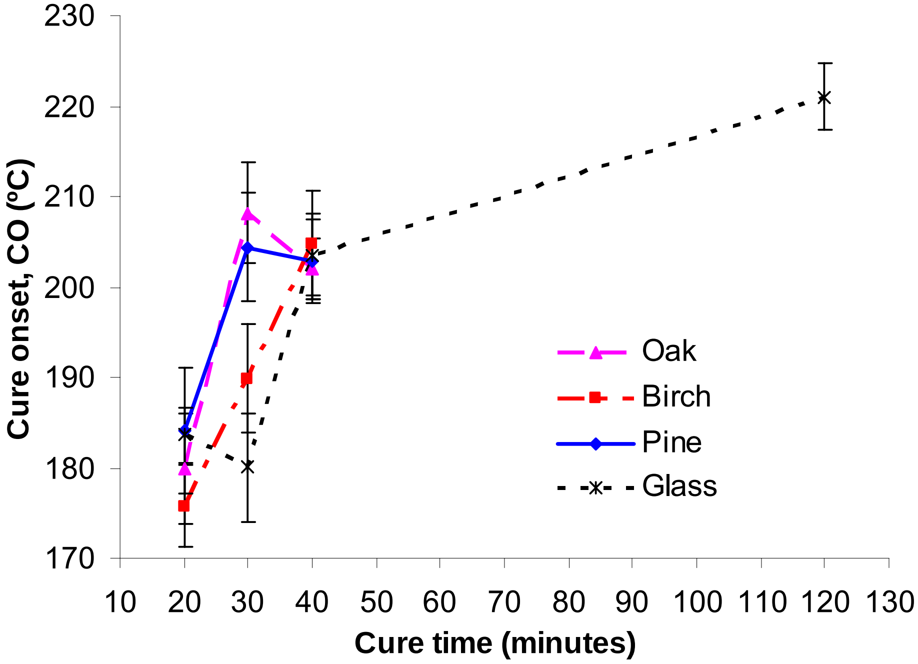



Tg values are higher after 30 minutes of pre-cure for pine and oak which signifies faster polymerisation reaction compared to birch and glass.

