DSR testing of GTR

Particle size effects

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DSR Test Plan

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- Crumb rubber sizes
  - #16-#20 (~1mm)
  - #20-#30 (~0.7 mm)
  - #40-#50 (~0.4 mm)
- Crumb rubber percentages
  - 15%, 20%, 25%
- Test geometry
  - Parallel plate
  - Concentric cylinders
- PG58-28 base binder

Sample preparation (wet process)

- Mixing temperature: 190C +-5C
- Mixing duration: 1 hr
- Mixing speed: 1000 RPM
- Two to three replicate batches

DSR testing

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- 25 mm plate
  - T = 46, 58, 70, and 82°C
  - ω = 10, 15.84, 25.12, 39.81, 63.09, 100 rad/s
  - 2 mm gap
- 8 mm plate
  - T = 15 and 30°C
  - ω = 10, 15.84, 25.12, 39.81, 63.09, 100 rad/s
  - 2 mm gap

Effect of Crumb Rubber size

At different percentages of rubber

CR sizes

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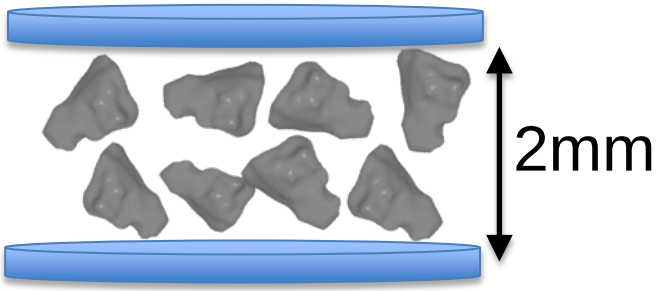
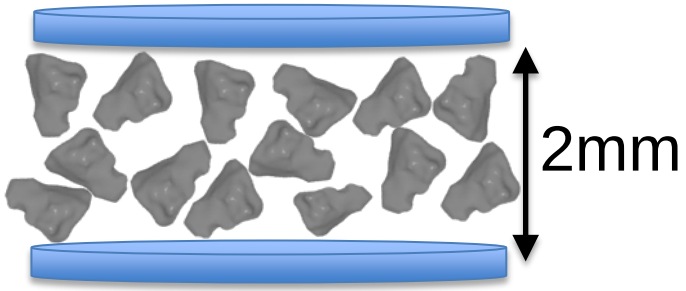
#16-#20

(1.18 - 0.85 mm)



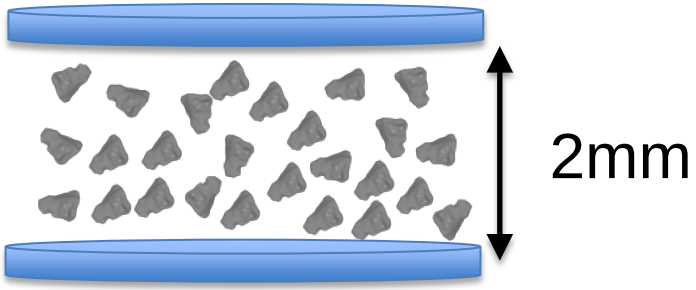
#20 - #30

(0.85 – 0.6 mm)



#40-#50

(0.425 – 0.355 mm)



X-ray CT of 15% CR

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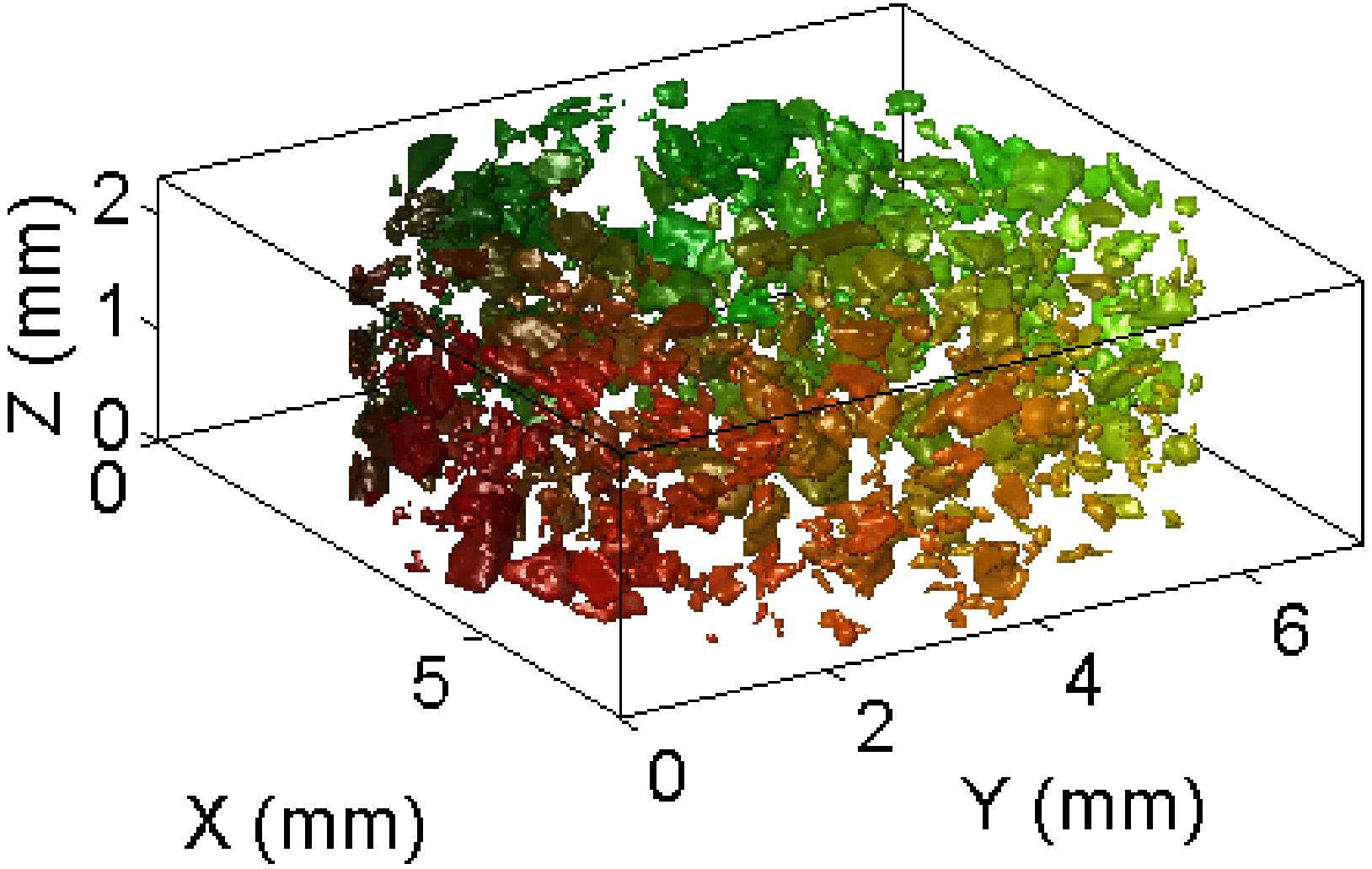
CR passing #30, retaining #40 sieve



Effect of CR size

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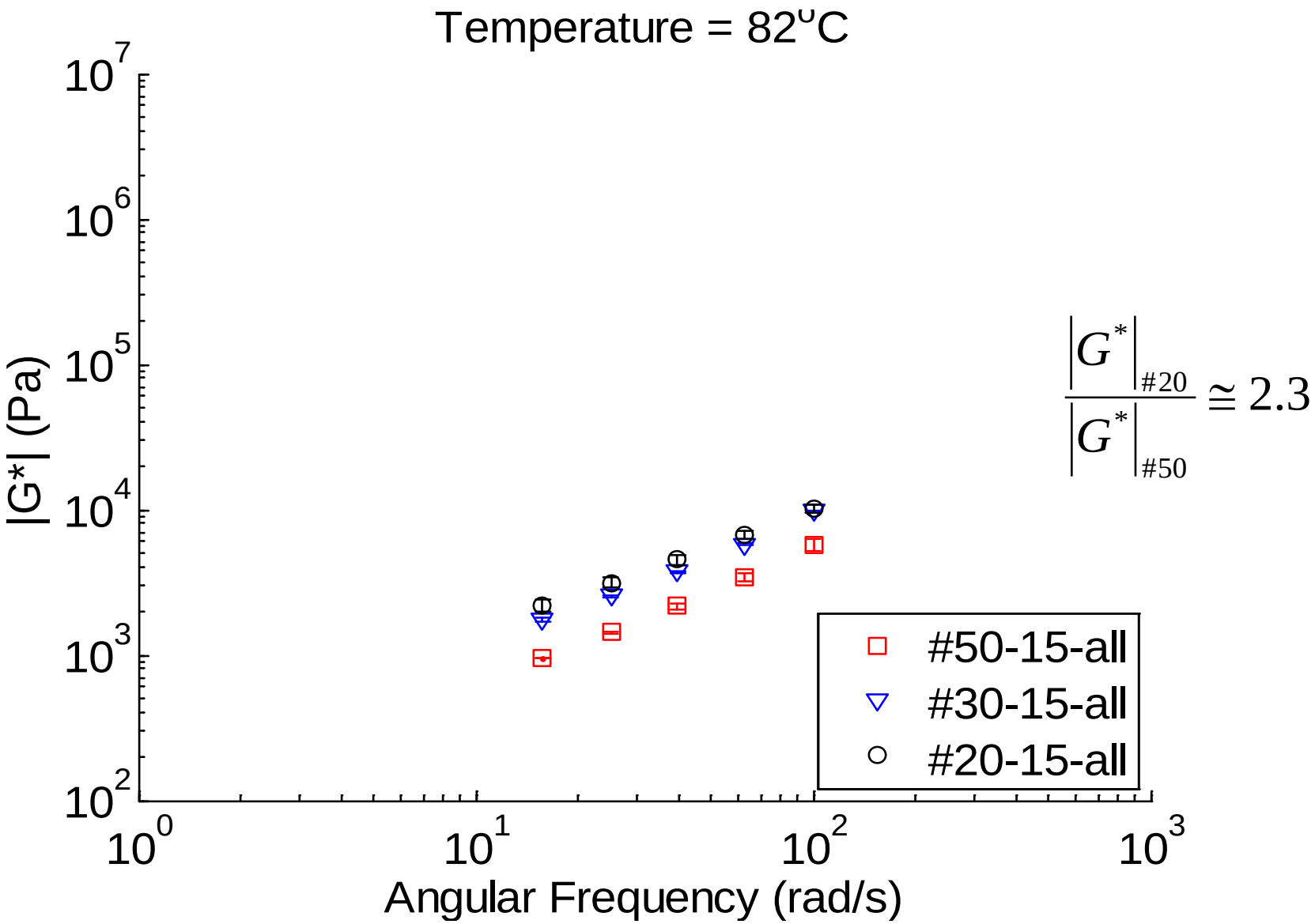
- For 15% CR content (by binder weight)



