Structure-Property Relationships in Absorptive Glass Mat (AGM)

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Motivation

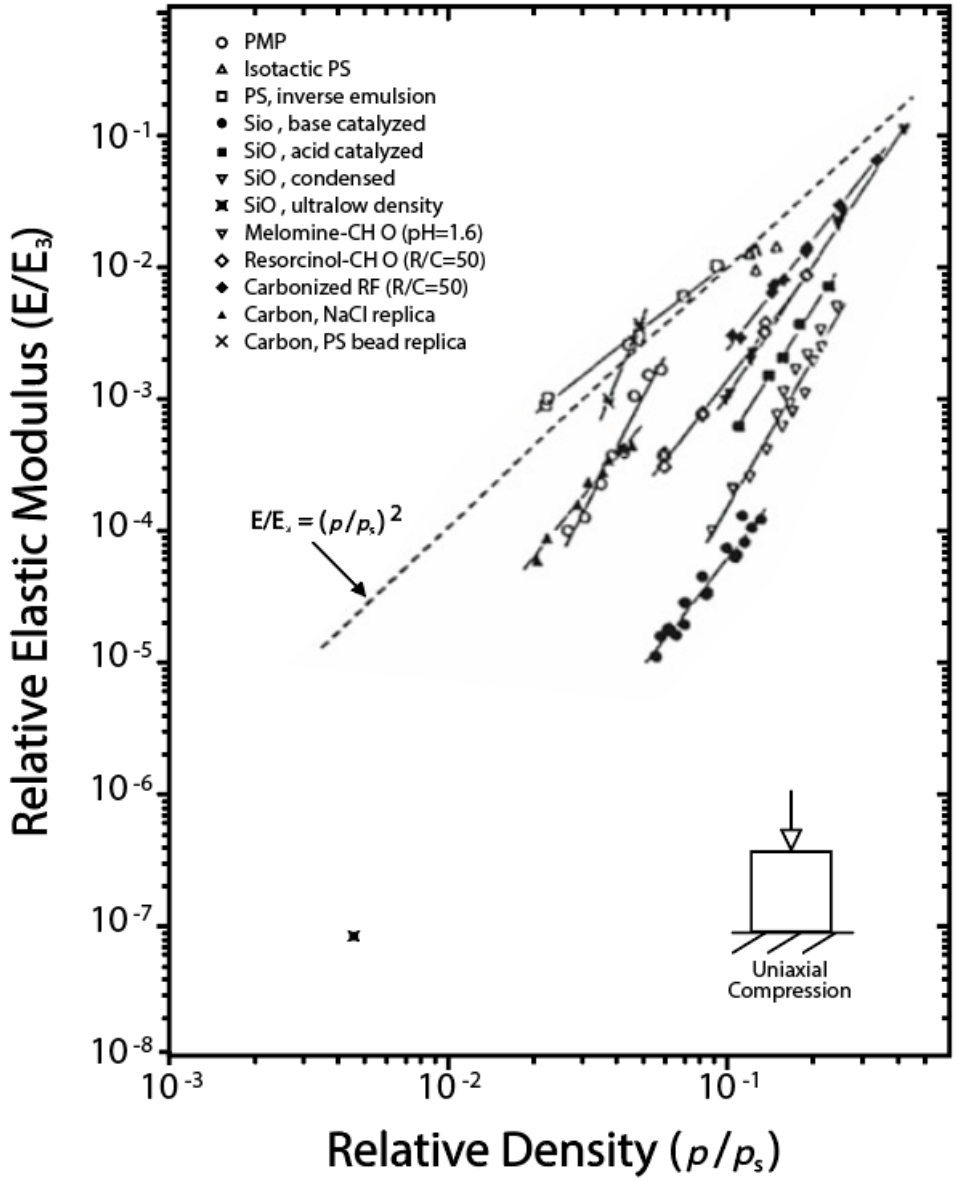
- New pilot AGM line

- Back to basics
  - Single diameter fiber formulations
  - Multiple diameter fiber formulations
  - Glass / organic fiber formulations

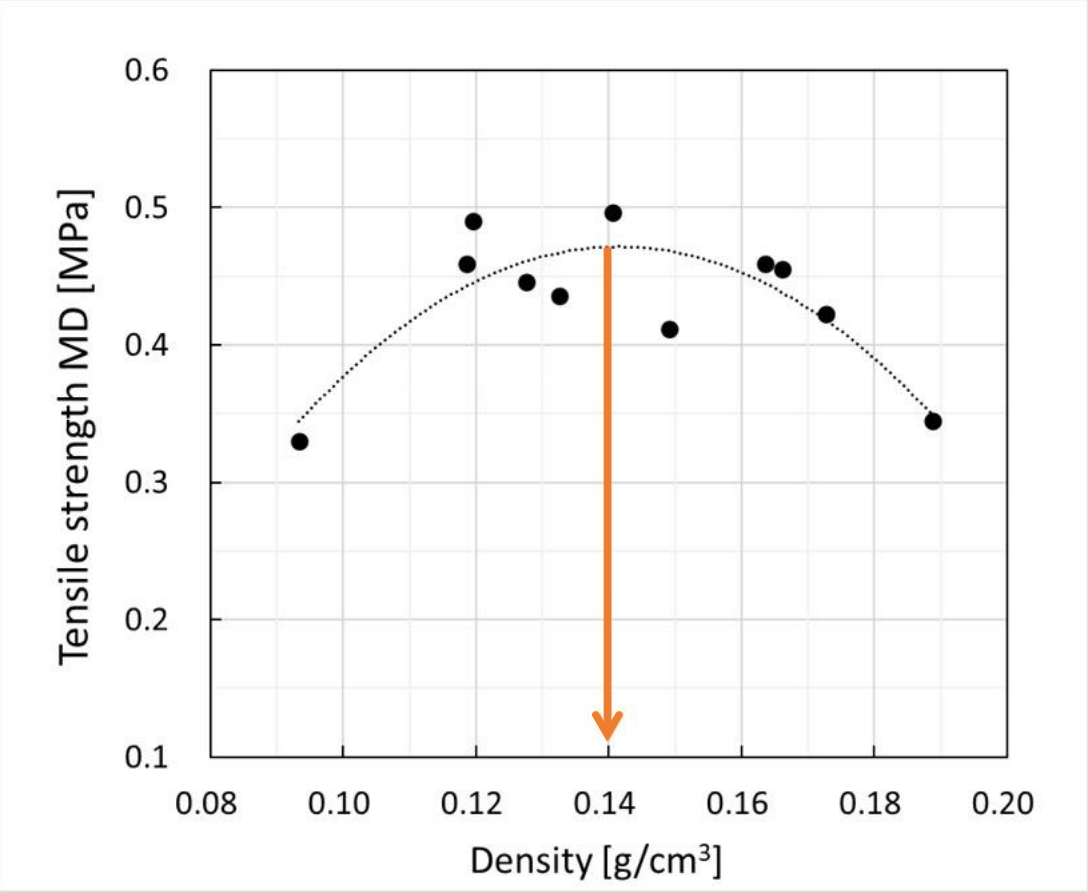
- How are key AGM performance characteristics impacted
  - Tensile strength
  - Compression-recovery
  - Wicking characteristics

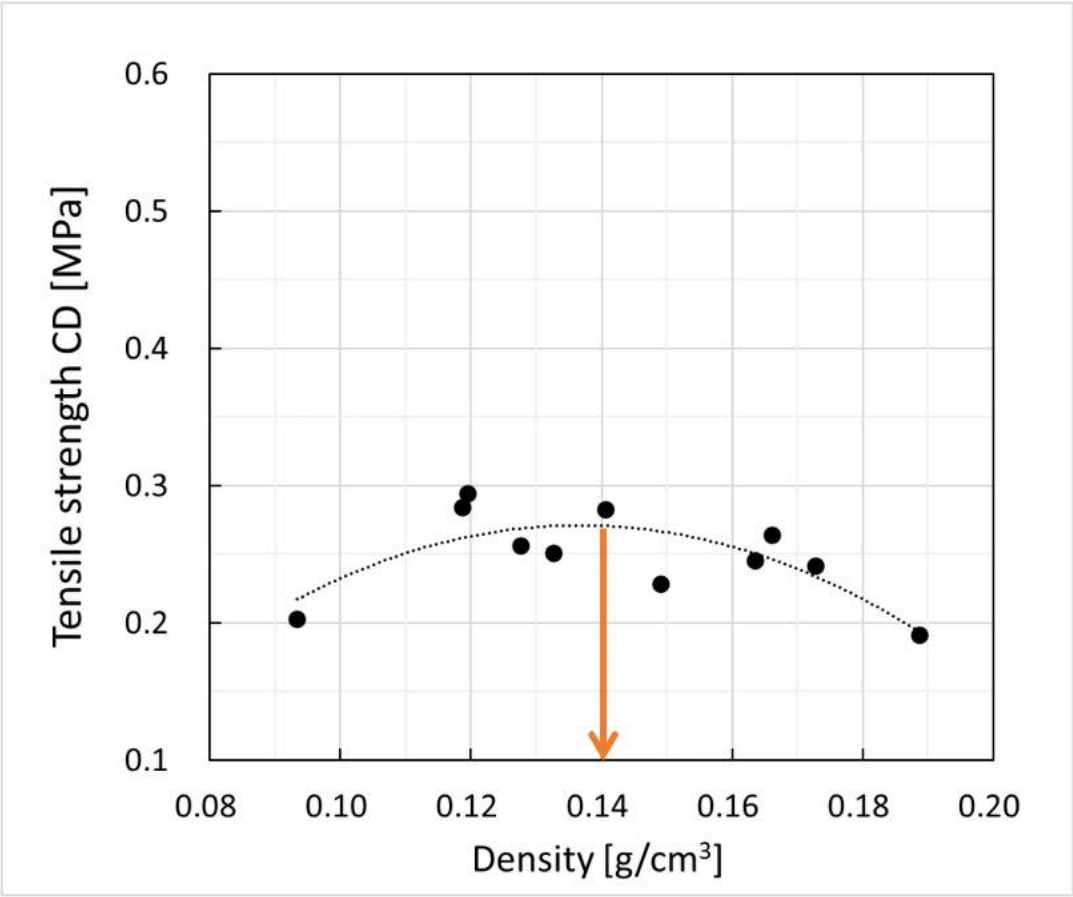
ENTEK AGM Pilot Line in Japan

Porous Materials - Mechanical Properties vs Relative Density



Single Glass Fiber Formulations (same basis weight, different densities)