*Johnson & Yan, Adhesive 2005*

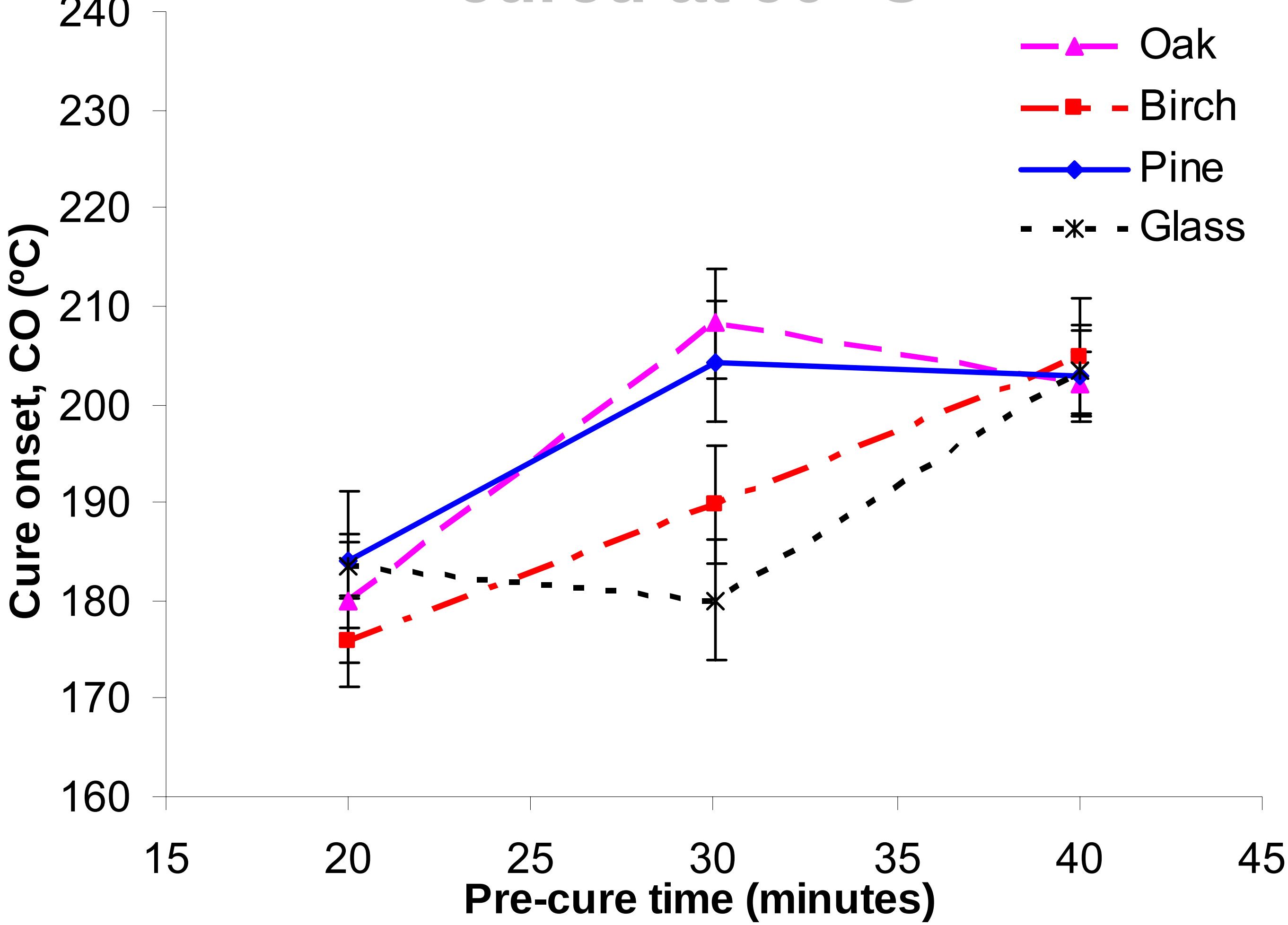
# Tg & Cure-onset of PF on glass substrate pre-cured at 90 ºC for 120 minutes




