Closing the Gap:

Improving Solution Accuracy with Better Material Models

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Goals

- Give you a clear understanding of open issues in material models
- How can we get Moldflow what it really needs
  - Without artifact
  - With existing technologies

Lets Follow the Plastic

- Screw and nozzle
- Runner
- Past the gate
- Into the mold
- As it hits the mold wall
- Packing
- Solidification and cooling

Open Issues-viscosity

- Molding occurs at very high shear rates
- Viscous heating occurs
- Viscosity increases with pressure
- Low temperature rheology

High-shear rheology

- Important for materials where shear thinning region is not well defined, eg. PC
- For thin wall injection molding
- For 2nd order models which tend to converge at high shear rate

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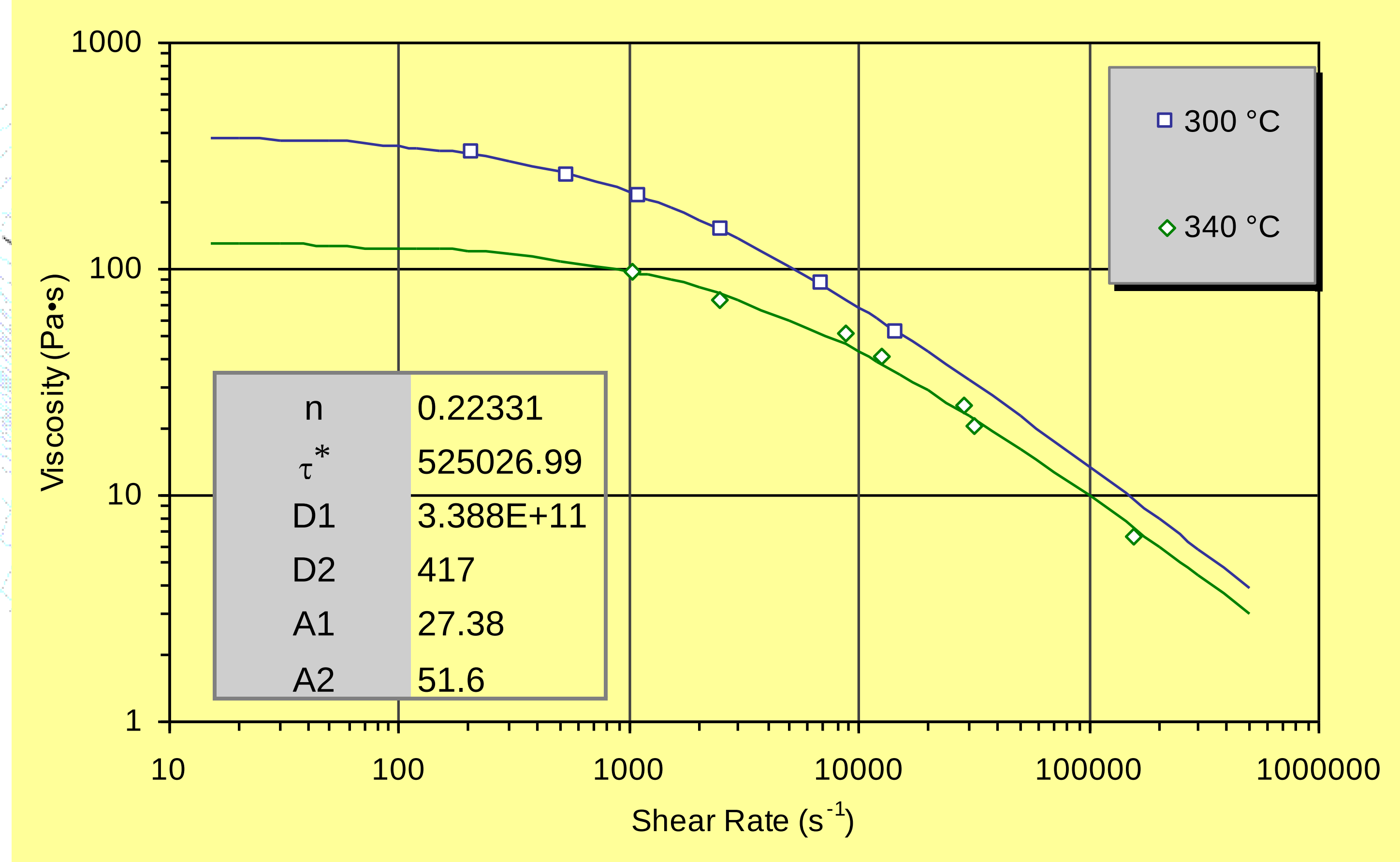
Technique- high shear

- High force servo-hydraulic rheometer
- ½ mm dies
- Cannot do fiber filled materials

Results to 100,000 /s



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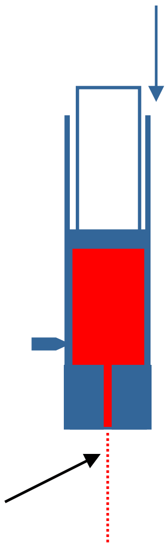
Viscous Heating