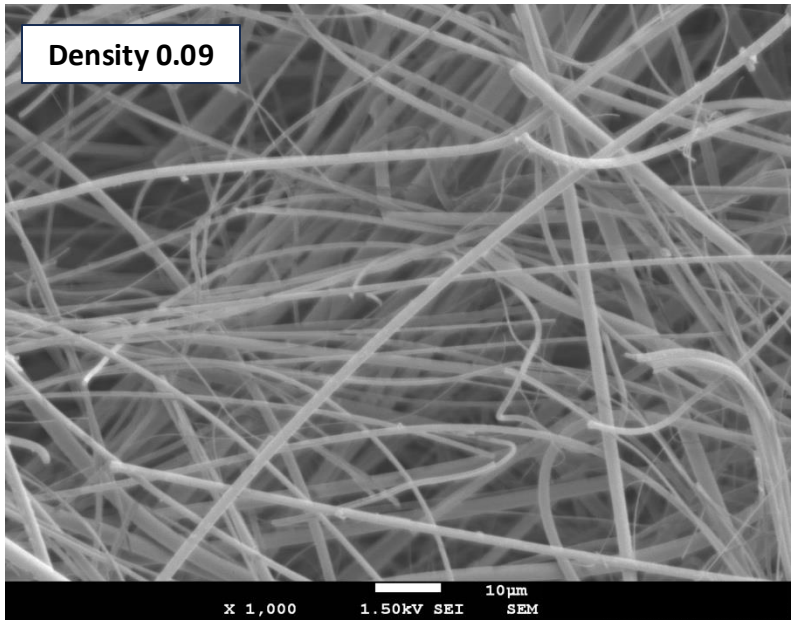


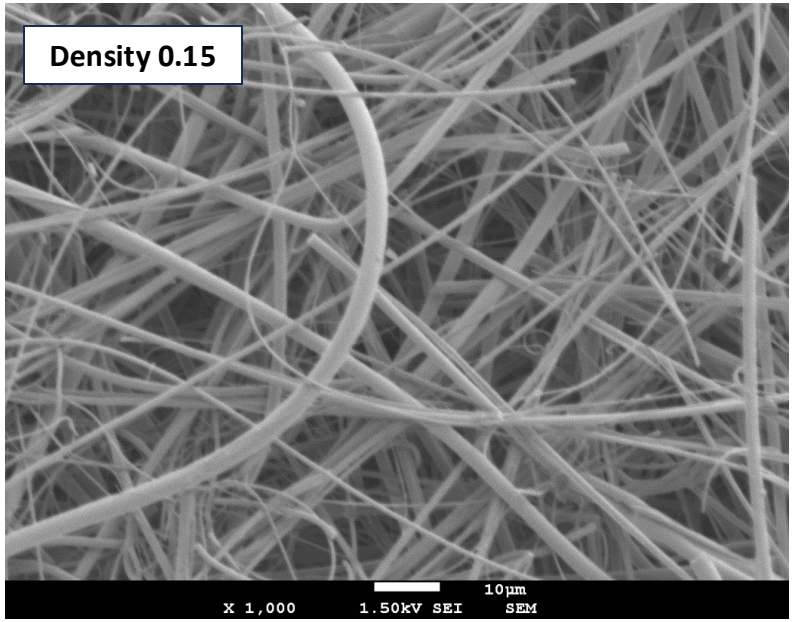


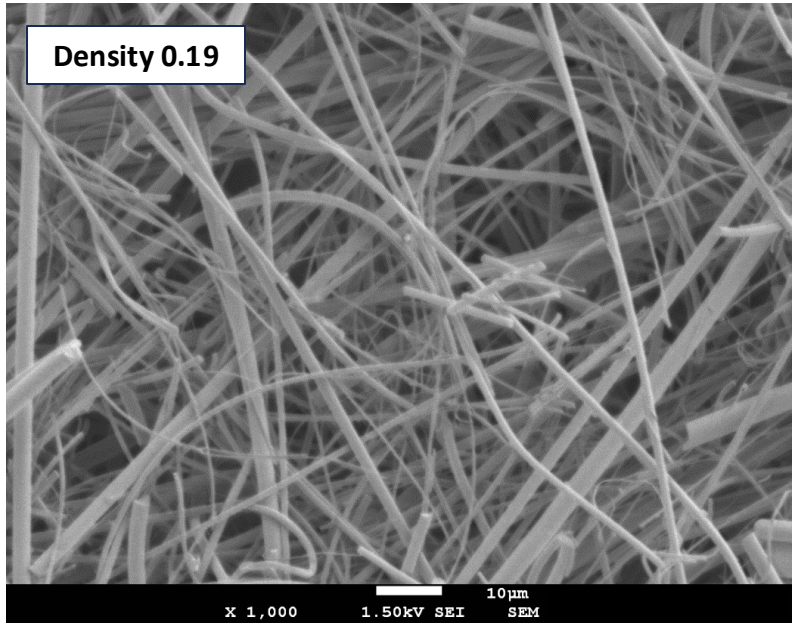
- Single micro-glass fiber with a diameter of 1µm was used to make AGM with the same basis weight, but different densities (adjusted by wet press).

AGM Morphology

- Scanning electron micrographs show little evidence of broken fibers in the AGM samples produced over the complete density range.



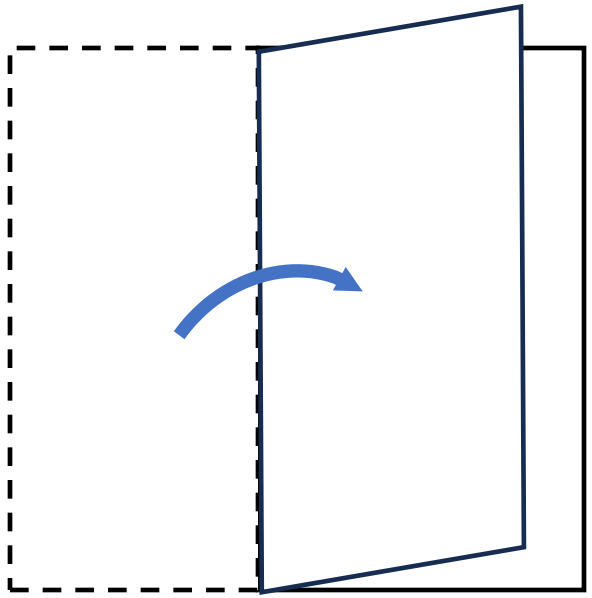




*Magnification 1000, SEM bar size = 10um

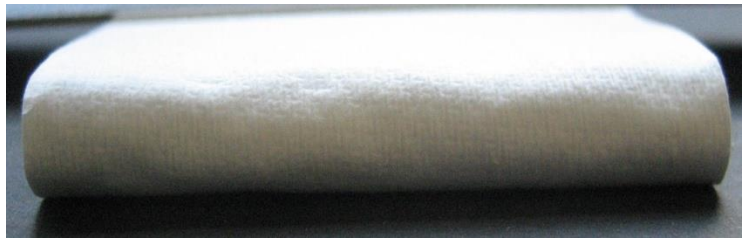
AGM Flexural Test - Fold Method

1. Bending 100mm square AGM to form crease



MD direction →

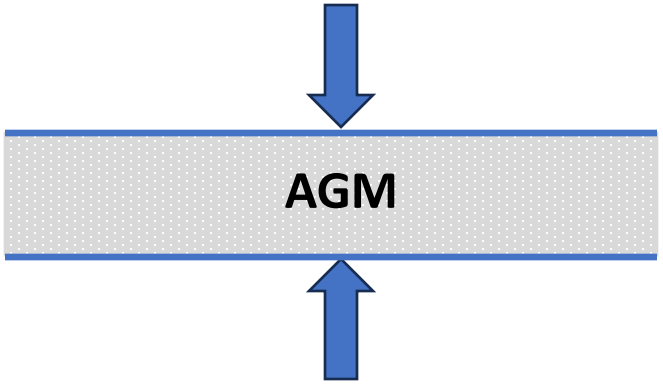
2. Cracks were only observed in the sample with 0.19 g/cc density