*Johnson & Yan, Adhesive 2005*

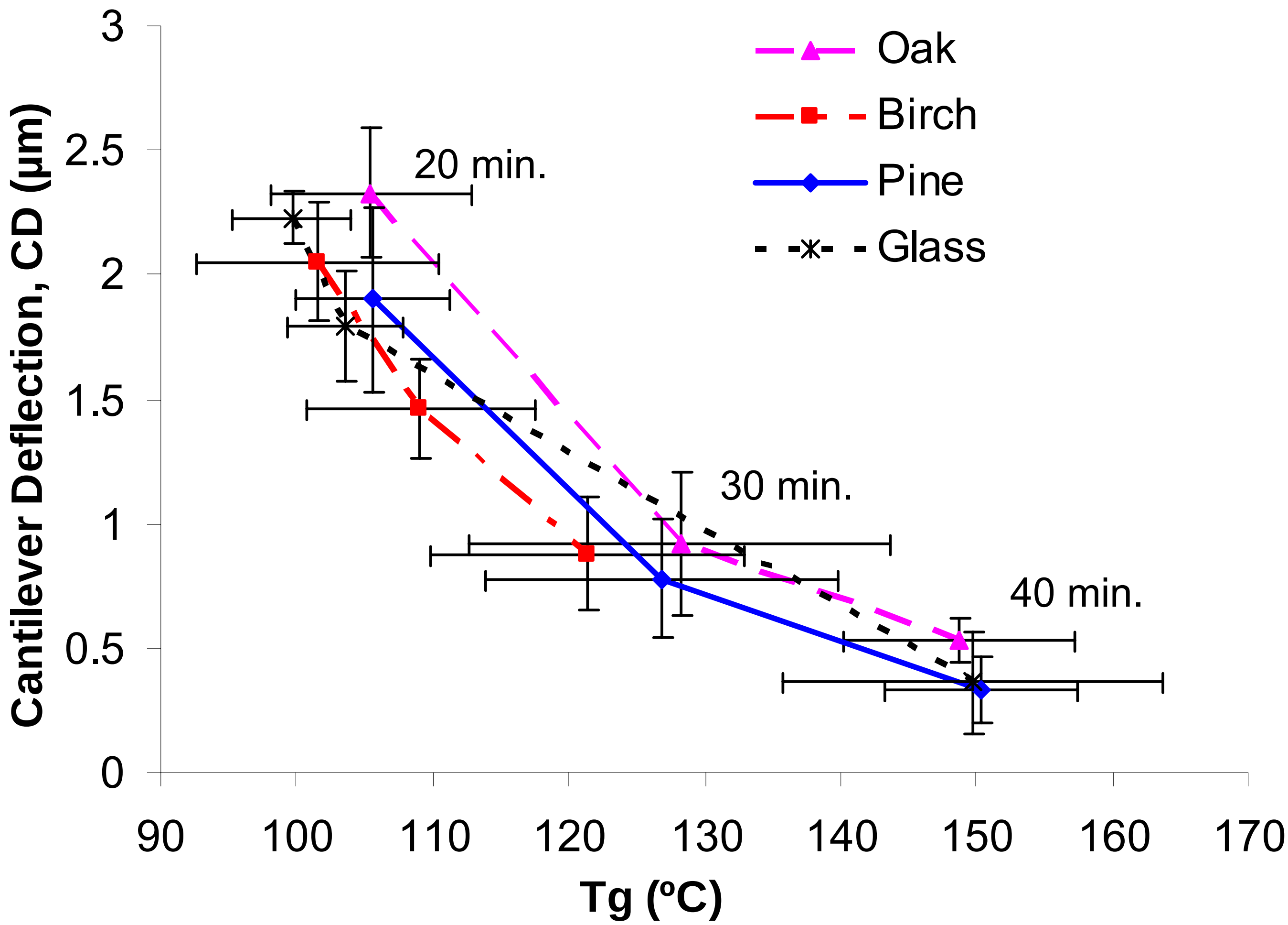
# Cure-onset of PF on different substrates pre-cured at 90 ºC




Cure onset decreases with the increase in cure time for oak and pine while it increases for birch and glass.

*Johnson & Yan, Adhesive 2005*

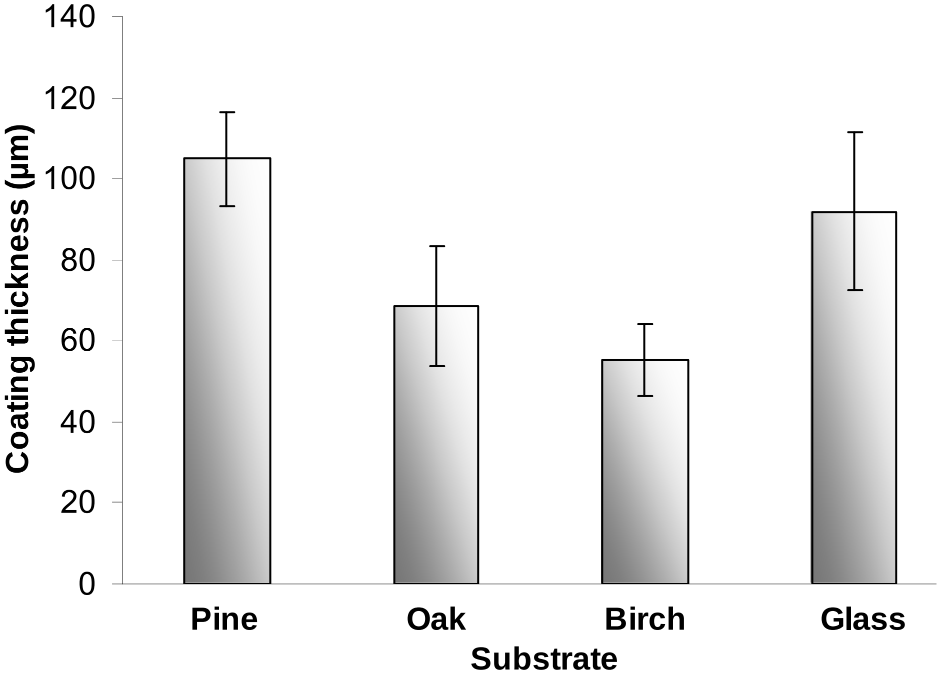
# Cantilever deflection measured for PF on different substrates pre-cured at 90 ºC