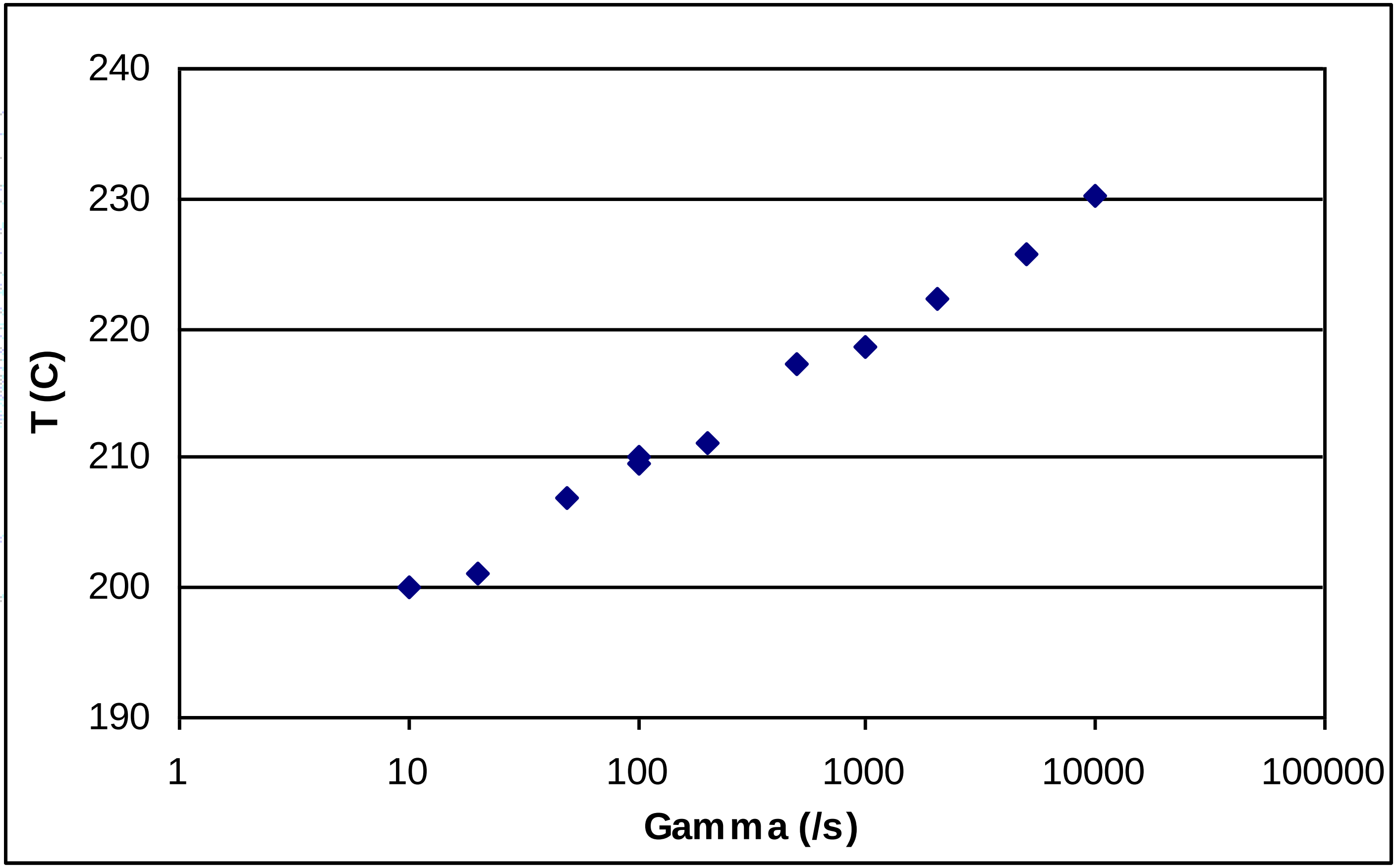
- Why it is important
  - Viscosity falls with temperature
  - Viscosity falls with shear rate
  - Viscous heating increases with shear rate
  - Viscosity rises with pressure
  - Higher pressure at higher shear rate

Technique



- Using temperature sensitive fluorescent dye in polymer
- Calibrate fluorescence f(T)
- Measure fluorescence at die exit
- Obtain exit temperature f(shear rate)

Results: +30C at 10,000/s



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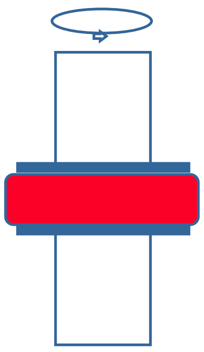
Open Issues -thermal

- Ill defined melt-solid transitions
- Uncertainty about the no-flow temperature
- Properties do not transition at same temperature