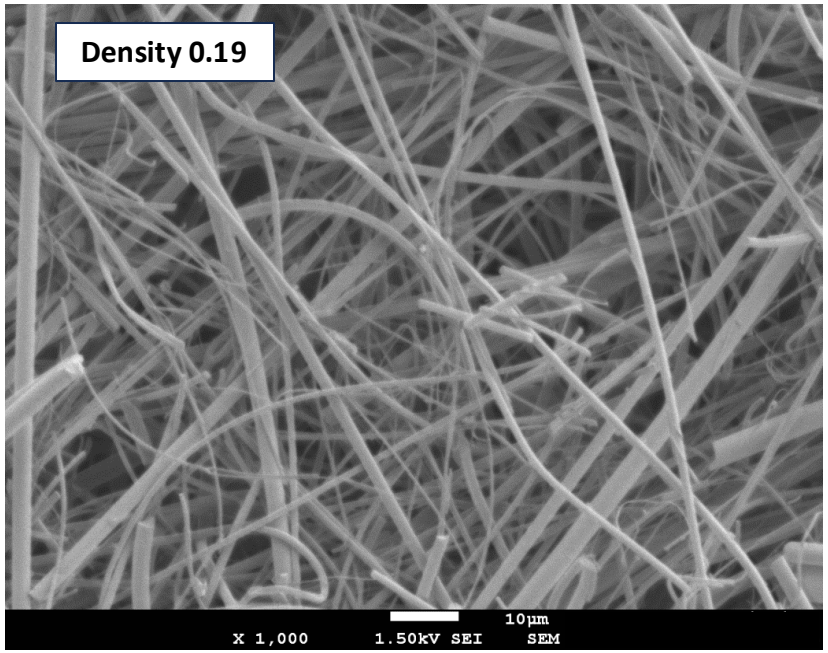
No cracking

Cracking

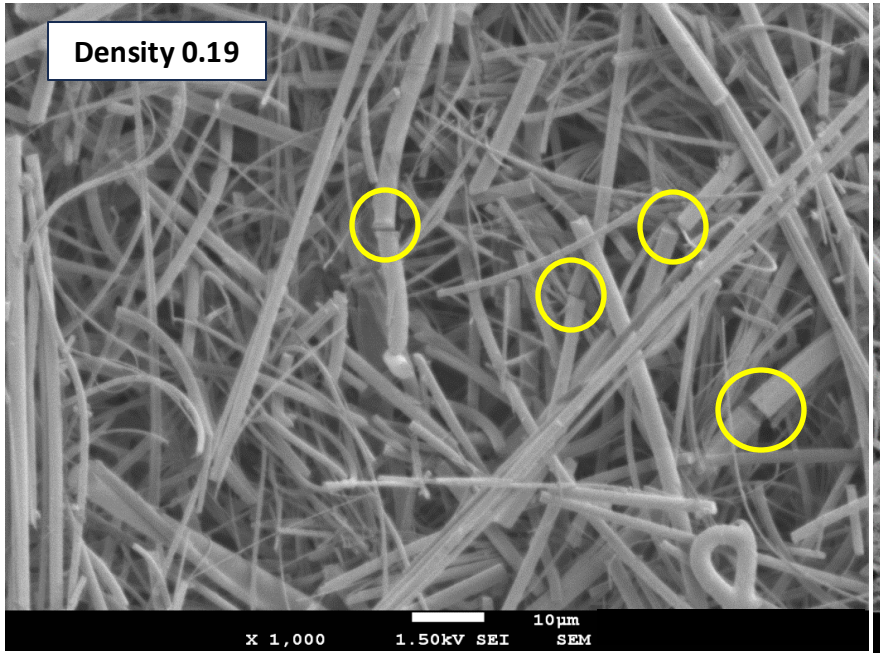
Can Fiber fracture be induced in AGM with pressure?



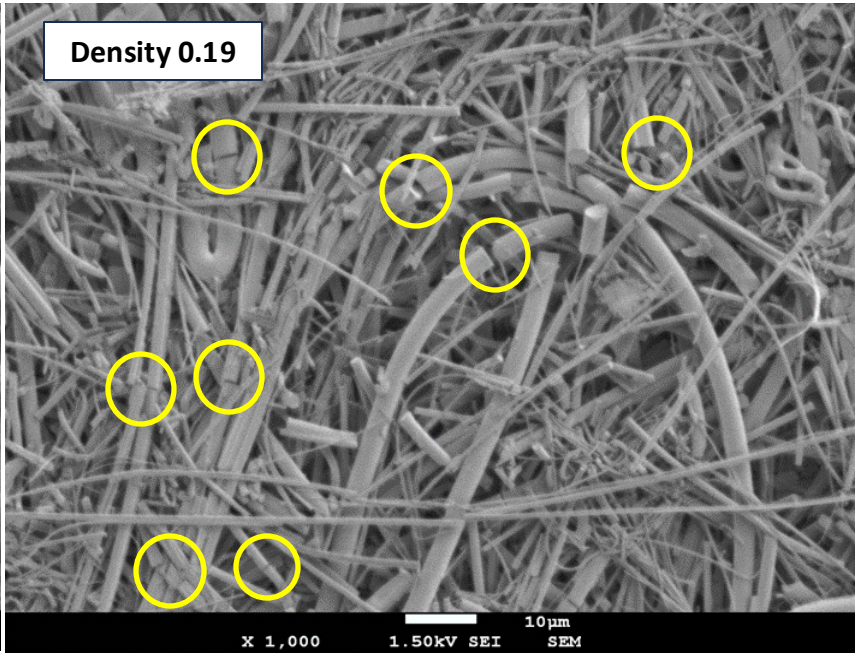
[As produced]



[0.1 MPa compression]

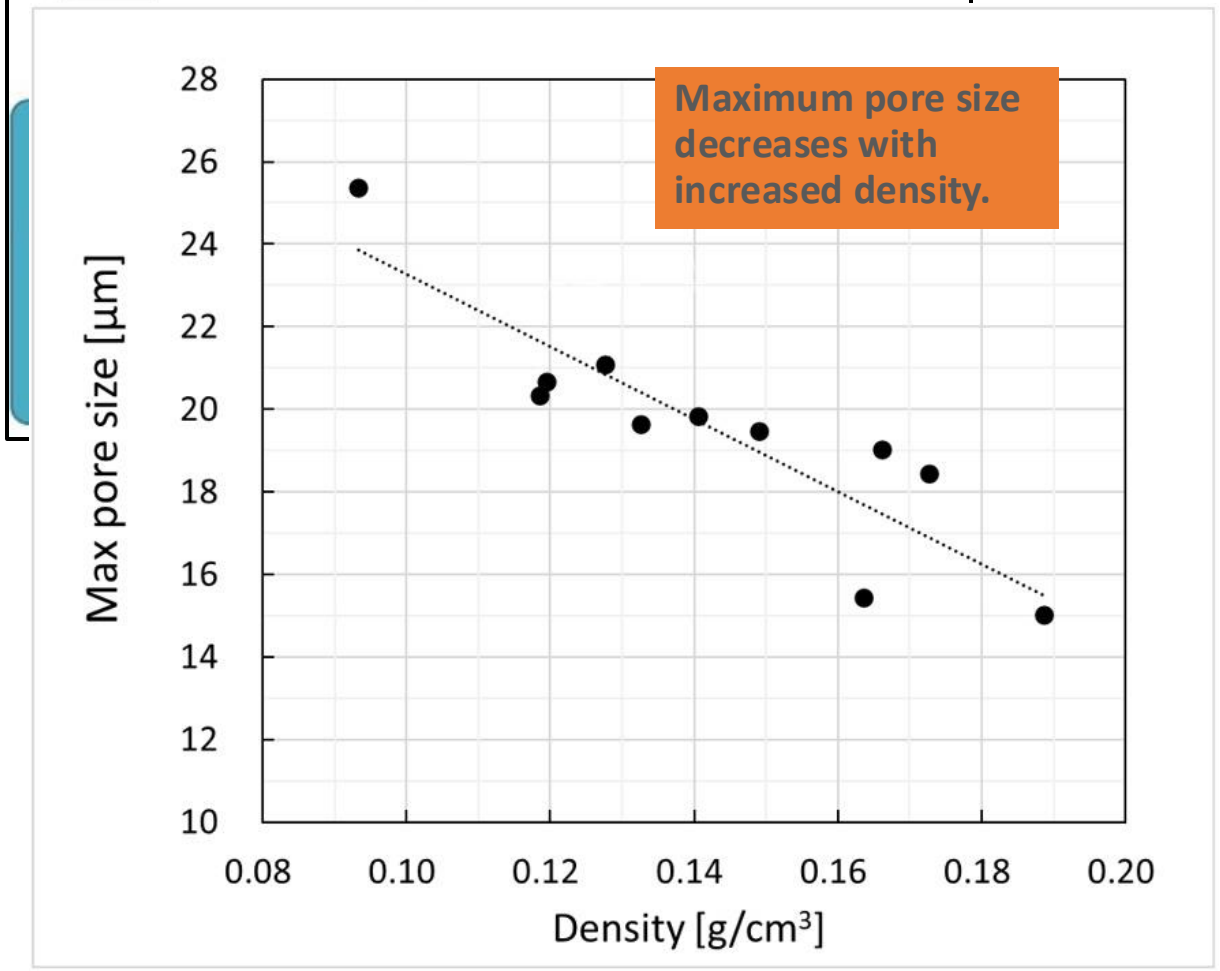


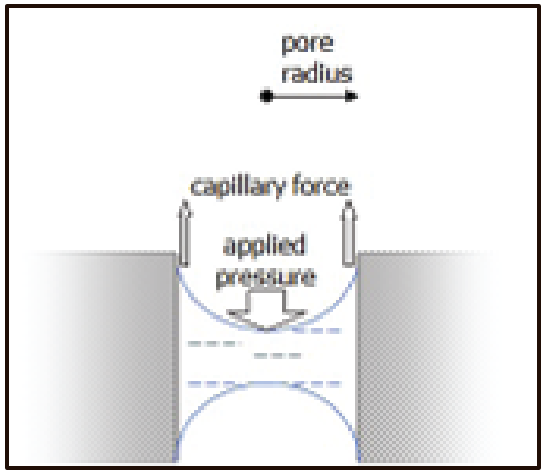
[0.5 MPa compression]