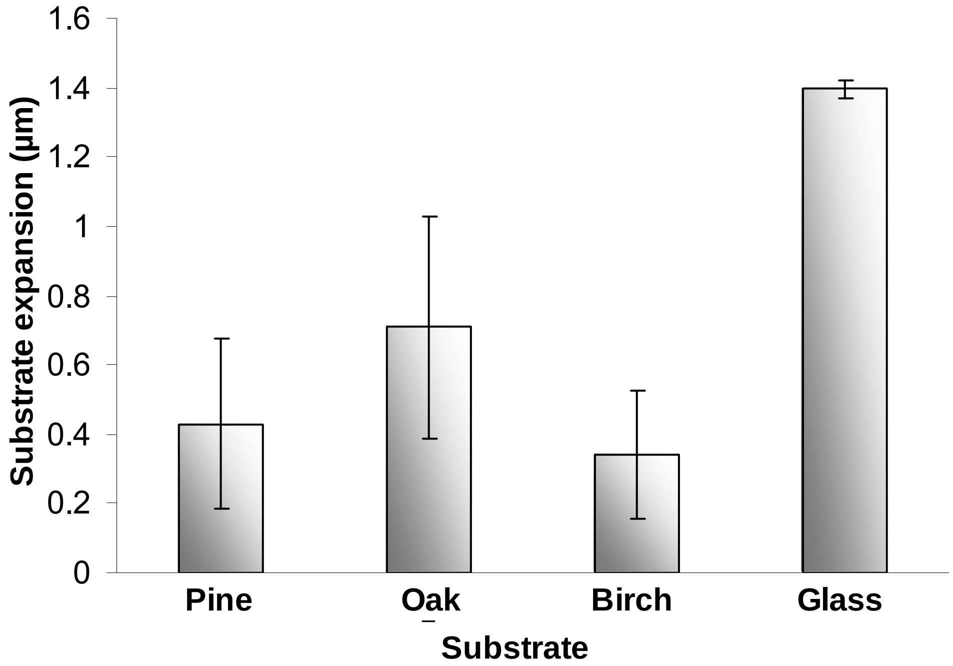



Cantilever Deflection decreases with increase in glass transition temperature (Tg).