Effect of CR size

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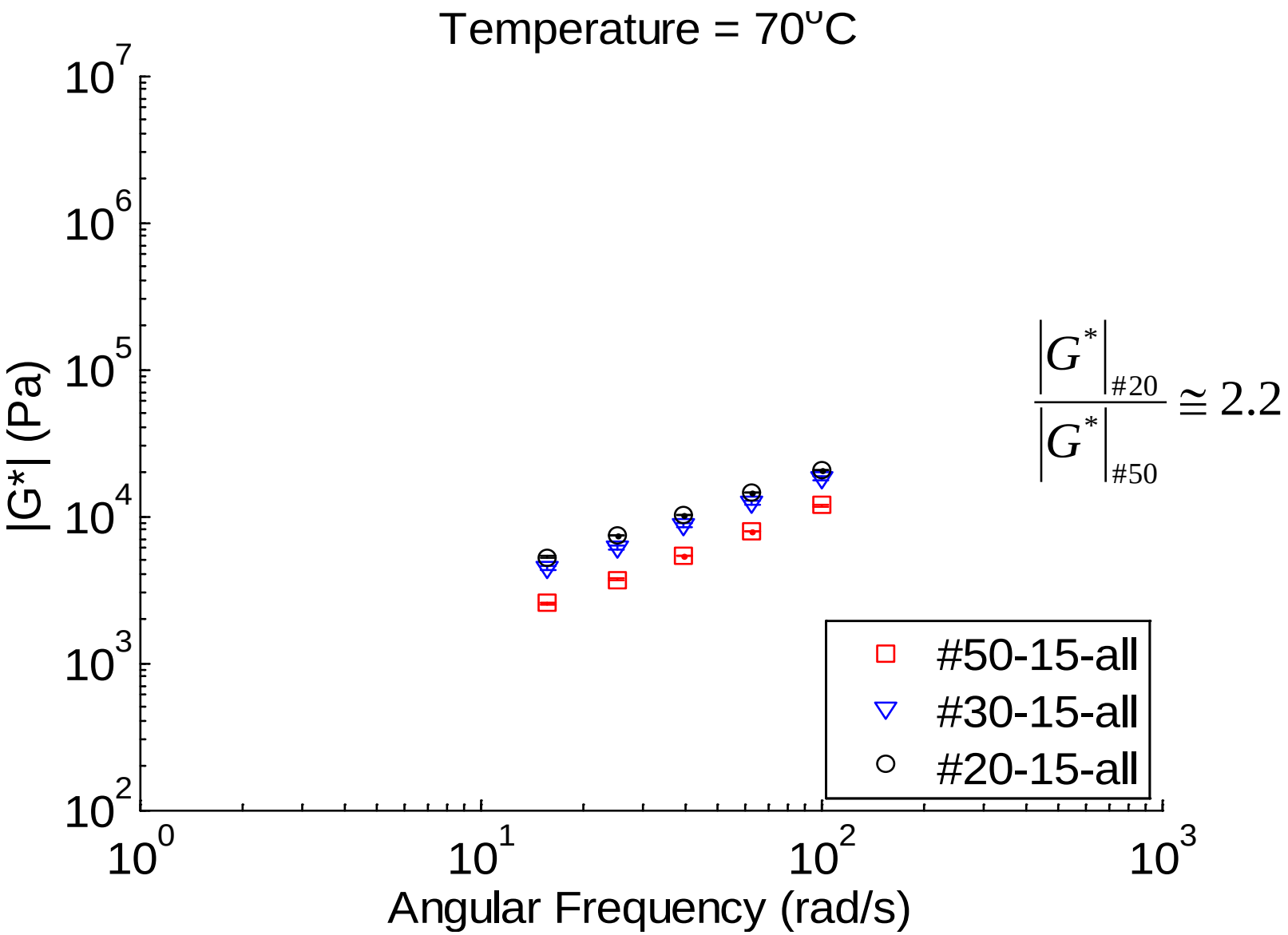
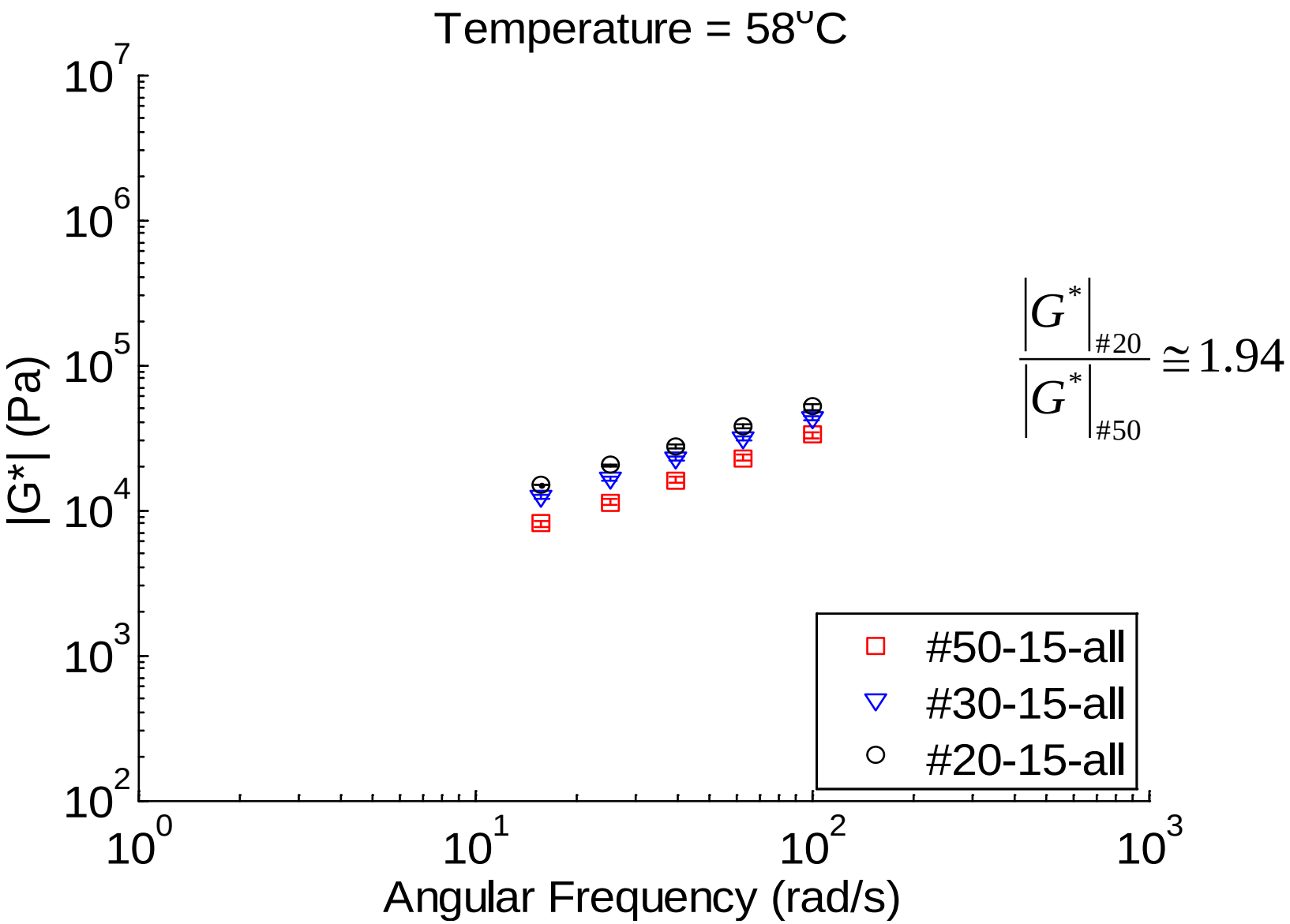
- For 15% CR content (by binder weight)



Effect of CR size

- For 15% CR content (by binder weight)



Effect of CR size

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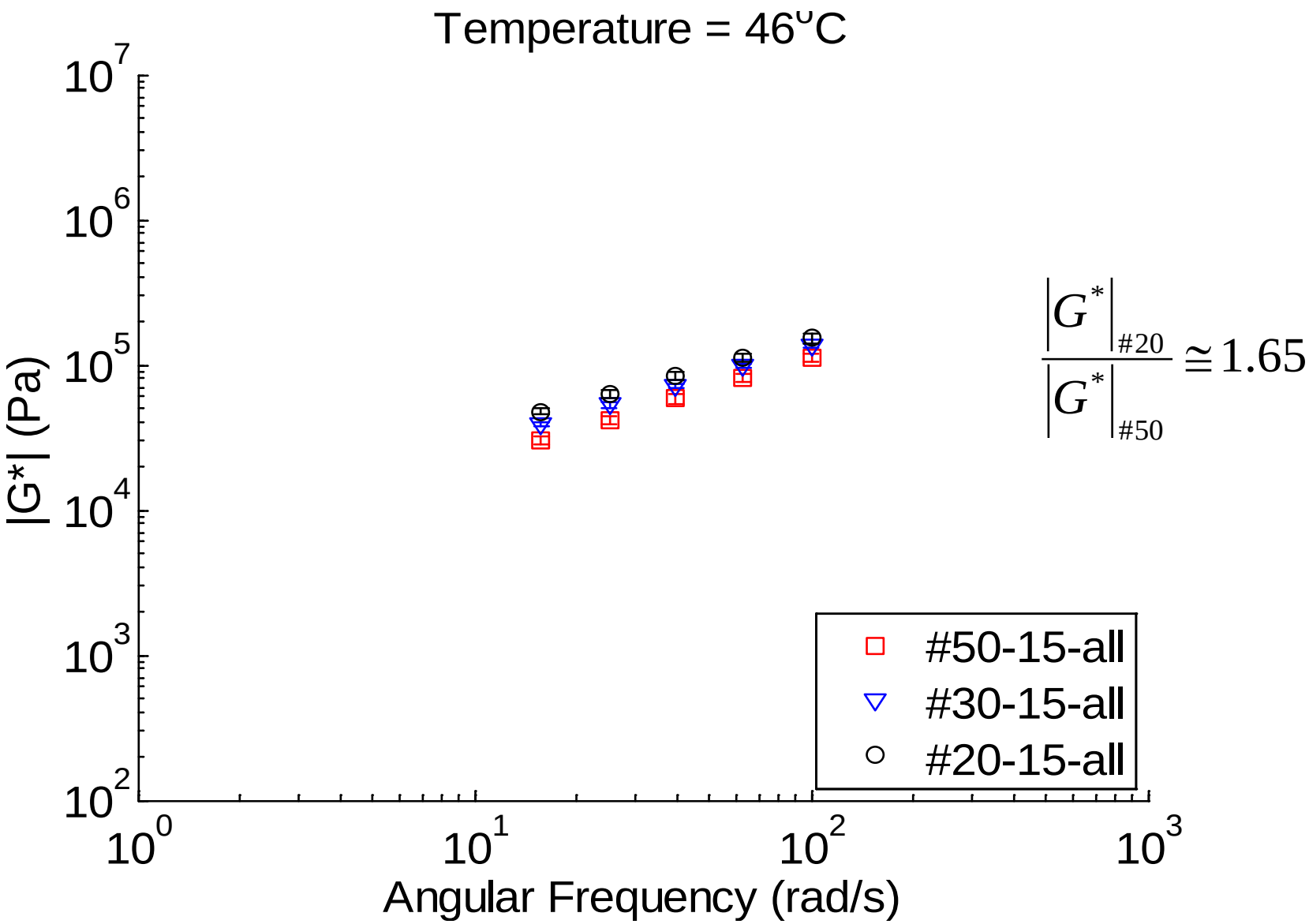
- For 15% CR content (by binder weight)