*Magnification 1000, SEM bar size = 10um

Bubble Point Test



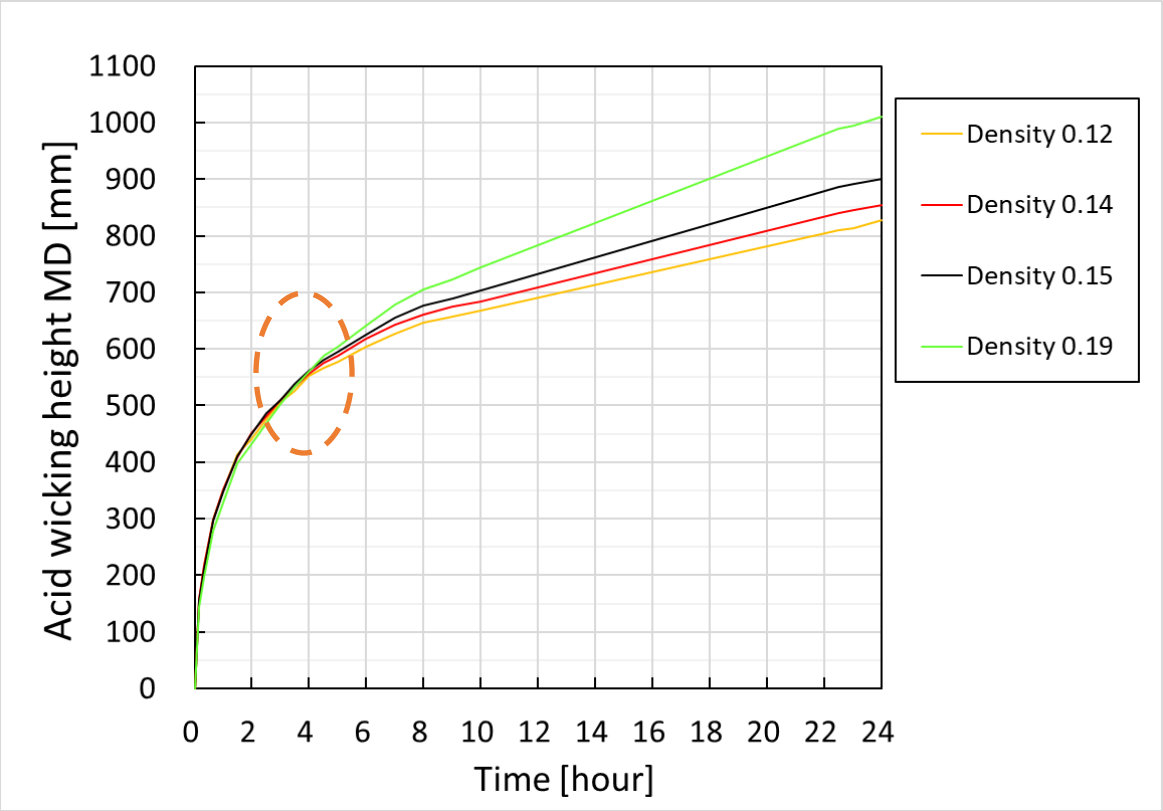


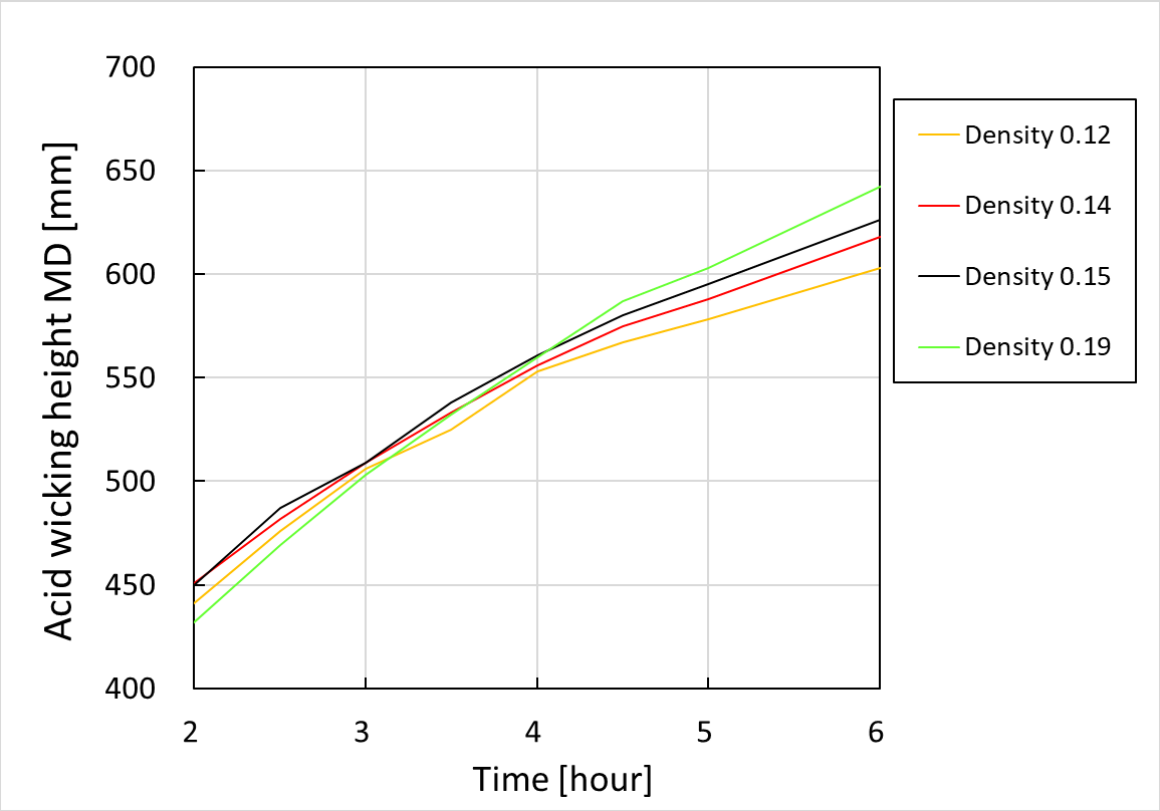
- Young-Laplace equation describing capillary pressure difference between two static fluids:

$$p = \frac{2\gamma cos\theta}{r}$$

  - p: capillary force ≡ applied gas pressure
  - γ: surface tension
  - θ: contact angle
  - r: radius of straight pore