No-flow temperature issues

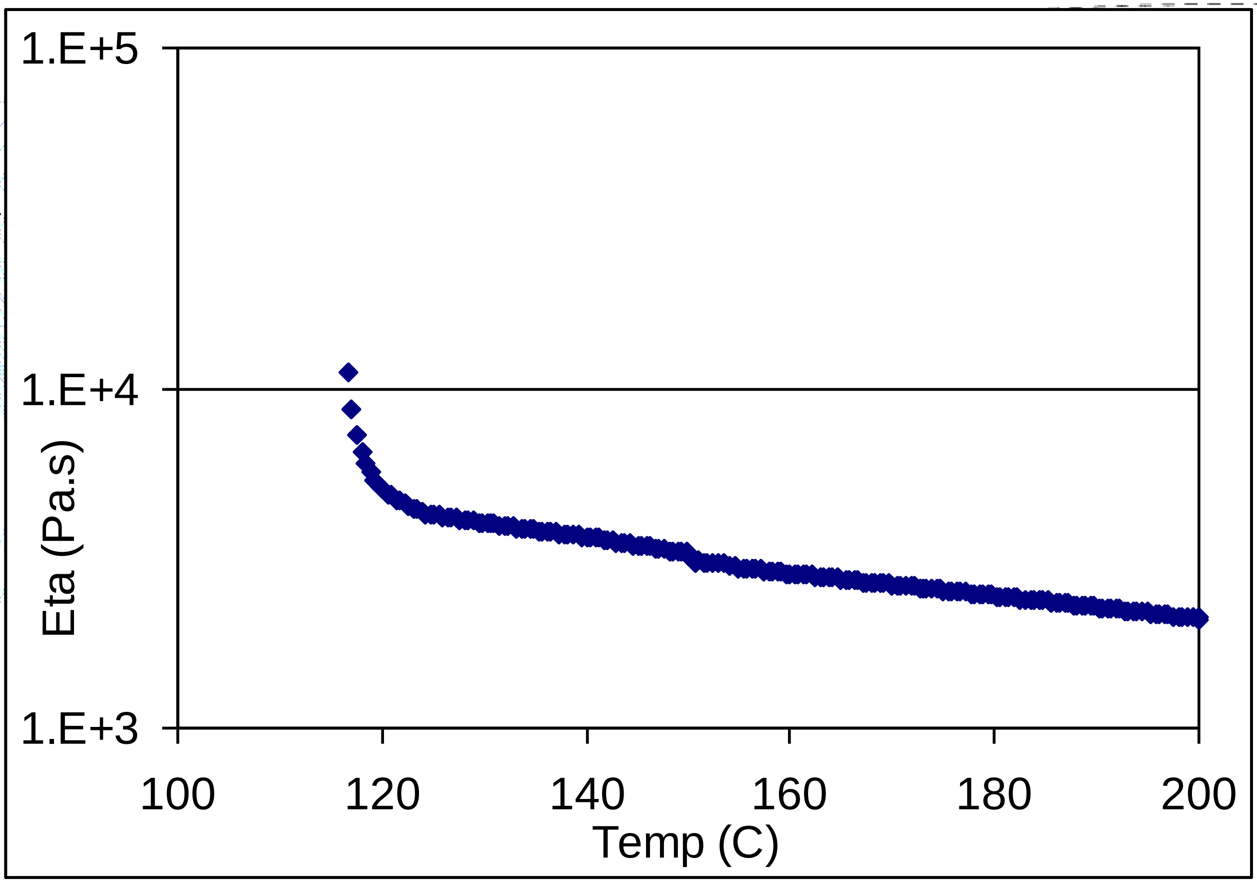
- Current measurement gives only a vague indication of transition
- Wide discrepancies in transitions compared to other techniques
- Source of great weakness to the simulation

Melt-solid transition



- Parallel plate DMA
  - Melt to solid
  - Constant frequency
  - Constant cooling rate
  - Use G'-G" crossover &/or cut-off viscosity (eg 10^7 Pa.s) to precisely define critical temperature.
  - Precise determination of temperature sensitivity of viscosity & transition