Effect of CR size

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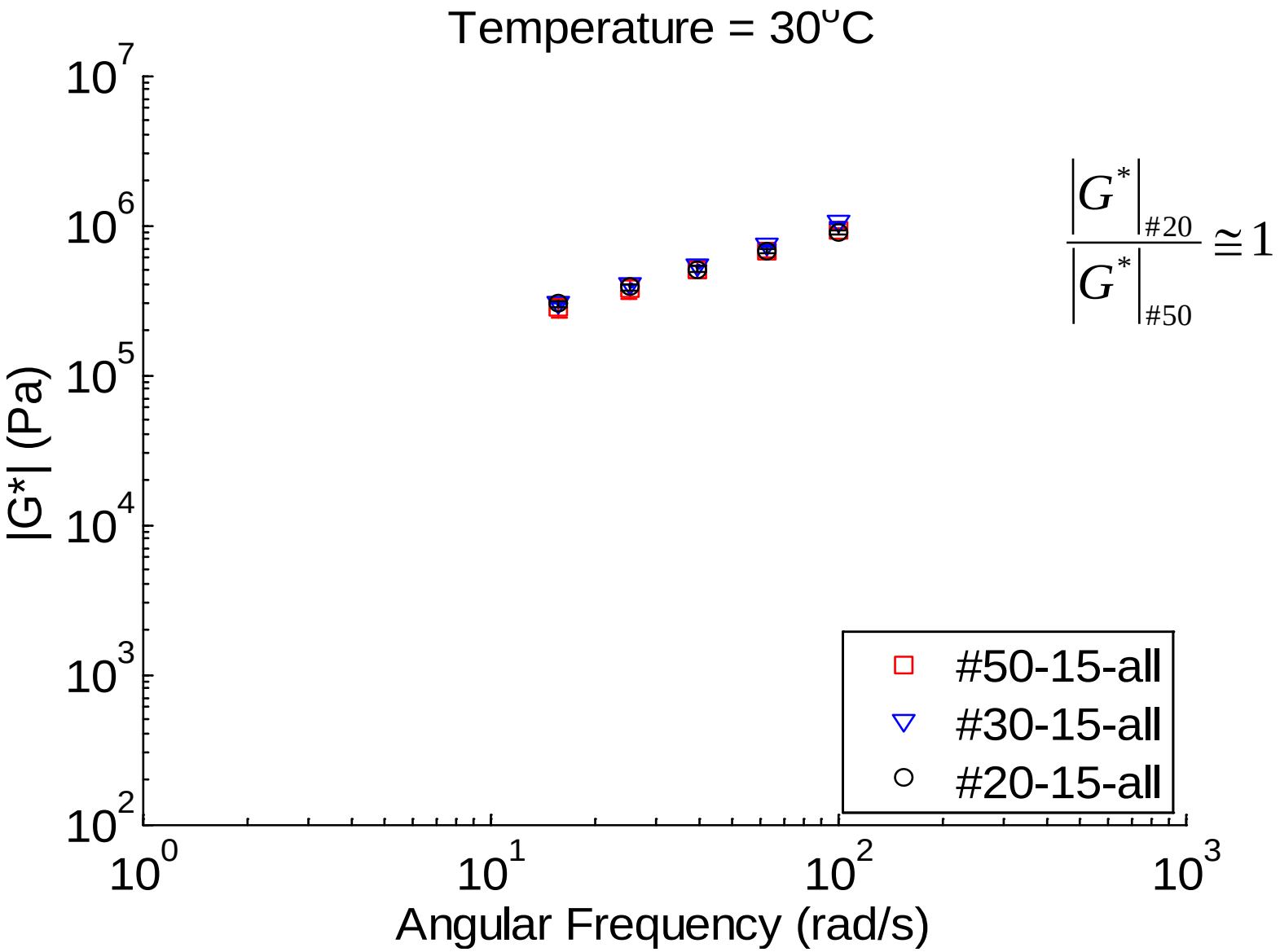
- For 15% CR content (by binder weight)



Effect of CR size

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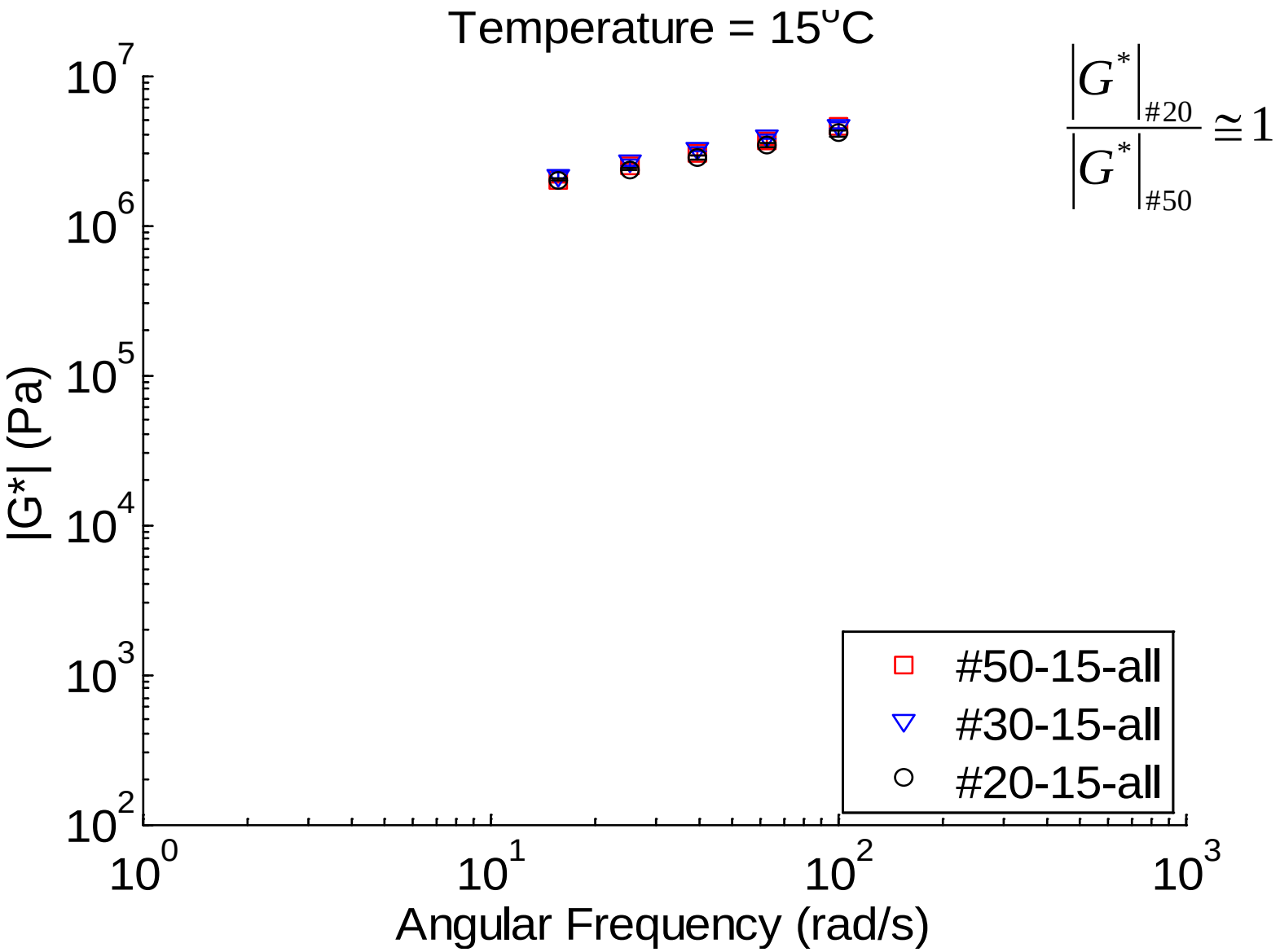
- For 15% CR content (by binder weight)



|G*| mastercurves (15% CR)

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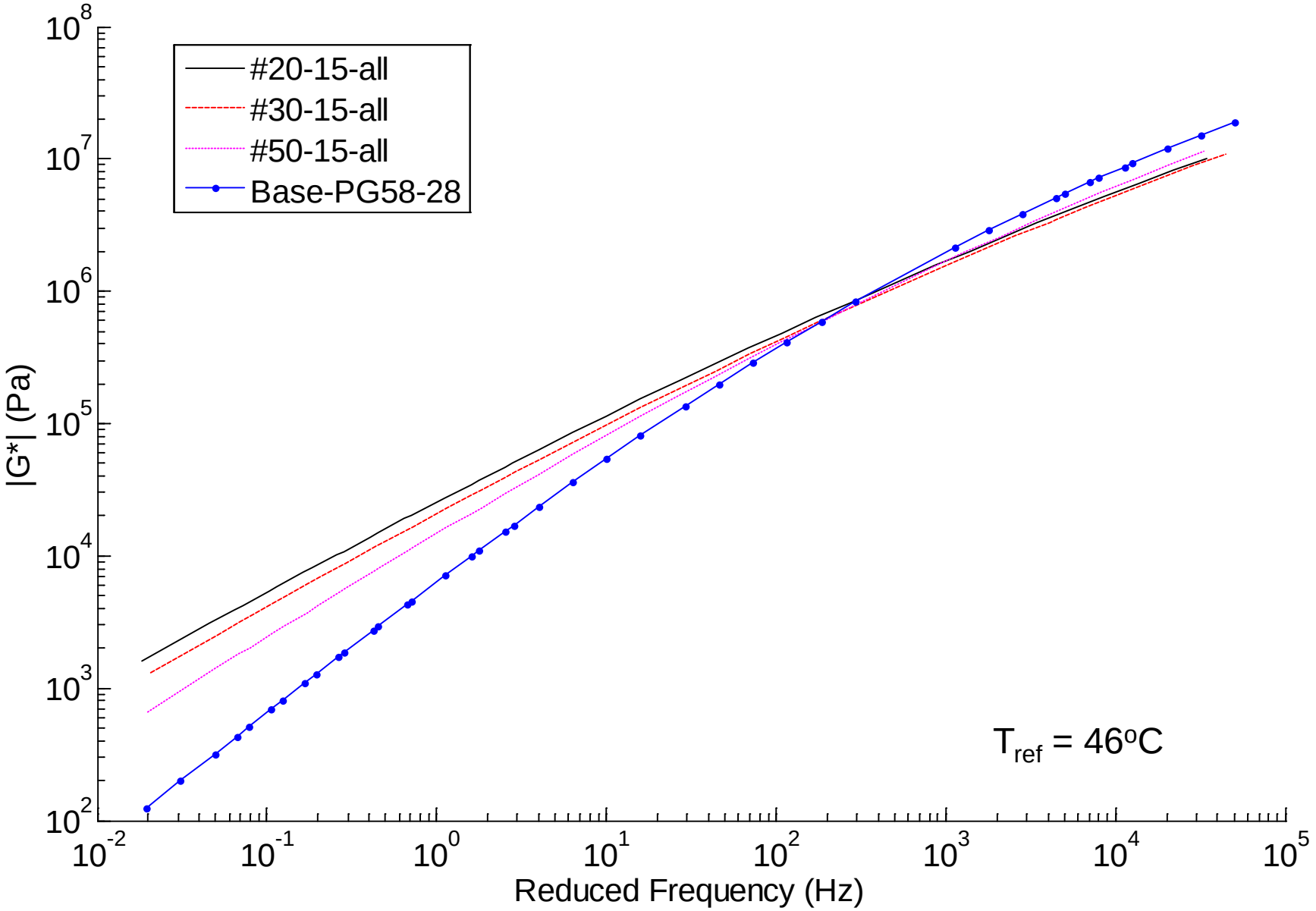