*Johnson & Yan, Adhesive 2005*

# Comparison of coating thickness and substrate expansion

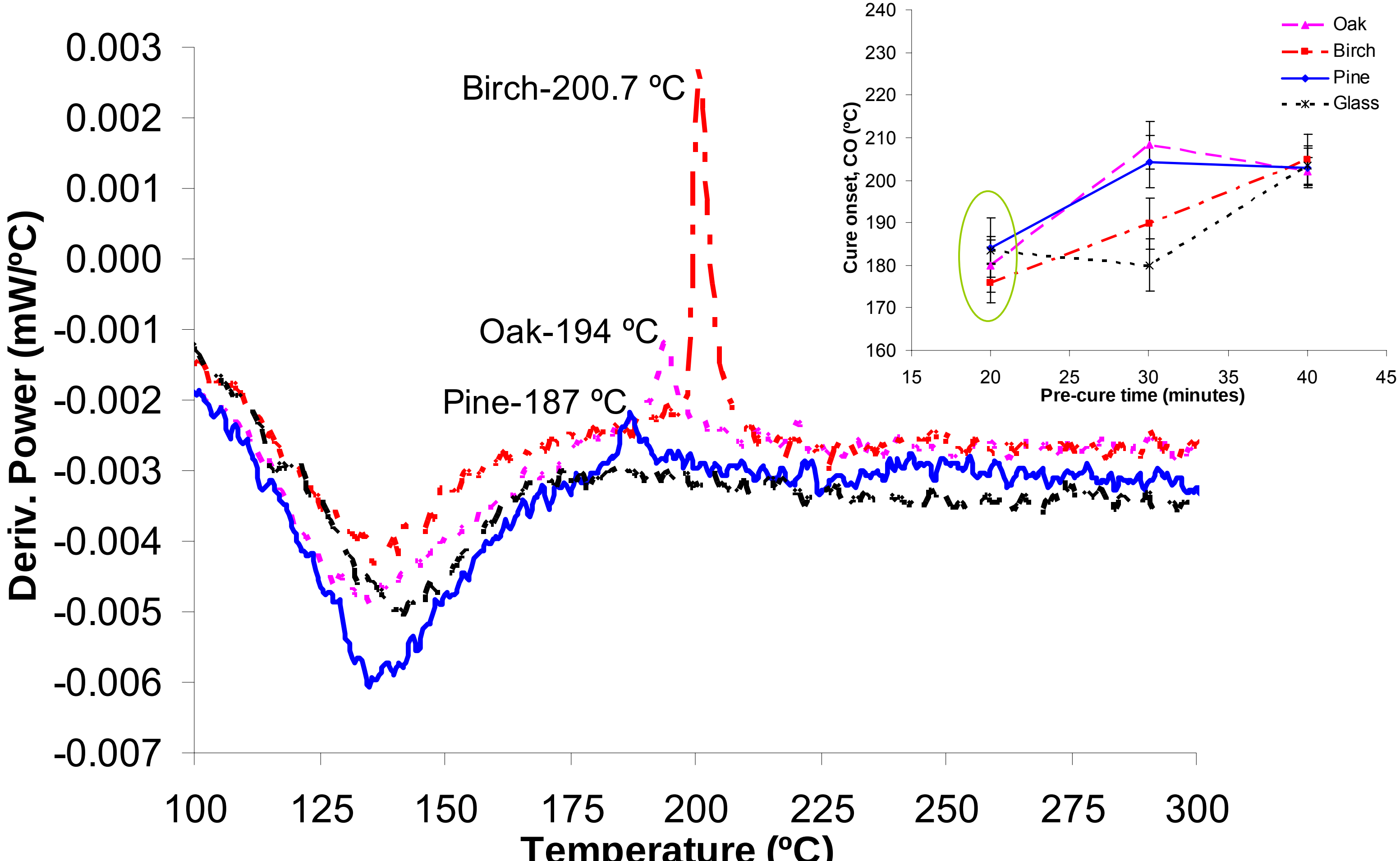



- Coating thickness is well above substrate expansion.
- This avoids probe contacting with the veneer.

*Johnson & Yan, Adhesive 2005*

# Cure exotherm detected for PF on different substrates pre-cured at 90 ºC for 20 minutes




Cure exotherm temperature decreases with increase in the degree of cure.

*Johnson & Yan, Adhesive 2005*

# Conclusions

- μ-TA was successfully used to identify the differences in curing behavior of PF resin caused by different substrates.
- Important thermal parameters such as glass transition temperature and cure onset were measured for partially cured PF resin.
- Pine and oak veneers were found to accelerate the curing process while birch veneer retarded the cure process.
- Cure exotherms associated with resin cure were detected for all wood substrates. However, for glass substrate no significant exotherms were detected suggesting catalytic activity of wood substrates.