Results: semi-crystalline



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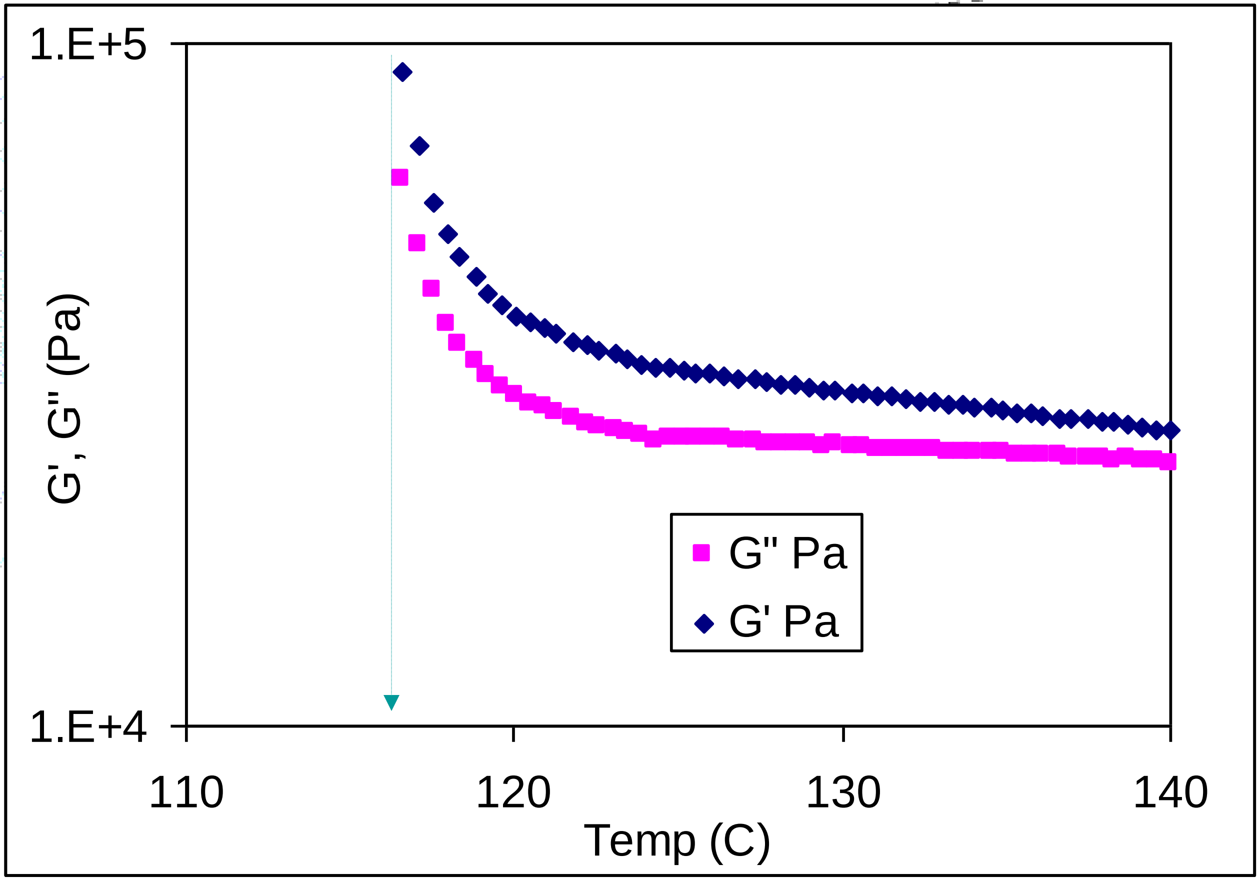
Results: semi-crystalline



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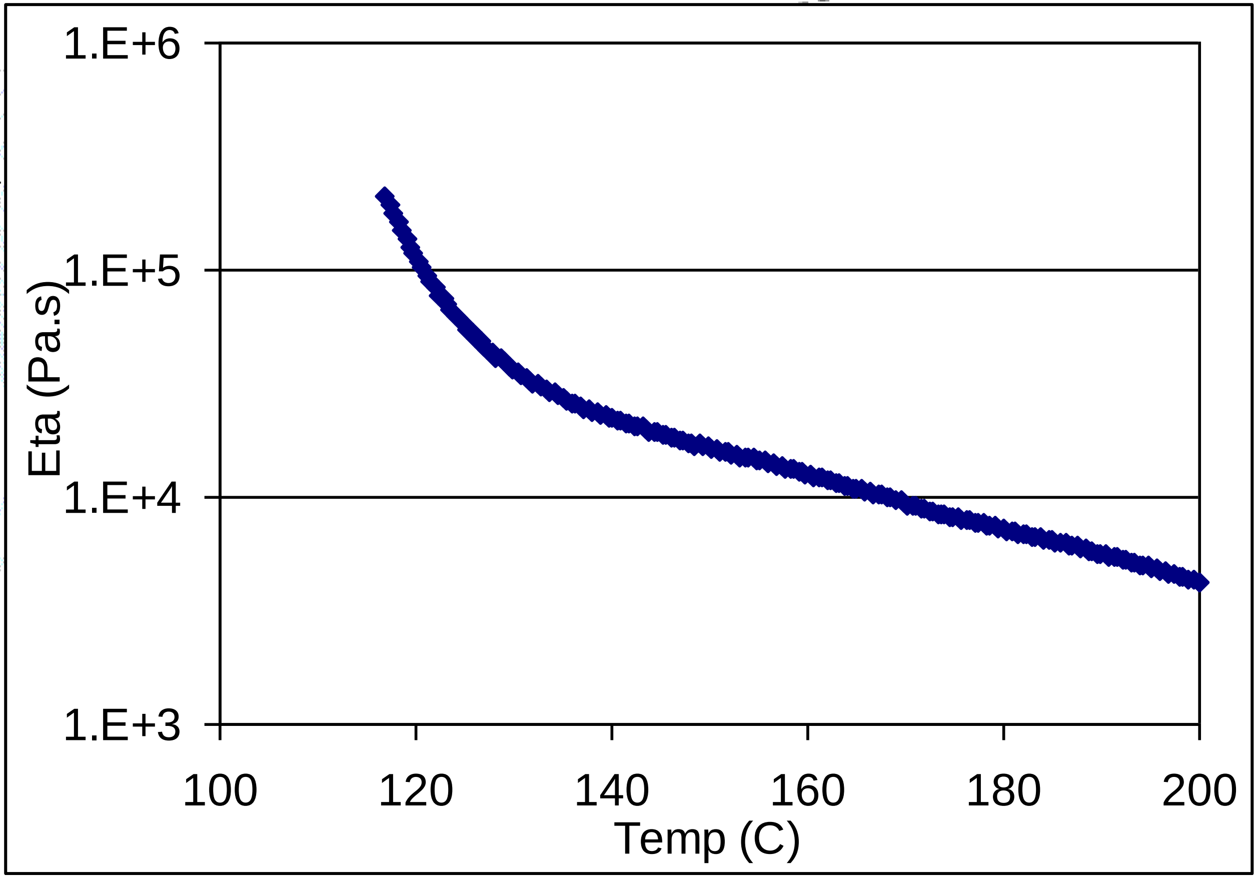
Results: amorphous