Effect of Crumb Rubber size

At 20% rubber

Effect of CR size

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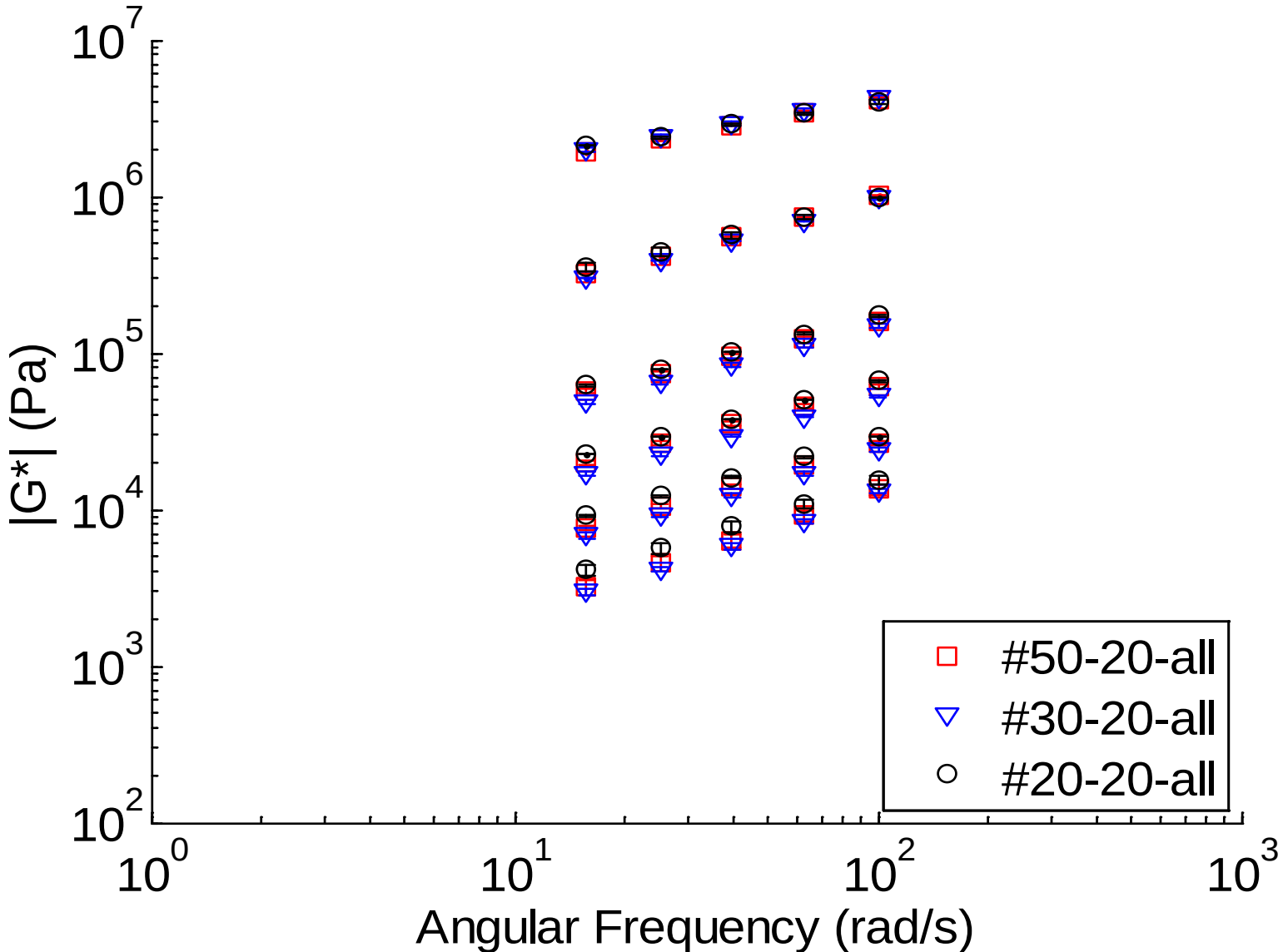
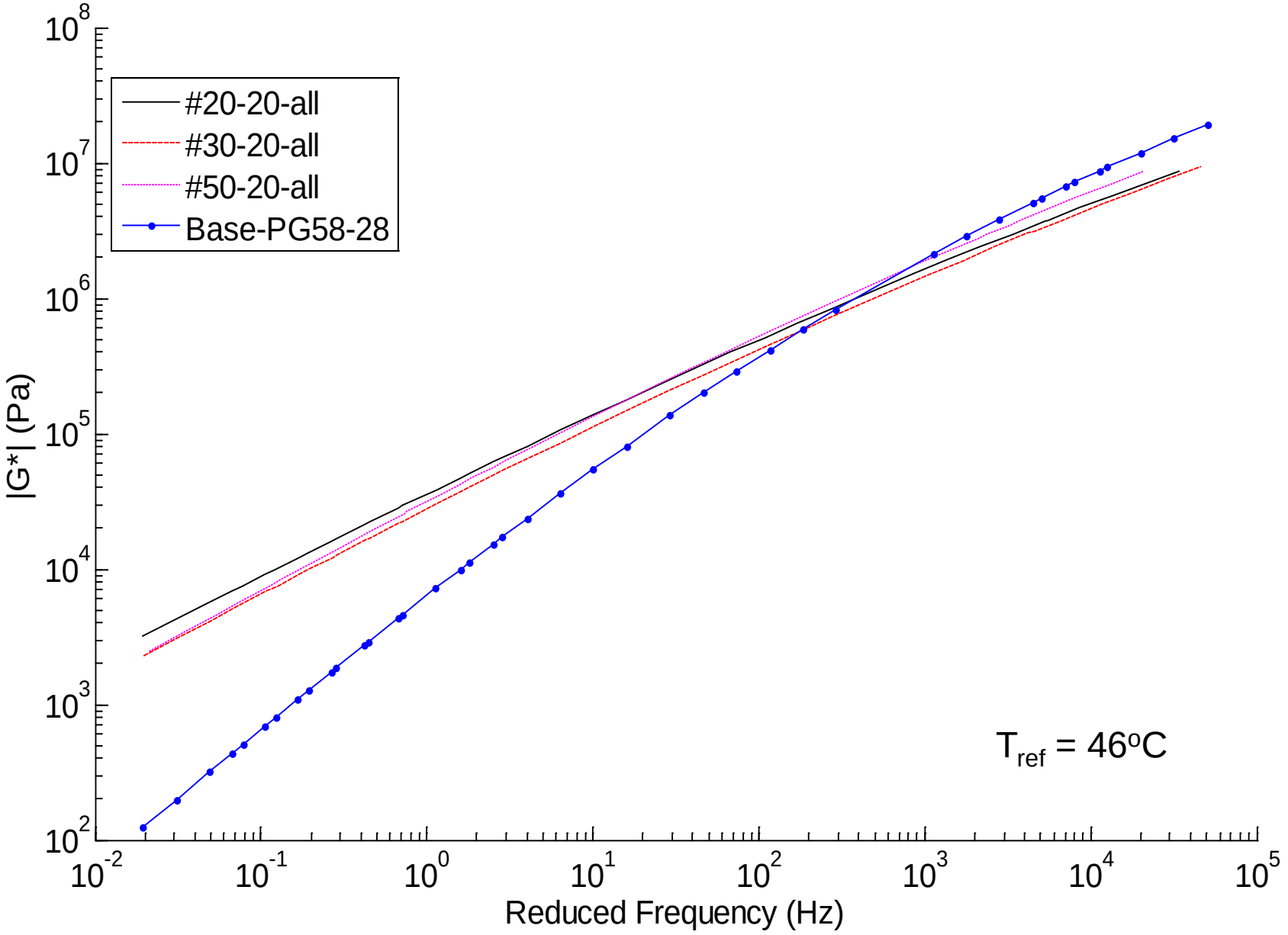
- For 20% CR content (by binder weight)



|G*| mastercurves (20% CR)



Effect of Crumb Rubber size

At 25% rubber

Effect of CR size

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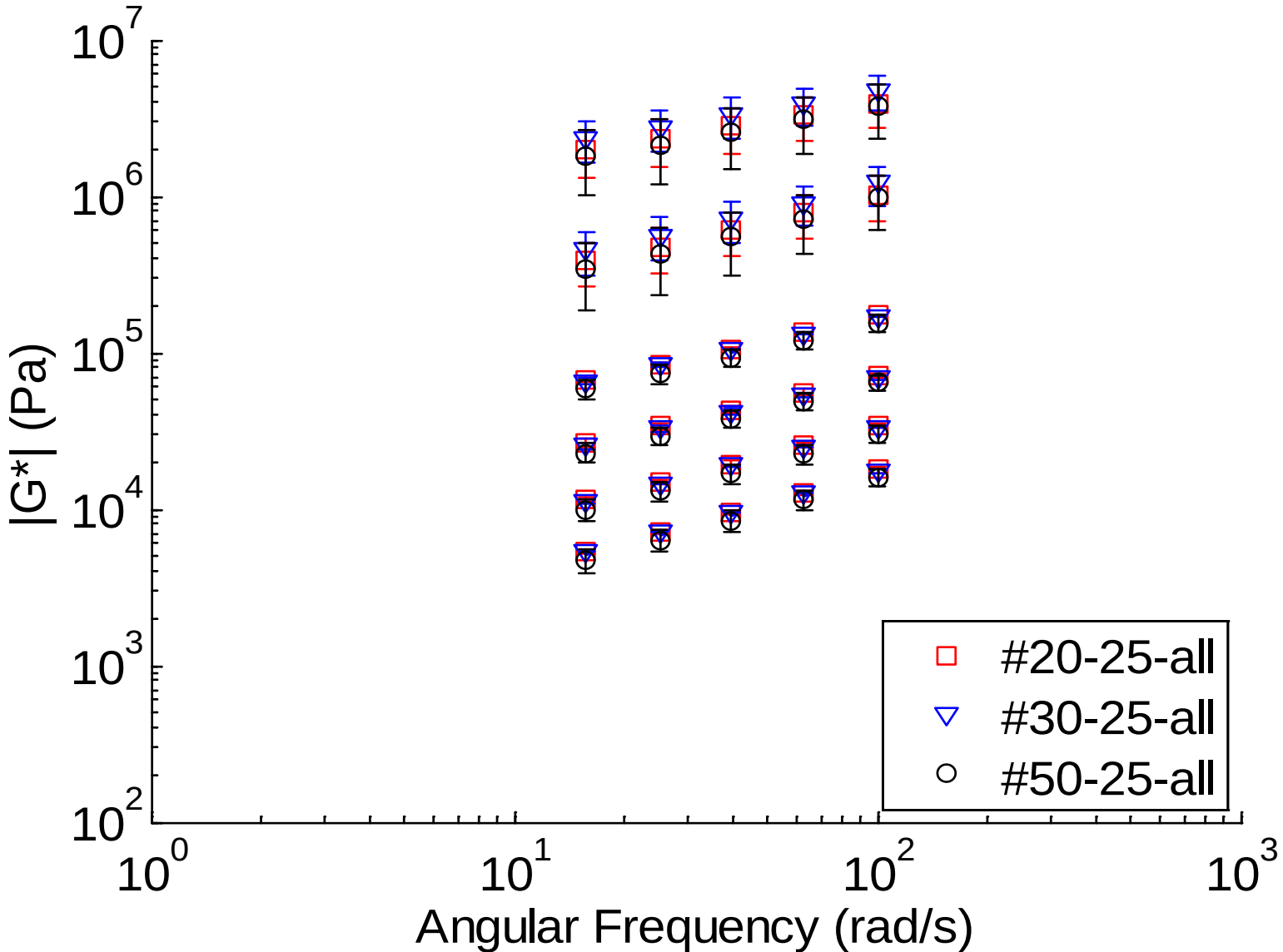
- For 25% CR content (by binder weight)