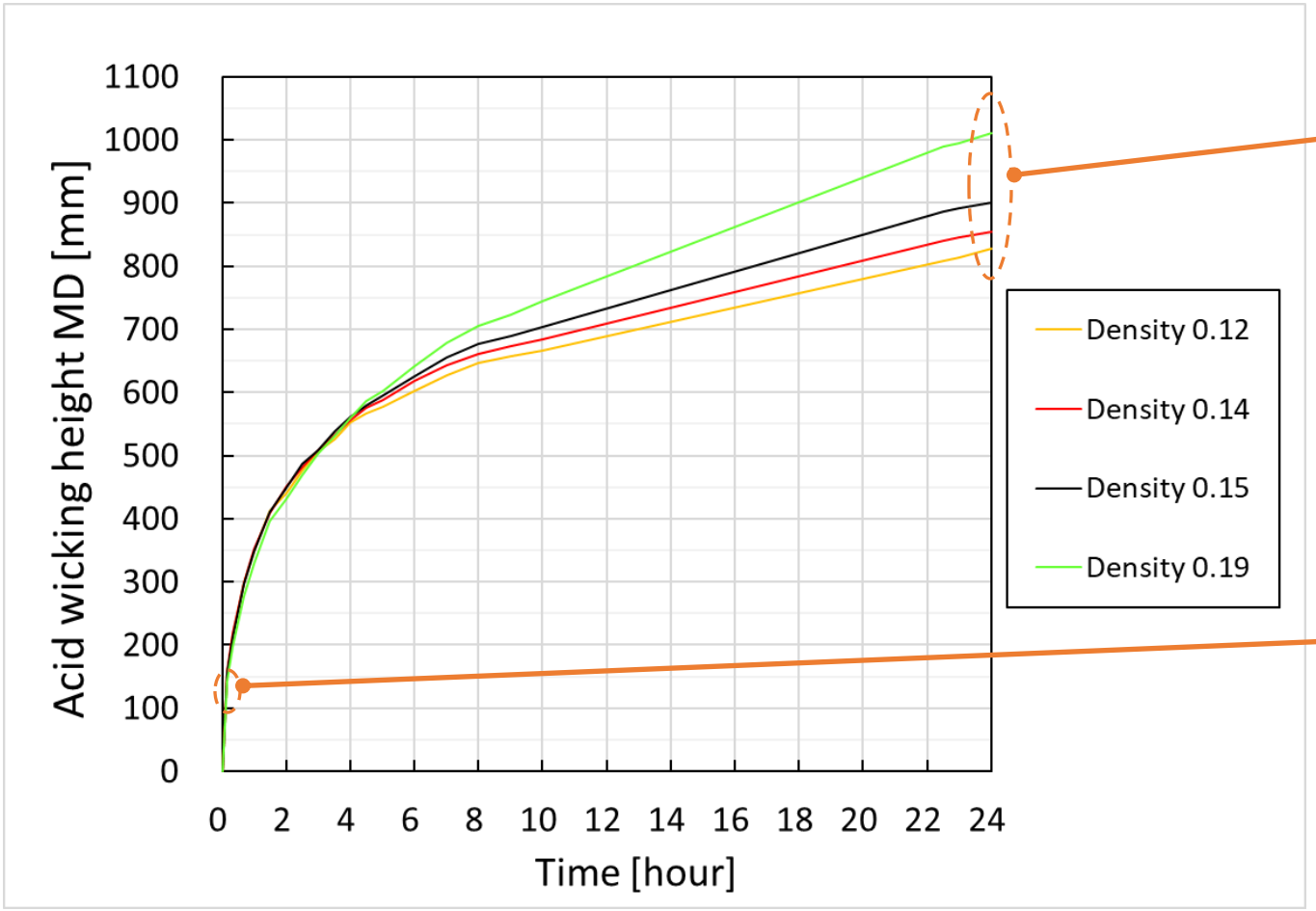
Wicking Behavior over 24 hours

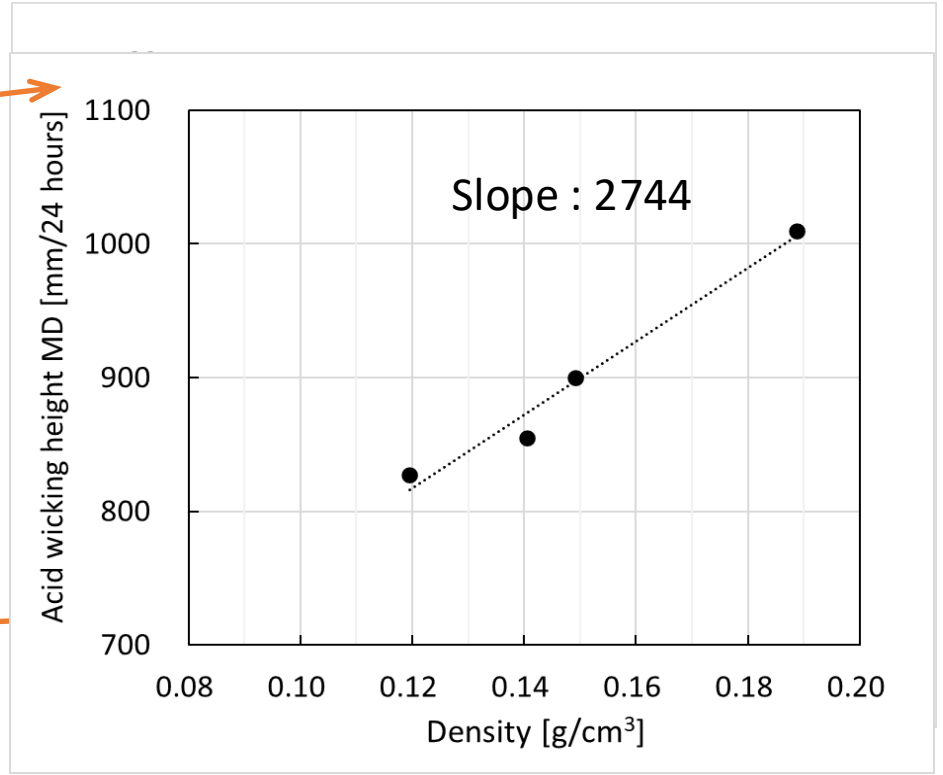




- After about 4 hours, AGM with highest density had the highest wicking height.