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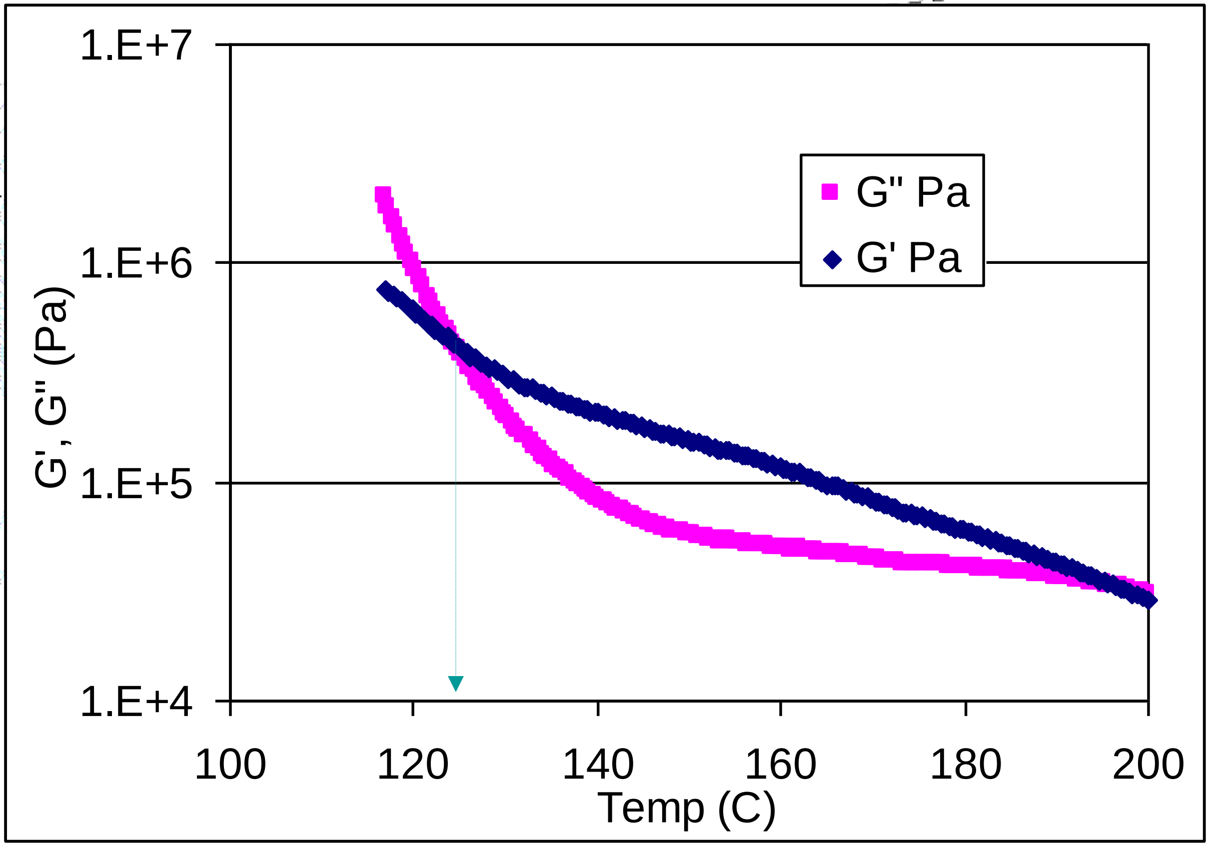
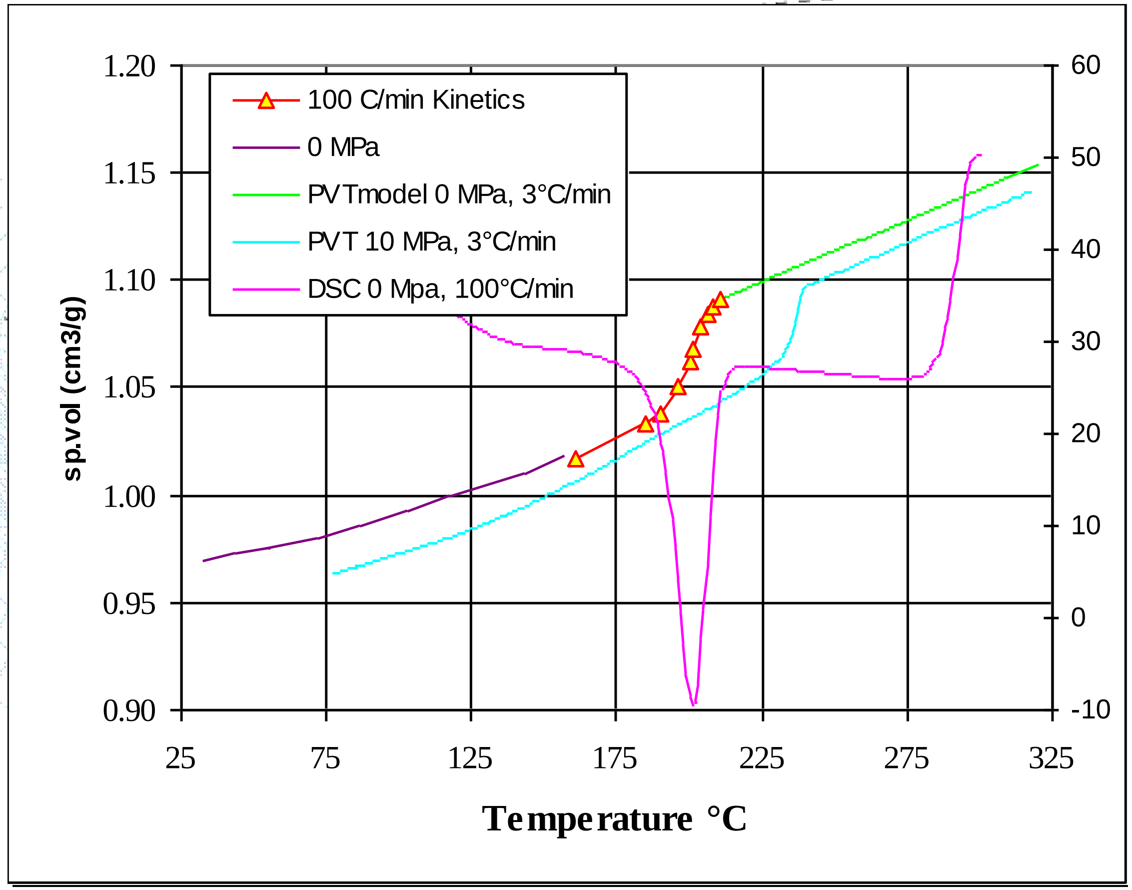
Results: amorphous