|G*| mastercurves (25% CR)

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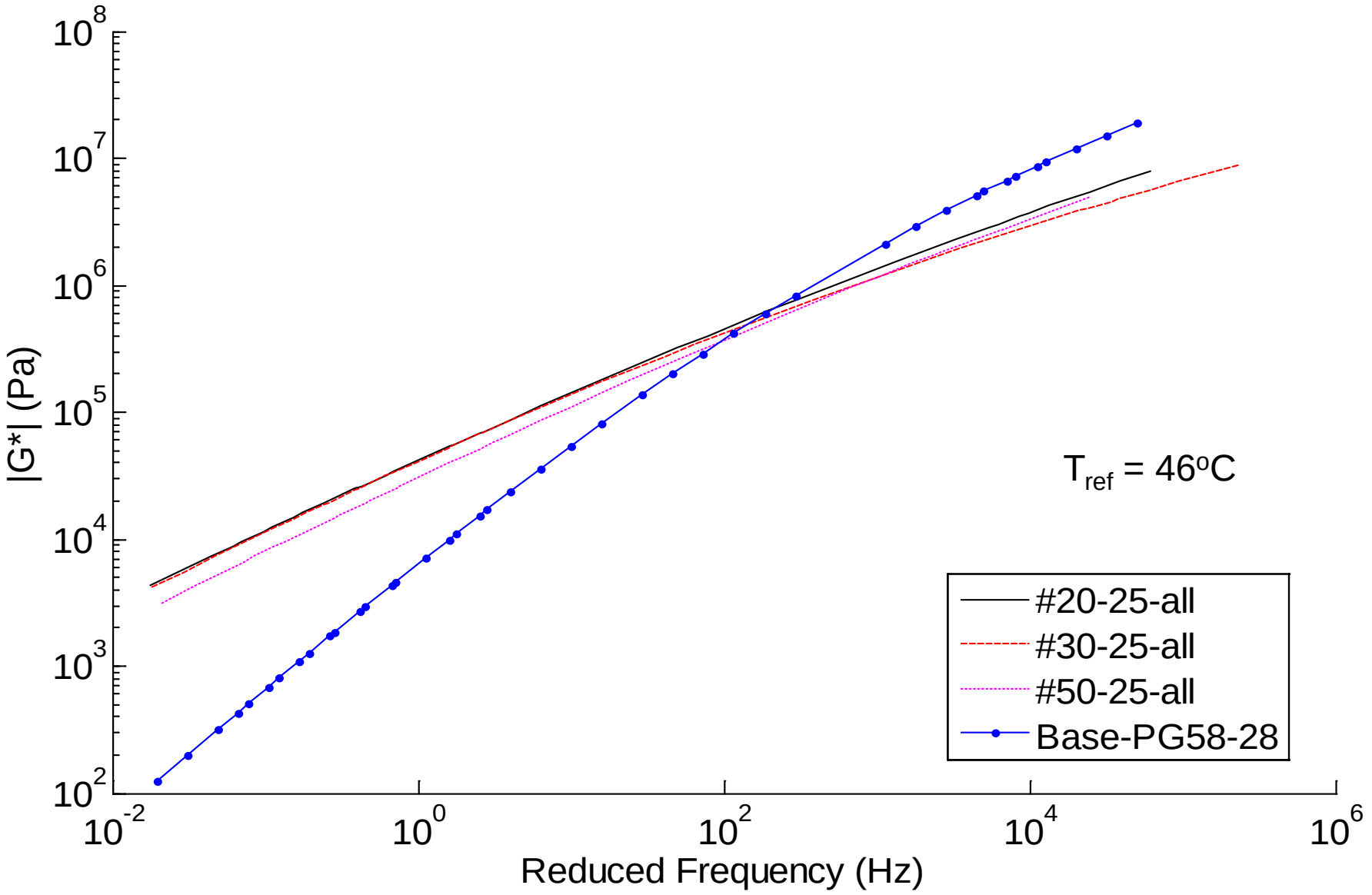

|G*| mastercurves (ALL sizes)

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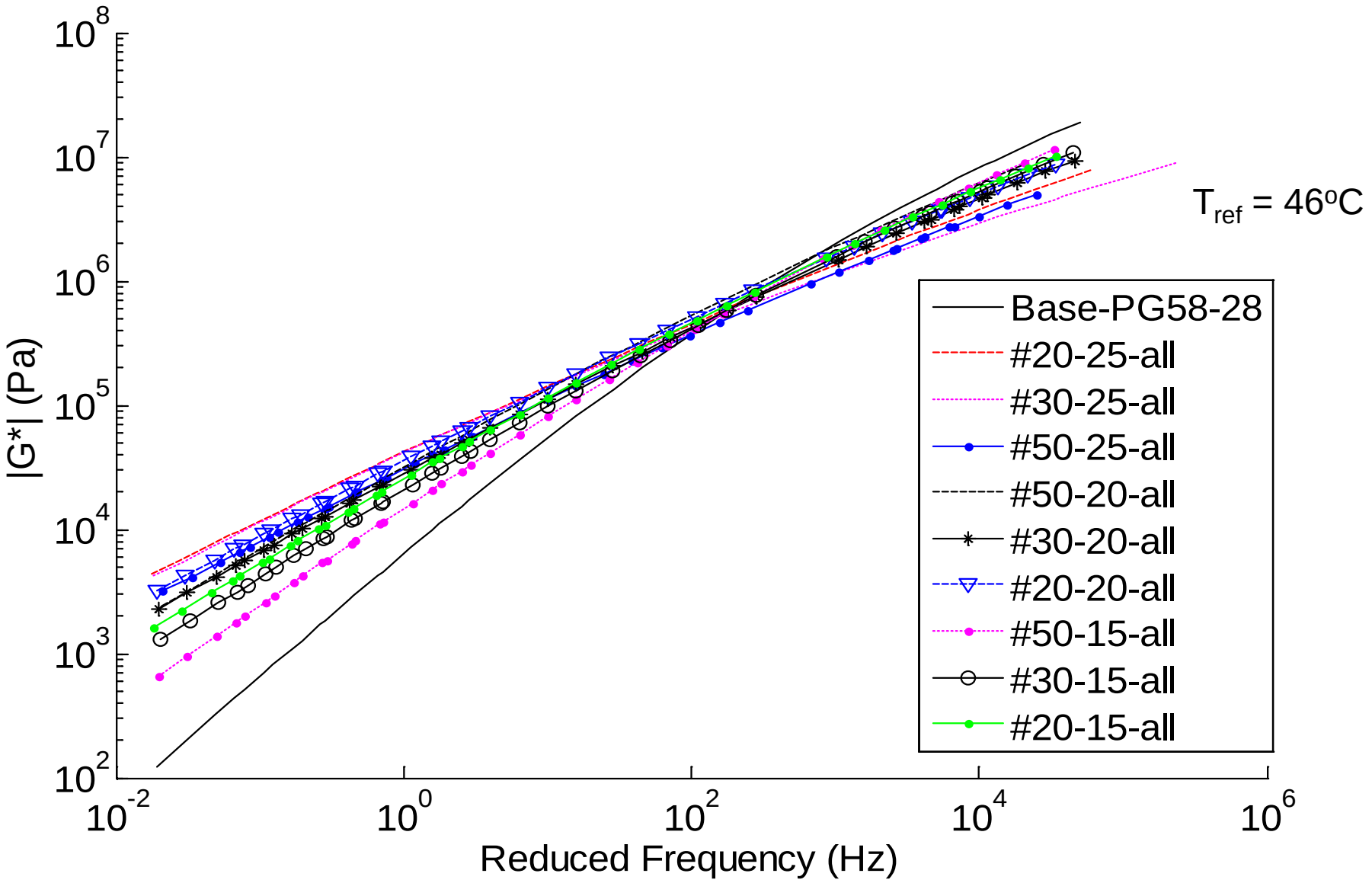
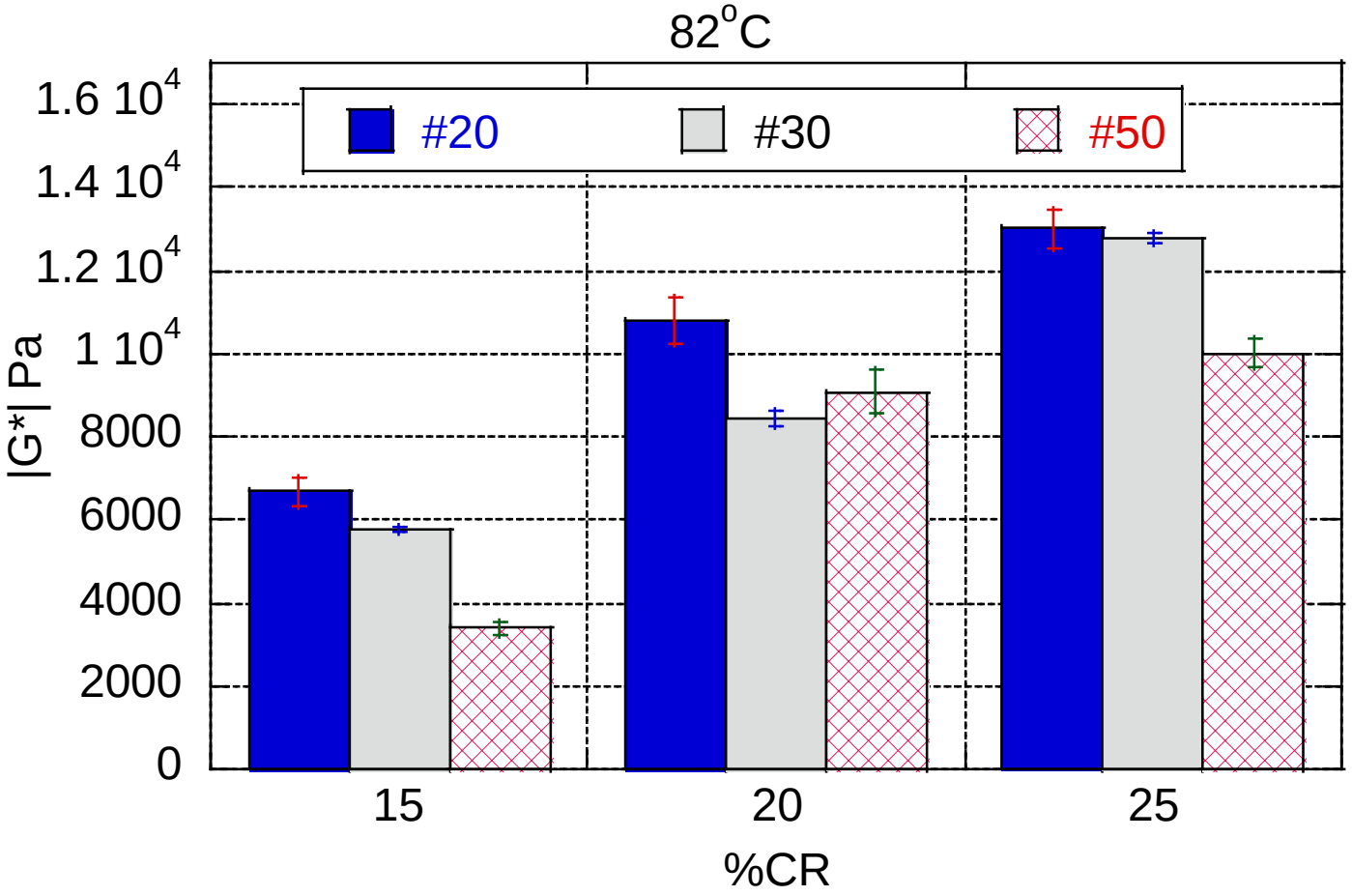