*Johnson & Yan, Adhesive 2005*

# Acknowledgements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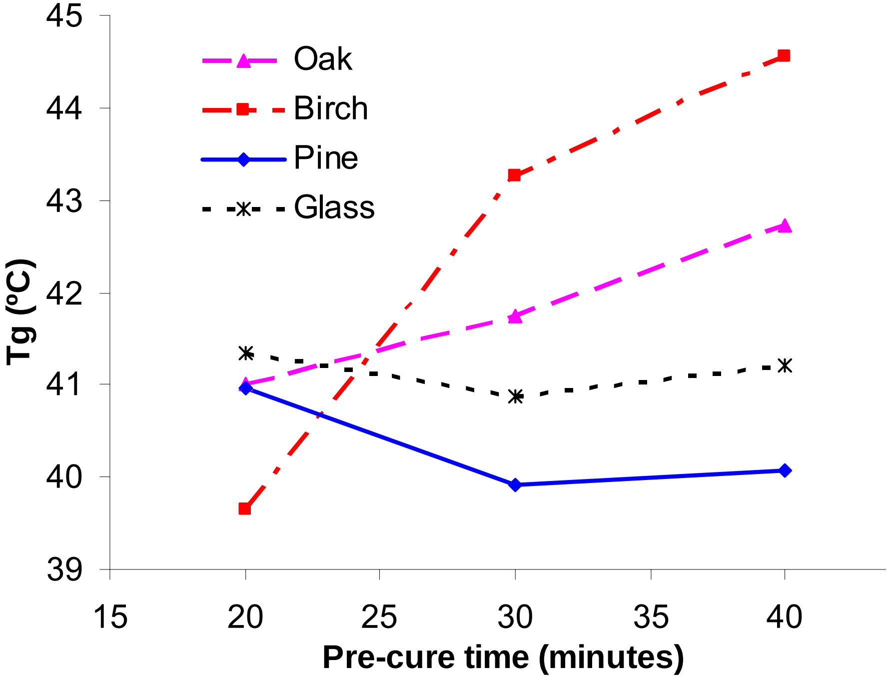
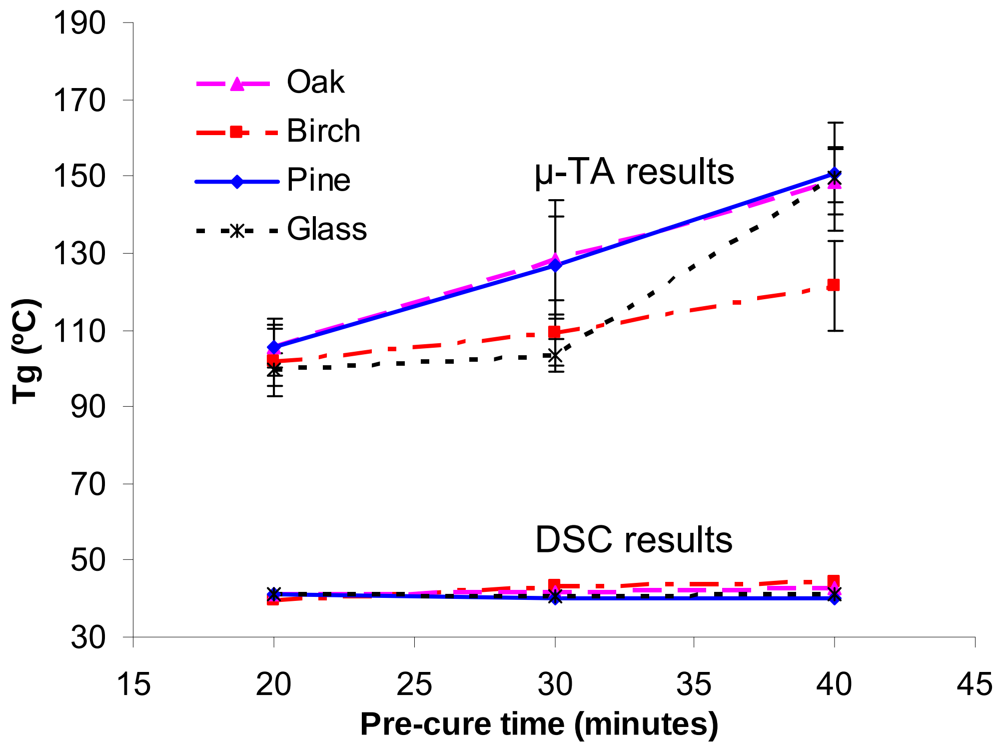
- We also wish to thank Sabina Di Risio for assistance with μ-TA and Dr. Guangbo He for useful discussions.

# Comparison of μ-TA results with DSC results




DSC results




*Johnson & Yan, Adhesive 2005*