Open Issues -PVT

- Melt transition <> crystallization transition
- Crystalline transitions temperature falls with cooling rate
- Crystallinity changes with rate
- Actual solidification transition is unknown
- Morphology of solid is non-uniform

Effect of cooling rate



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Unifying the flow model

- Viscosity will rise with falling temperature until solidification
- Thermal properties will change at solidification temperature
- PVT will transition at same temperature
- Stresses will begin to build below this temperature

Open Issues -Mechanical

- Properties depend on
  - specimen size
  - aspect ratio
  - flow distance
- Properties are a function of temperature
- Significant effect on CTE ratios

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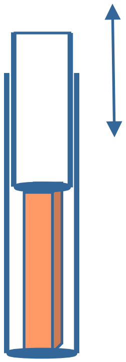
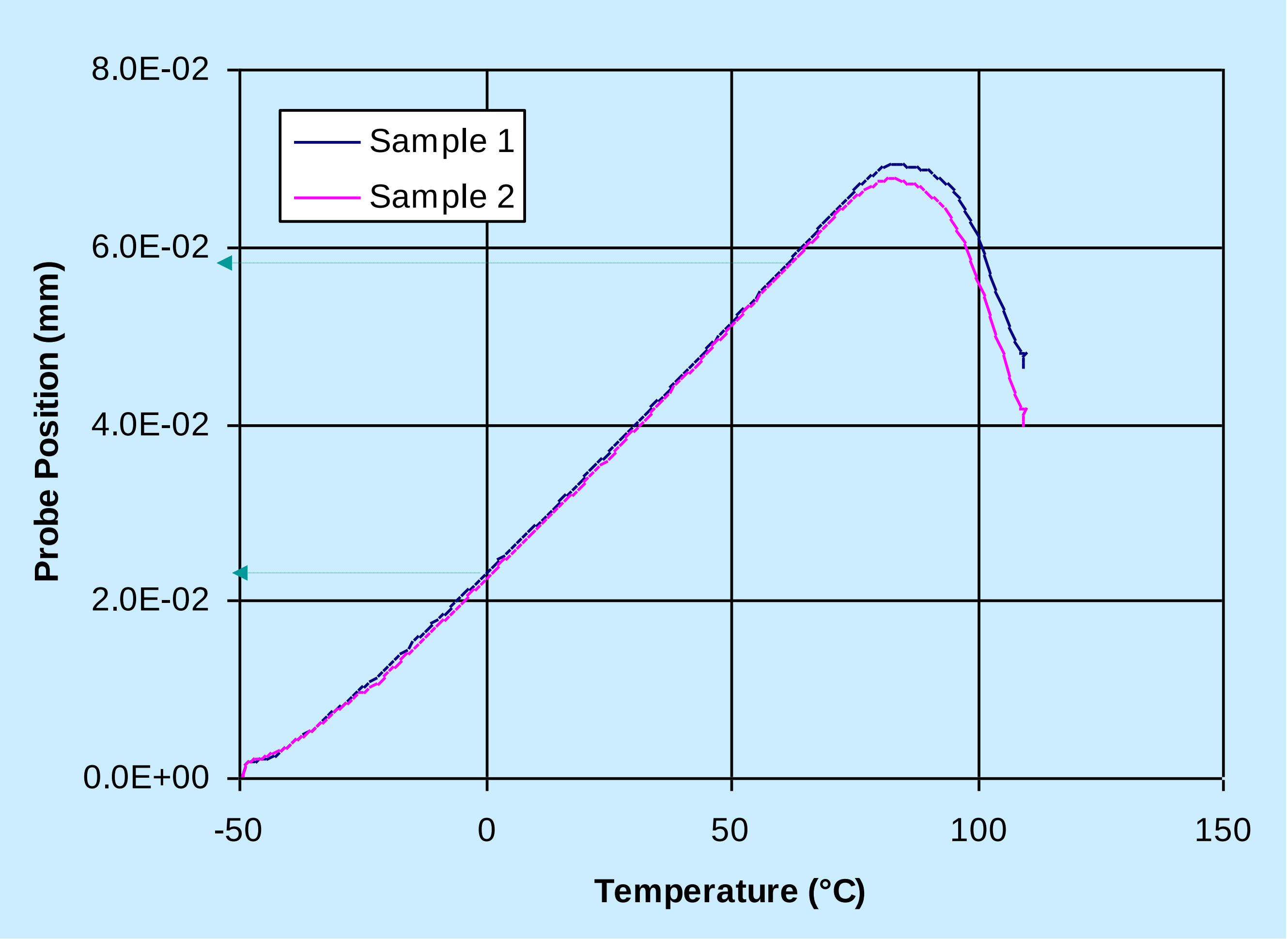
Thermal expansion issues