Effect of CR percentage & size

|G*| at 10Hz


82°C
#20
#30
#50
1.6 10^4
1.4 10^4
1.2 10^4
1 10^4
8000
6000
4000
2000
0
|G*| Pa
15
20
25
%CR

High T versus Low T

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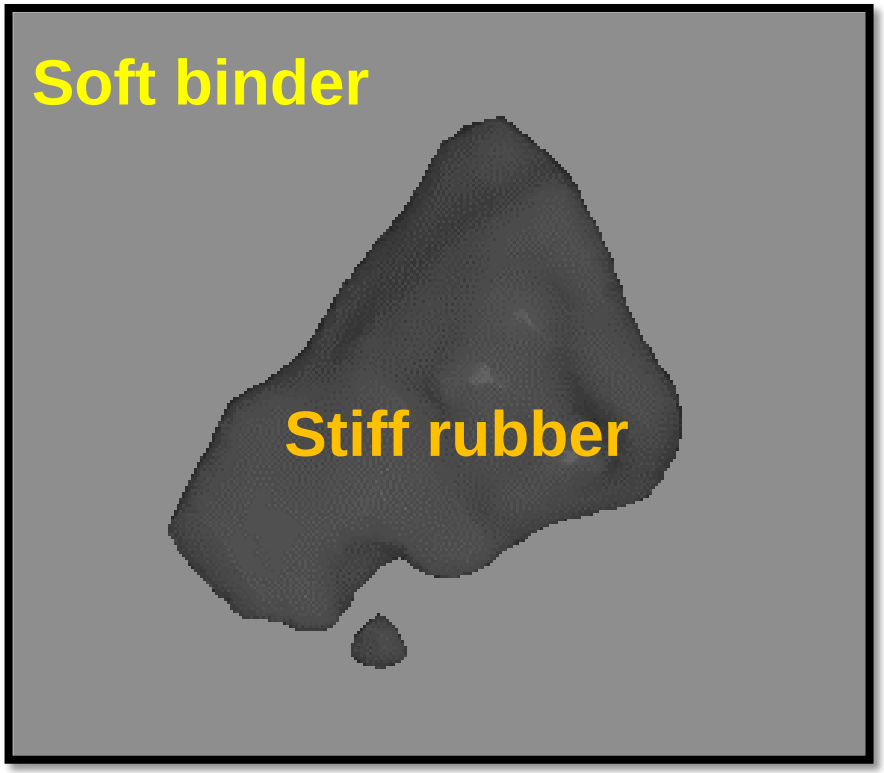
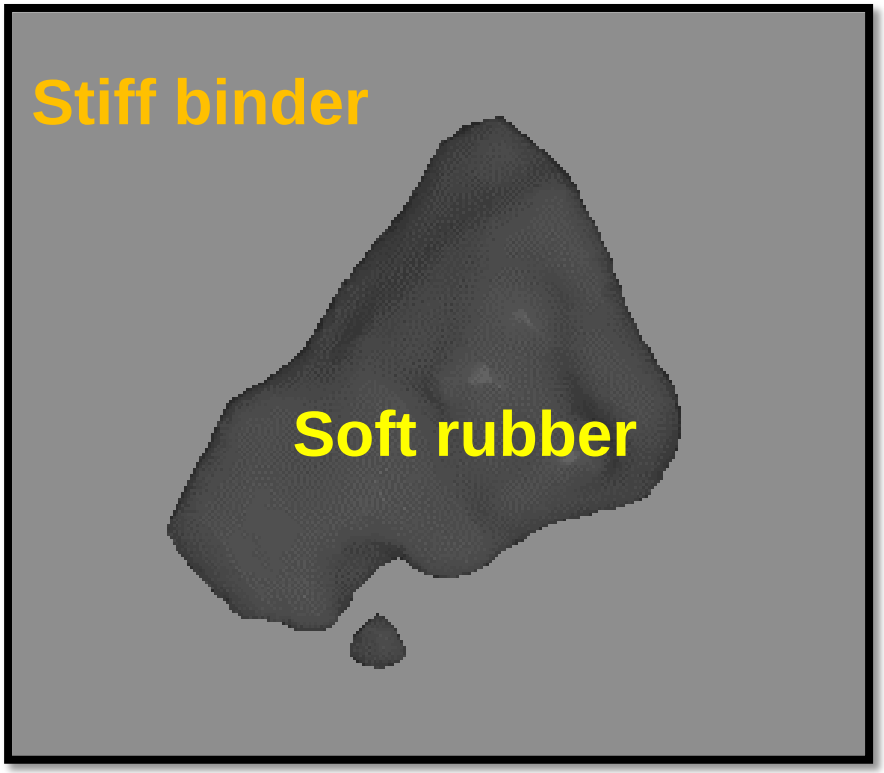
T = 76°C