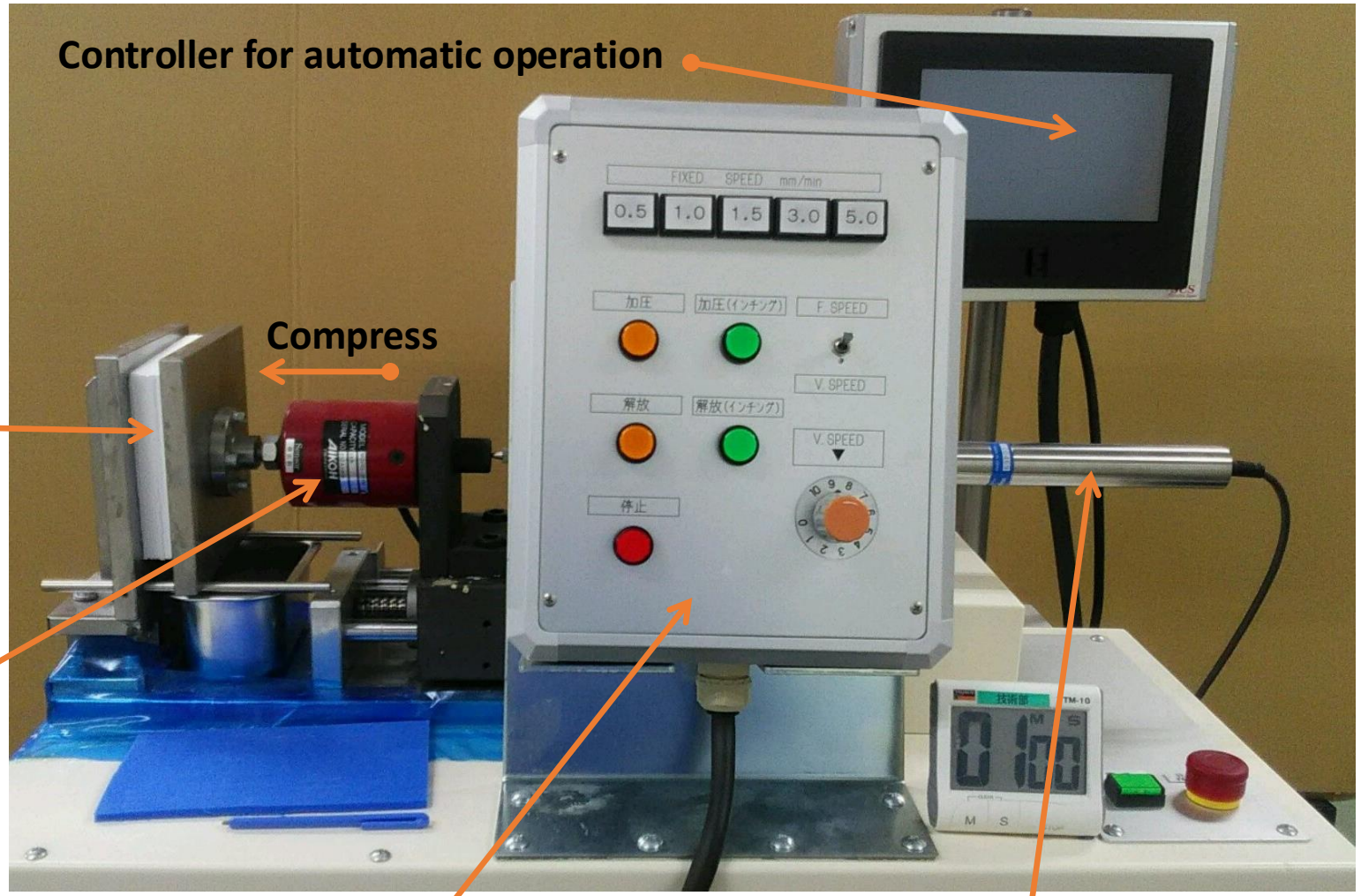
Wicking Behavior



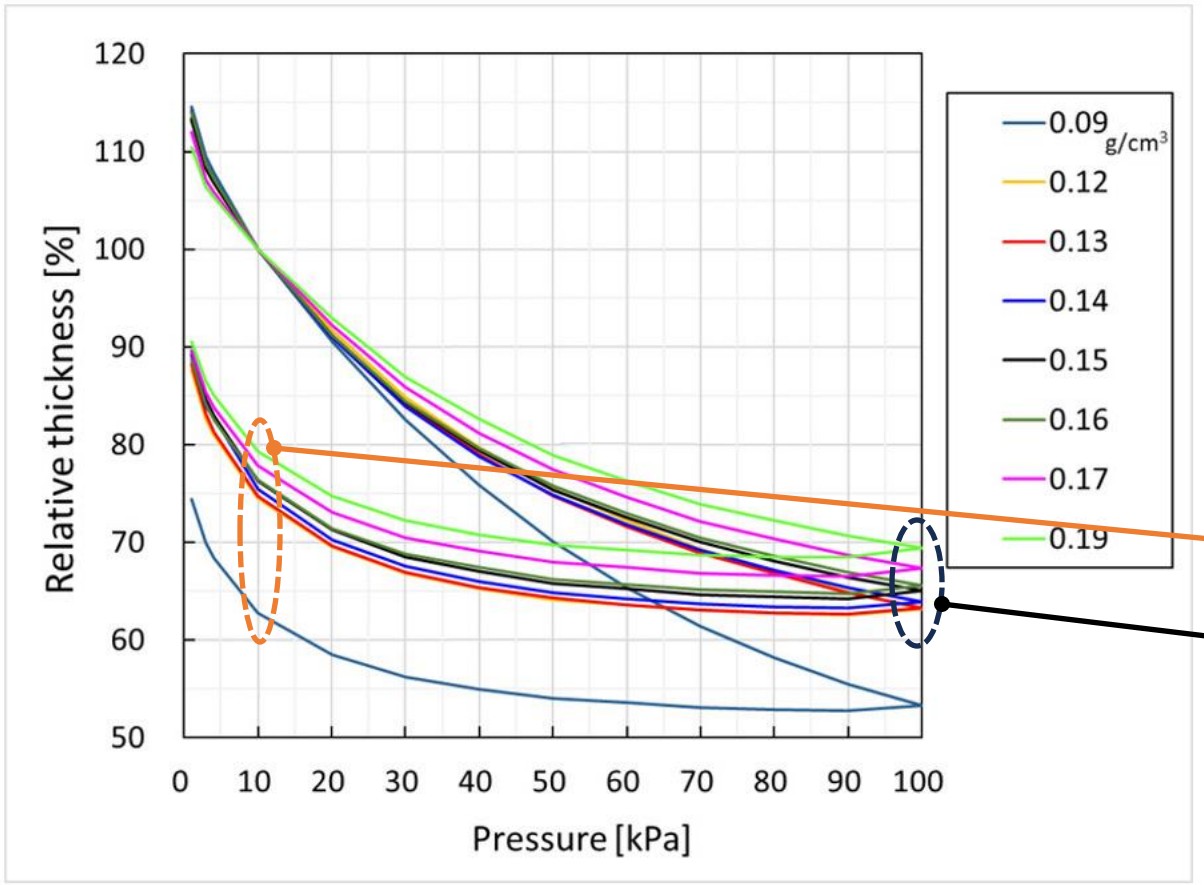


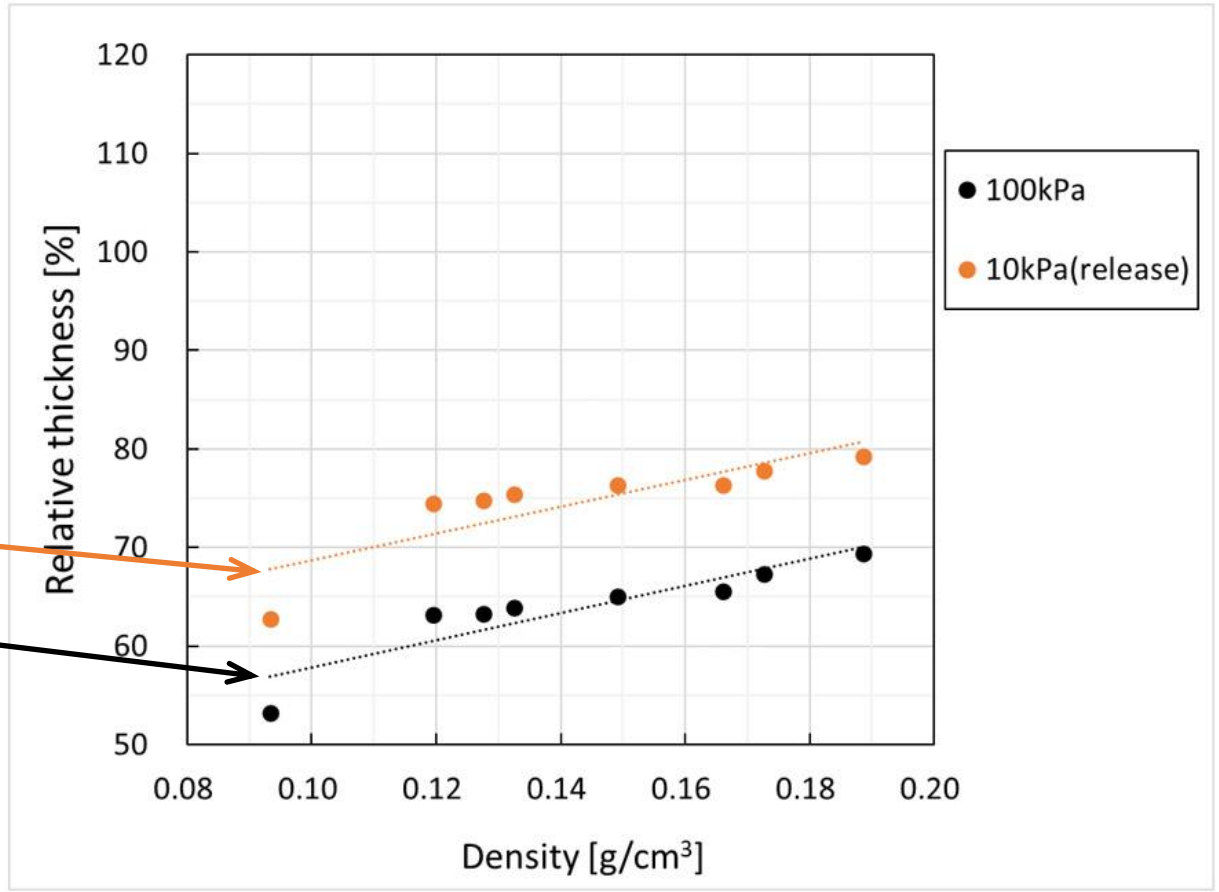
- Larger pores dominant wicking at short times (2 min.) whereas smaller pores dominant wicking at longer times (24 hrs.)