- CTE by TMA
  - Highly accurate
  - Can use small specimens
  - Observe temperature dependency

CTE -Normal



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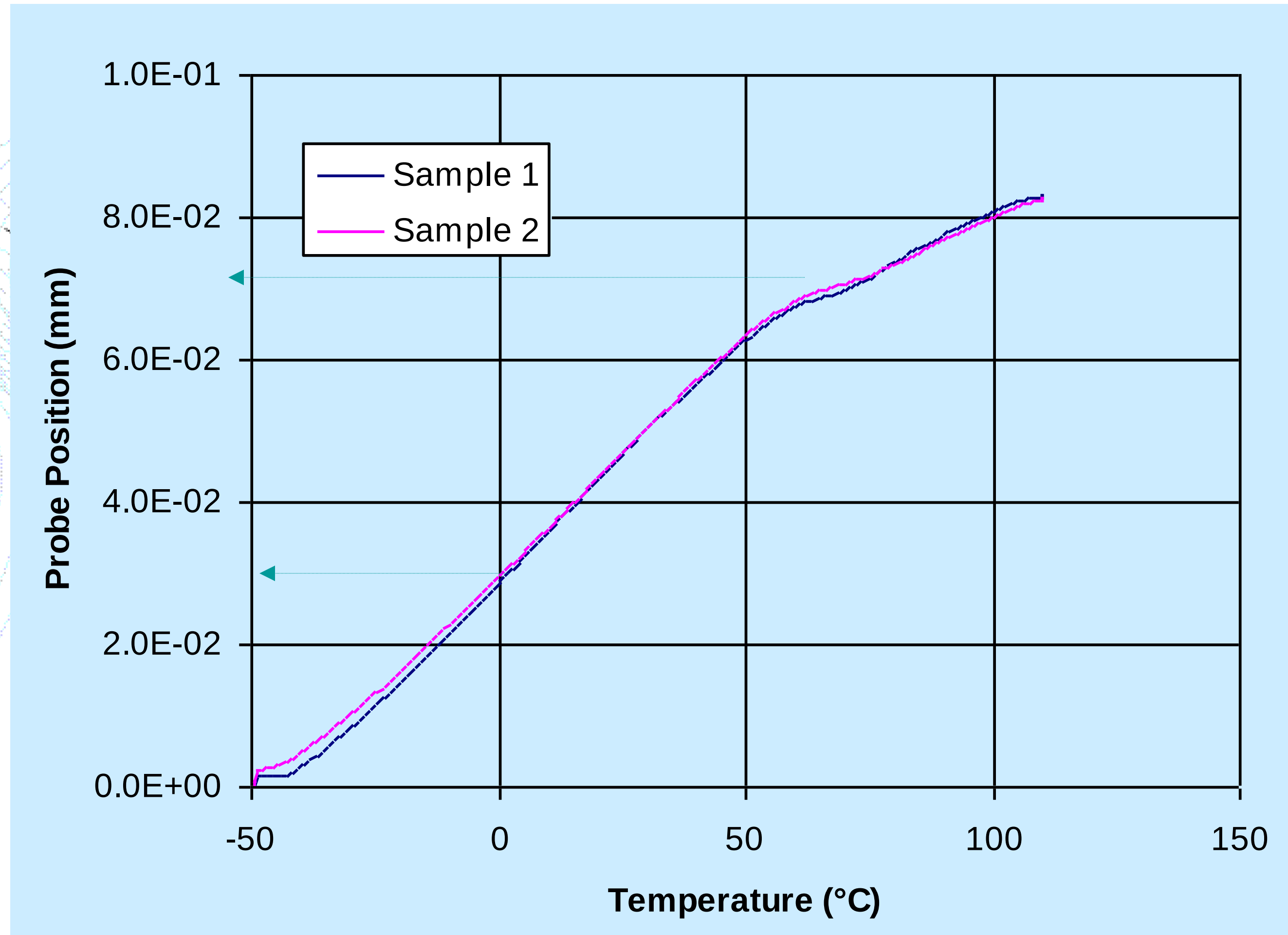
CTE –Transition Effect