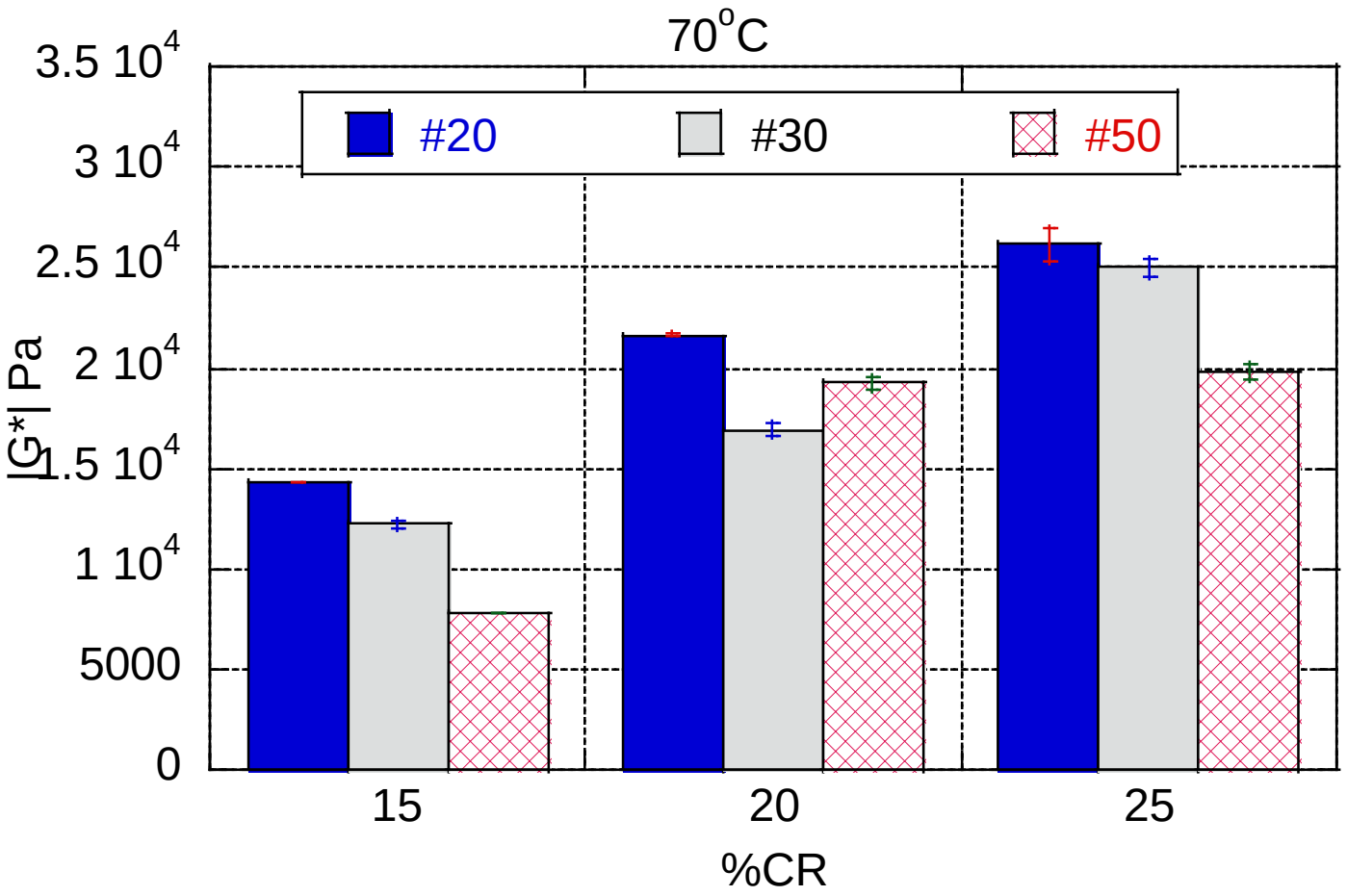
Rubber ↑ |G*| of mix ↑

T = 15°C

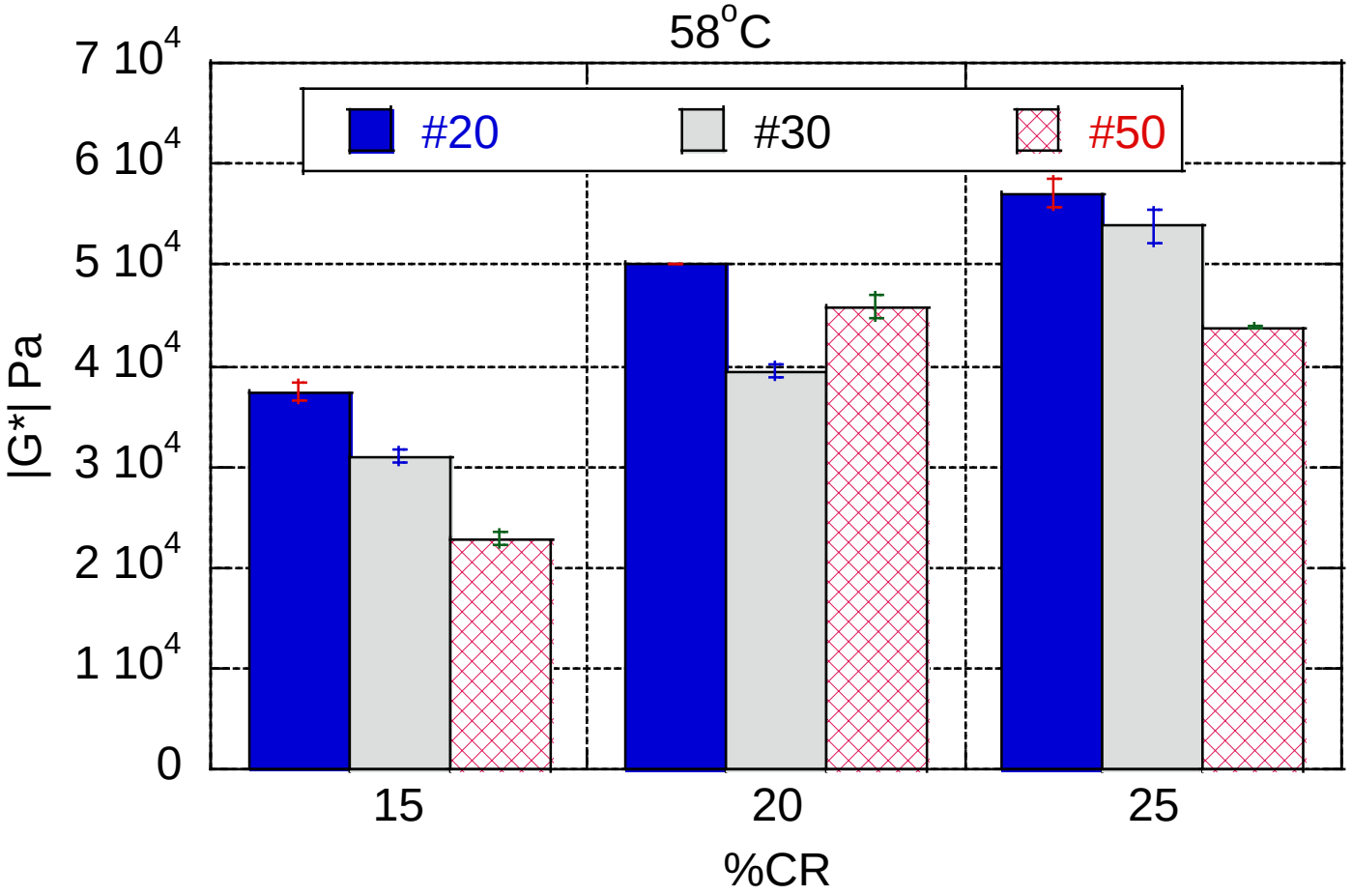


Rubber ↑ |G*| of mix ↓

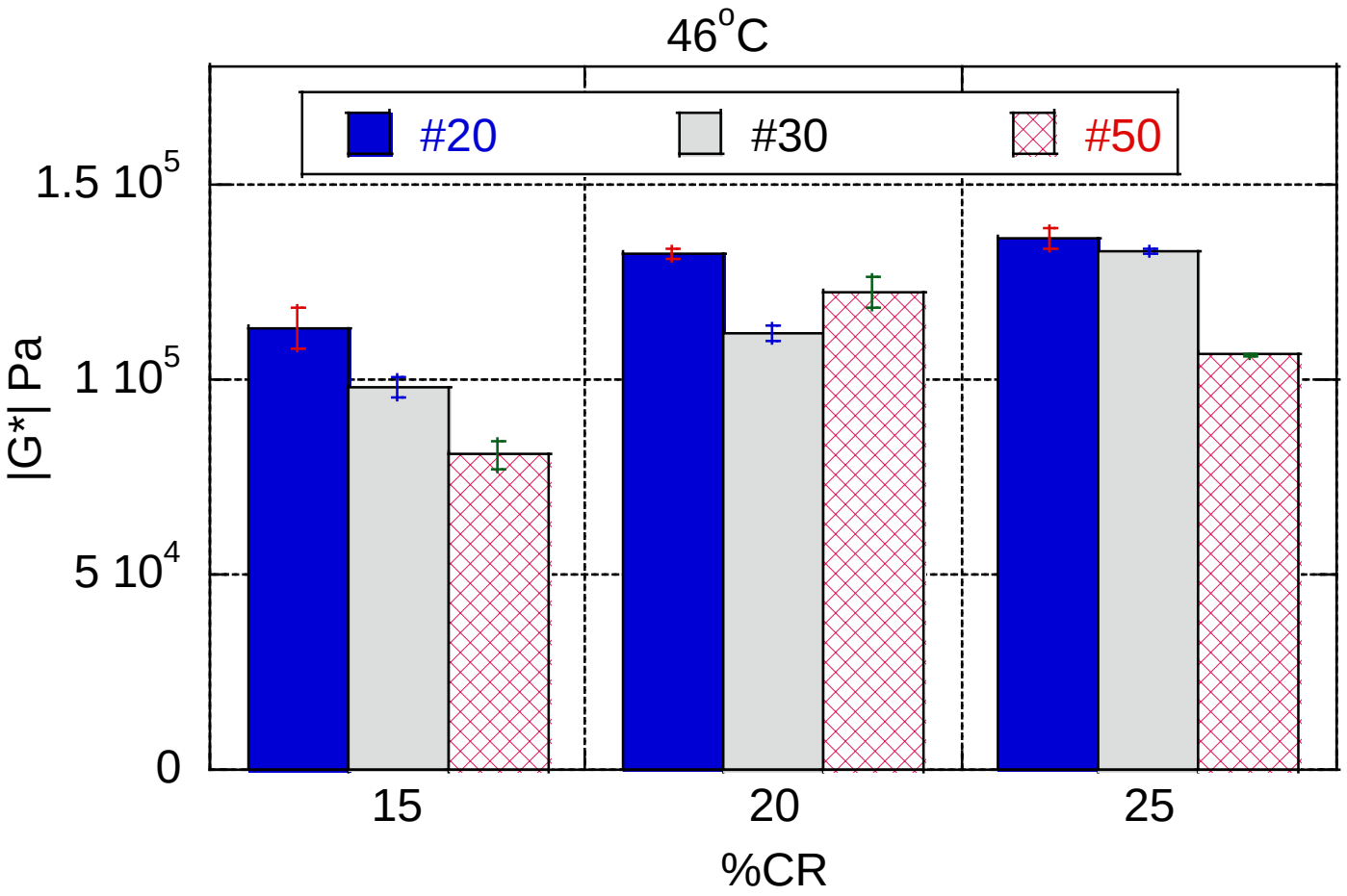
|G*| at 10Hz


70°C
#20
#30
#50
3.5 10^4
3 10^4
2.5 10^4
2 10^4
1.5 10^4
1 10^4
5000
0
|G*| Pa
15
20
25
%CR

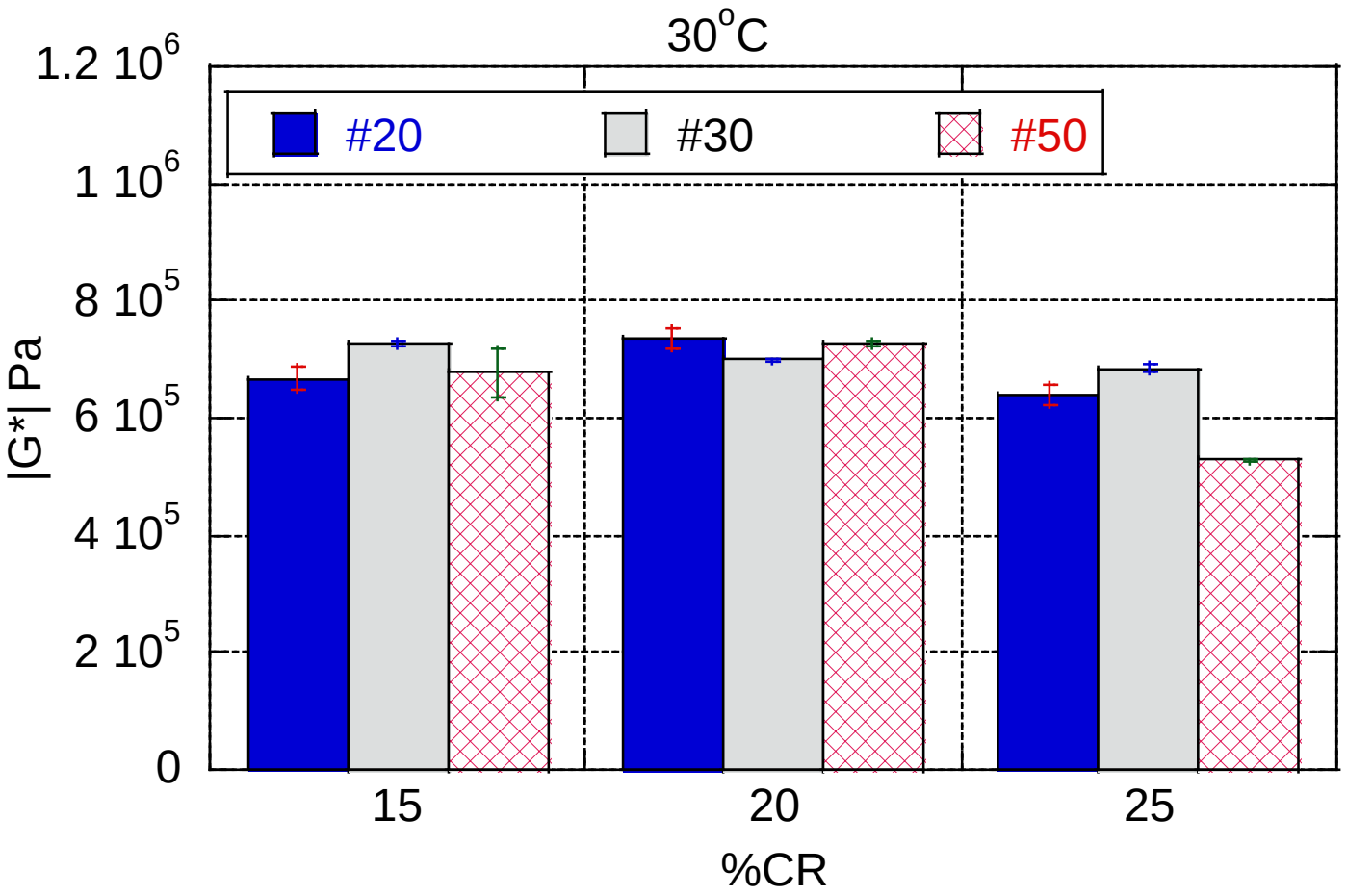
|G*| at 10Hz



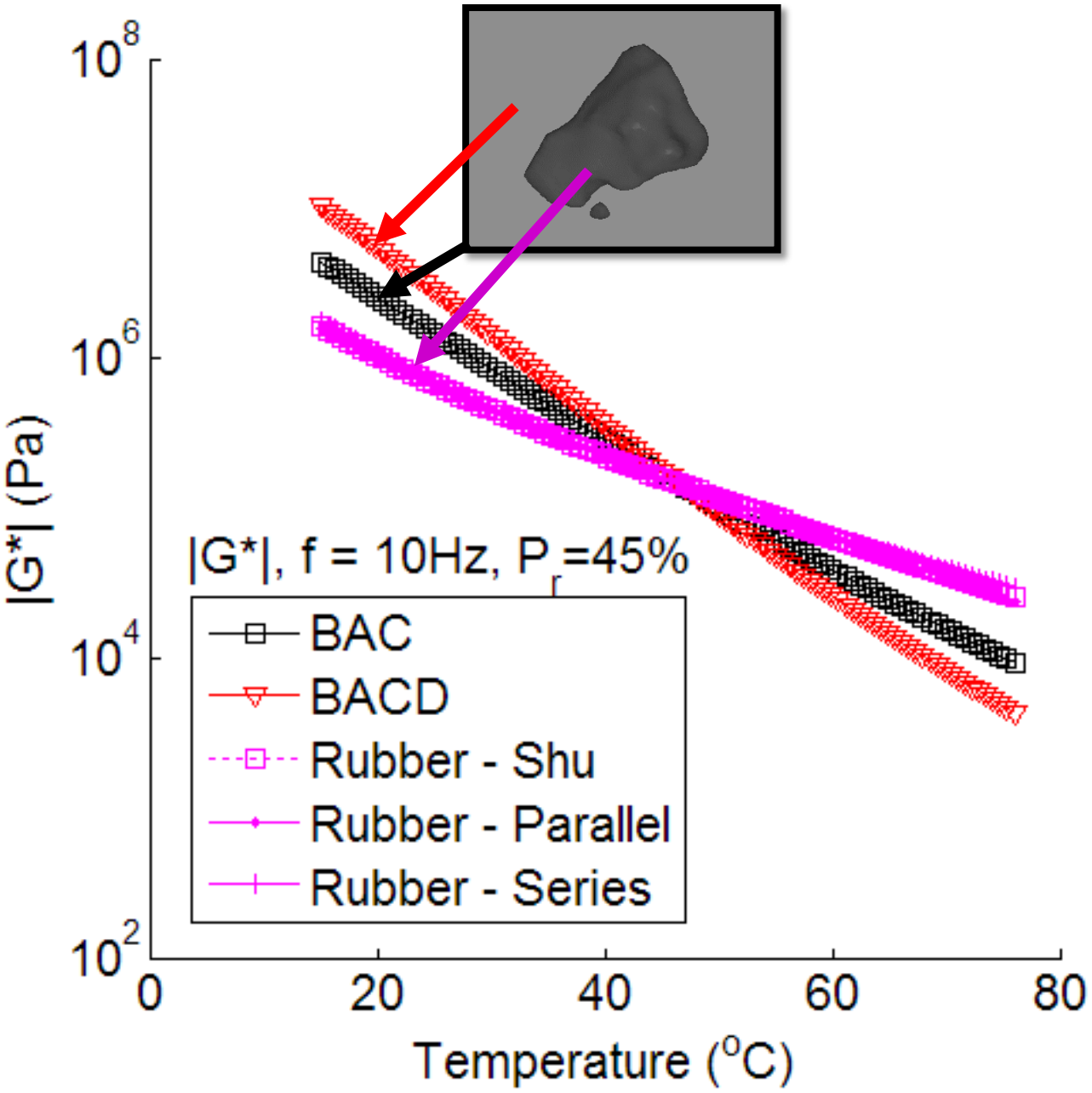
|G*| at 10Hz



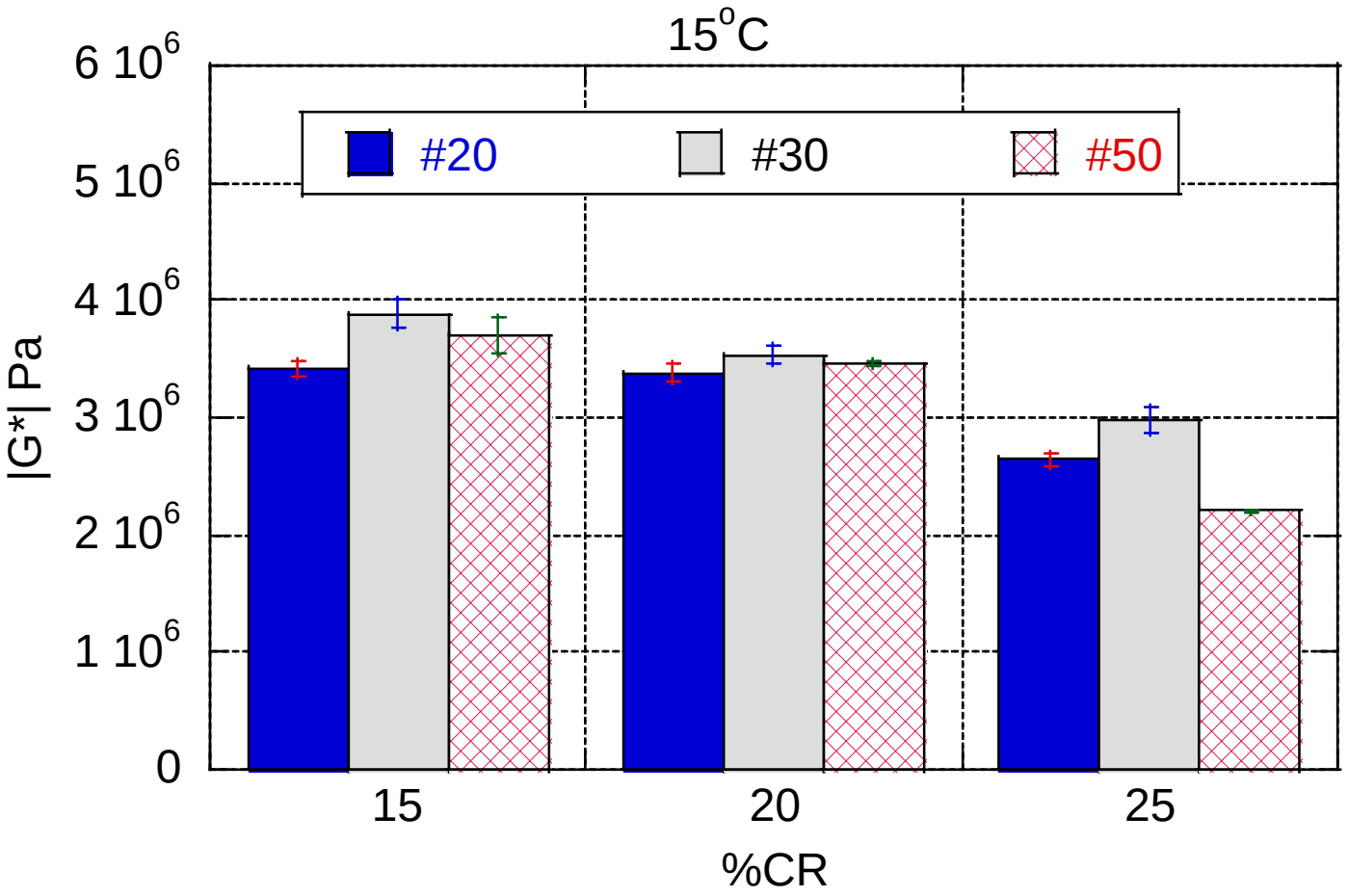
|G*| at 10Hz



Estimated |G*| of swollen rubber



|G*| at 10Hz



Observations/Conclusions

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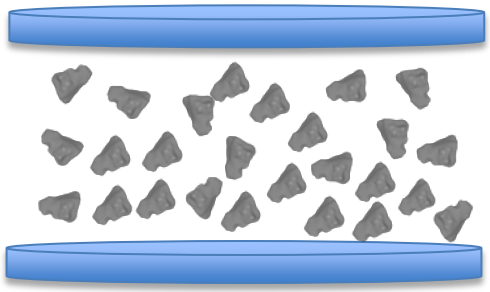
- At low CR% and high DSR temperatures:
  - Significant effect of CR size
  - At low CR%:
    - Particle interaction (cushioning) effect becomes visible with increasing CR size

#40-#50
(0.425 – 0.355 mm)



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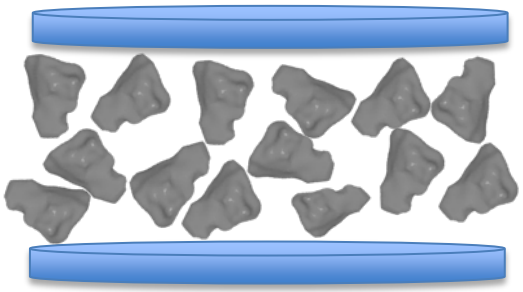