Compression-Recovery Apparatus

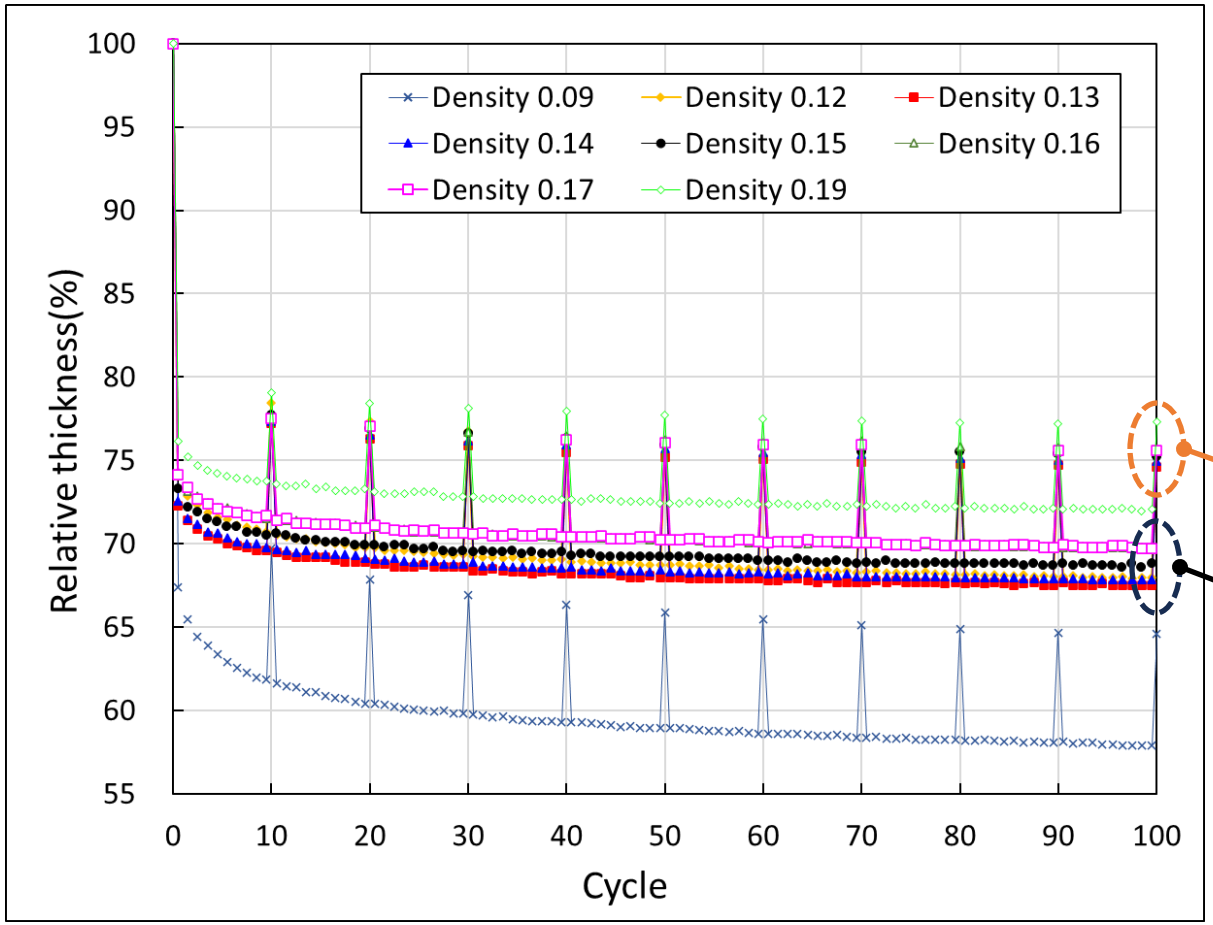


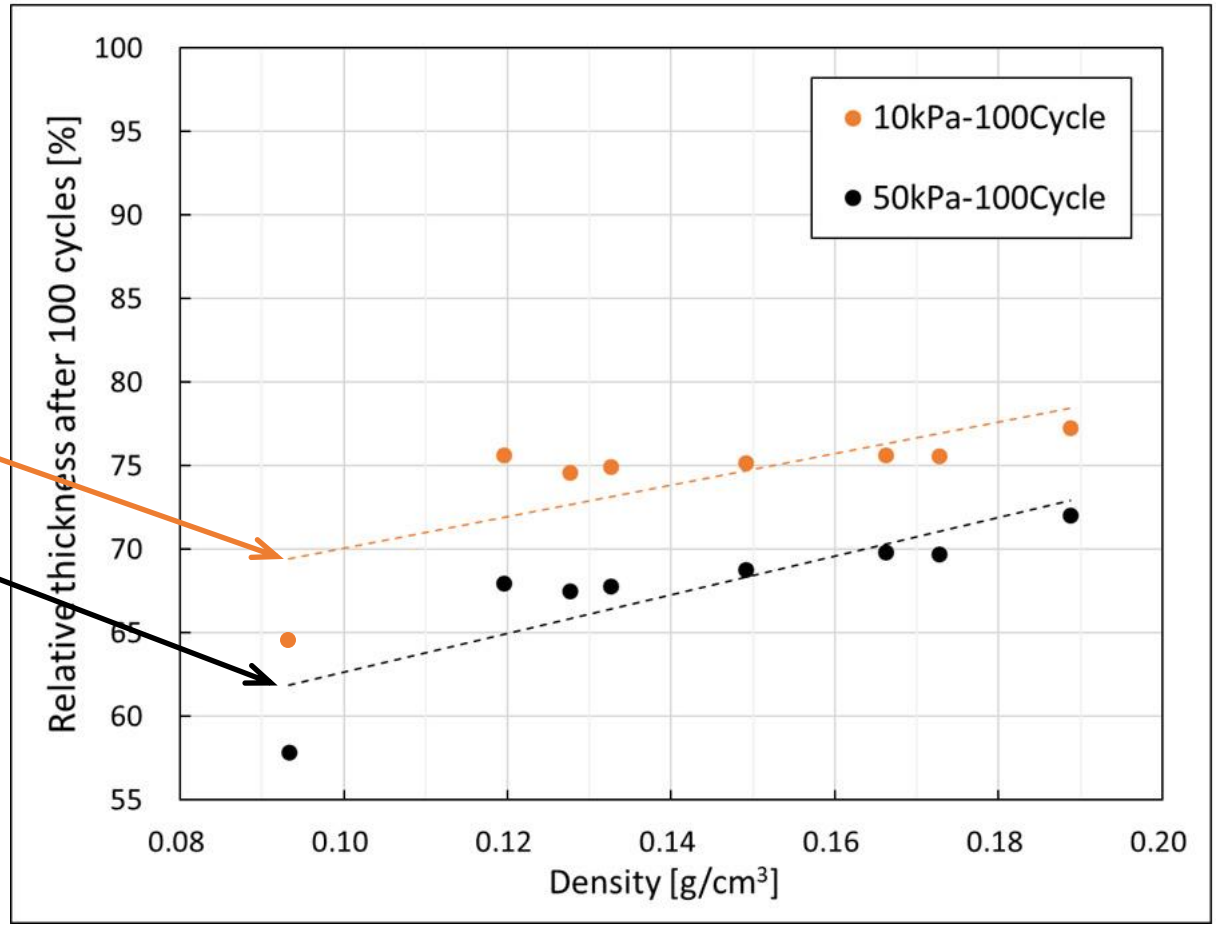
Compression - Recovery Behavior (Dry)





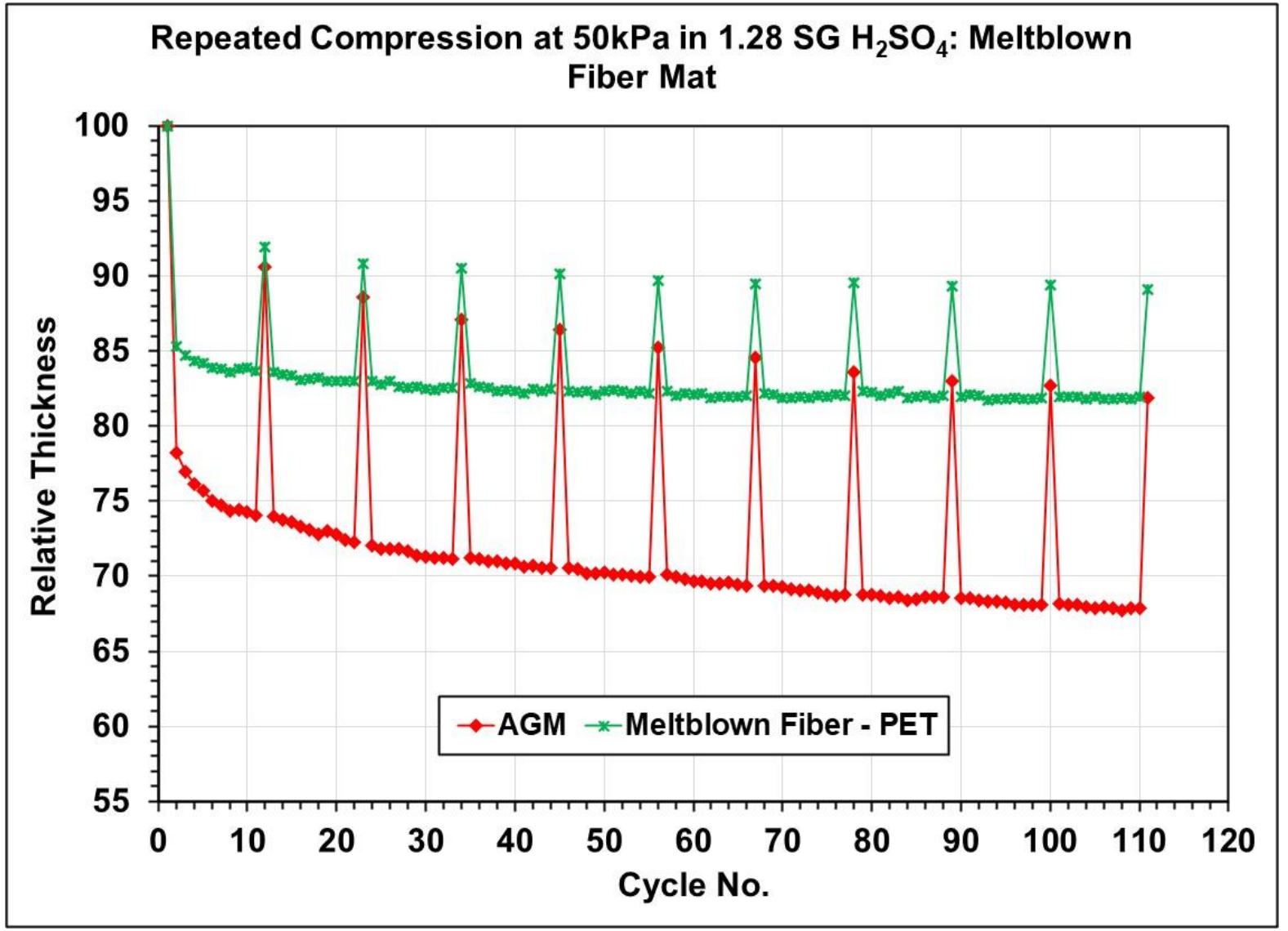
Compression - Recovery Behavior (Wet) vs. Cycle Life





- In wet conditions(H_2SO_4), the AGM was repeatedly compressed between 10kPa and 50kPa 100 times.