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Conclusion

- These improvements can make a substantial difference
- They are available now (current technology)
- Will ensure robust, cleaner and long lasting material model
- Reduce dependency on empirical models = lower cost of testing

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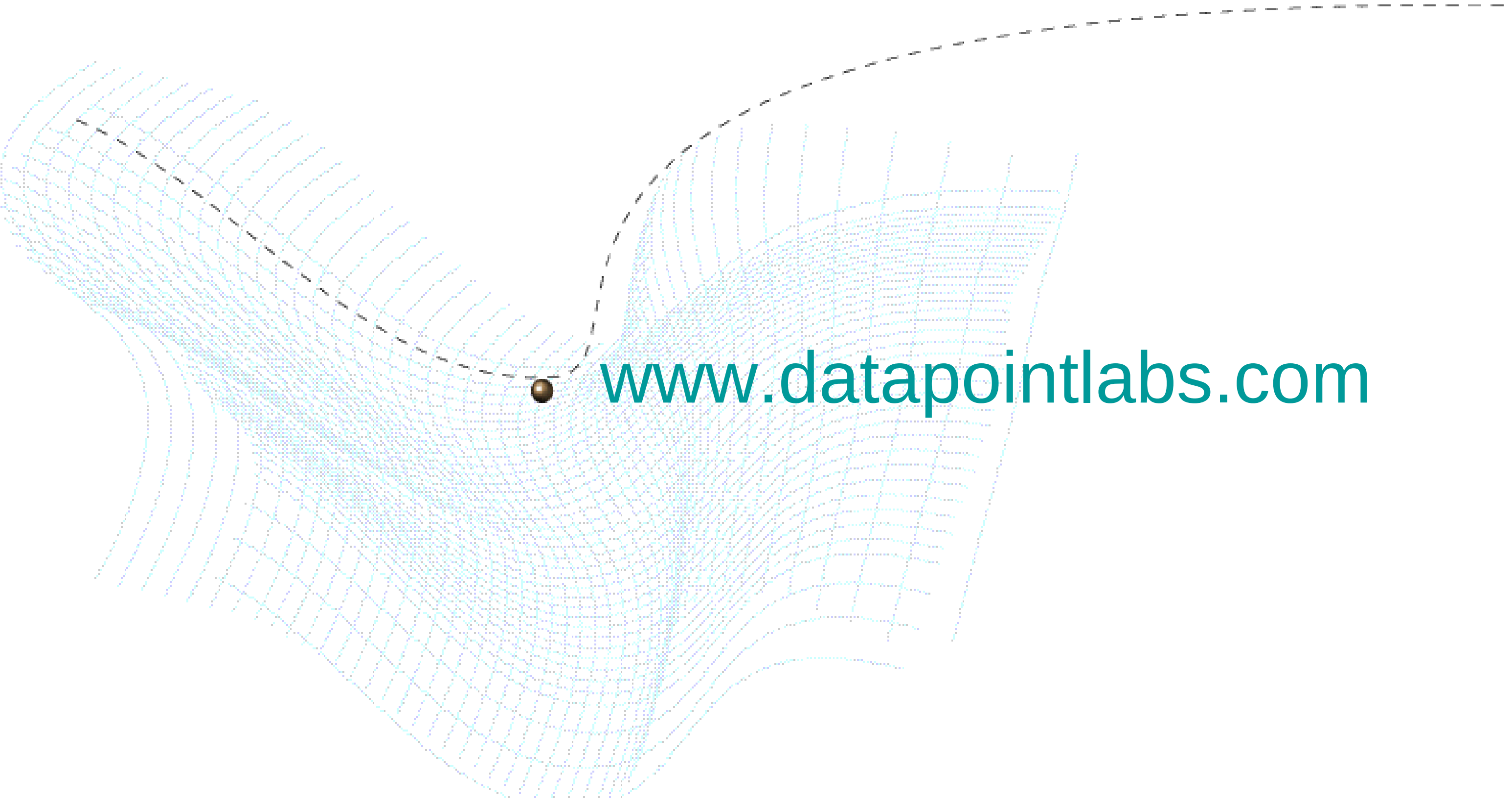
Questions



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