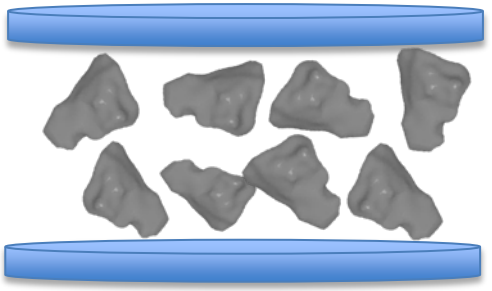
(0.85 – 0.6 mm)



#16-#20
(1.18 - 0.85 mm)



Observations/Conclusions

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- At high CR% and low DSR temperatures:
  - No effect of CR size
  - At high CR%
    - Regardless of the CR size, the particles are already interconnected (i.e., cushioned)
  - At low DSR temperatures
    - Binder between the CR particles are as stiff or stiffer than the CR, therefore, no effect is visible
      - » Material acts like a ‘mixture’

Thoughts/Future work

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- Mixture |E*| versus |G*|
  - Is it more appropriate to intentionally test the “rubber” in DSR?
  - Rubber modified binder is already “squeezed” between the aggregates
  - Does running the CR binder tests in “loose state” more or less representative of behavior in mixture.
- Repeat the tests using concentric cylinder
  - Compare with mix |E*|

THE END