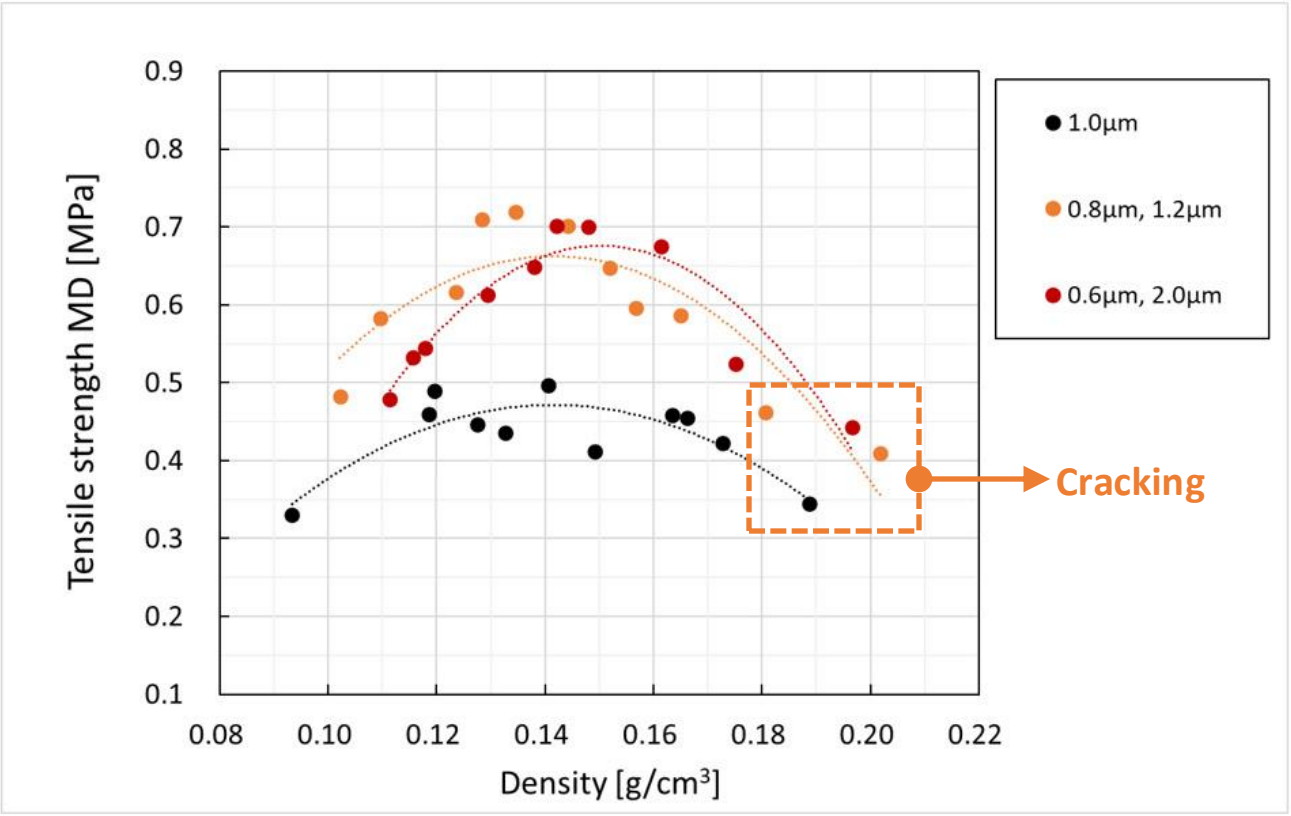
Compression - Recovery Behavior (Wet) vs. Cycle Life

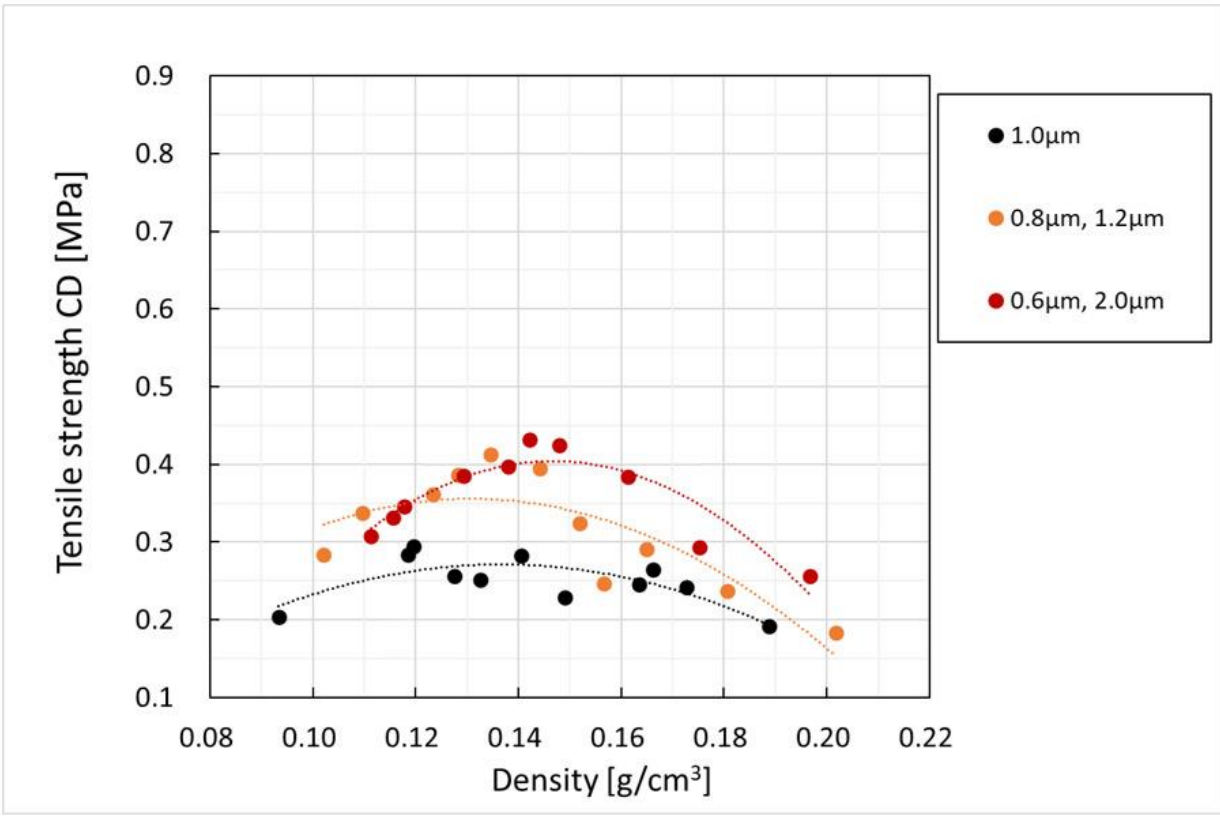


PET
0.18 g/cc
87% porosity

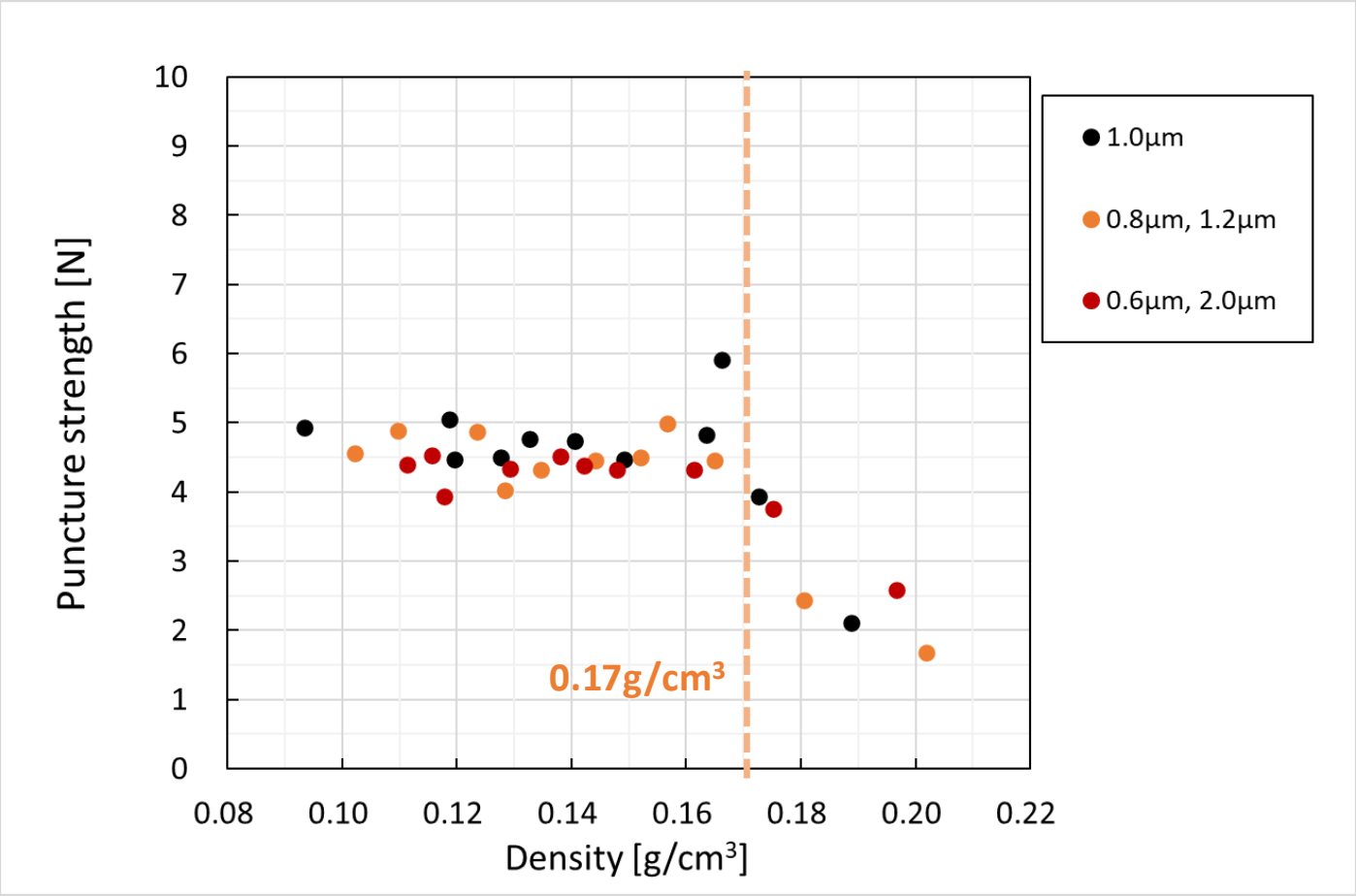
Competitor AGM
0.15 g/cc
94% porosity

Multiple Glass Fiber Formulations (same basis weight, same SSA, different densities)



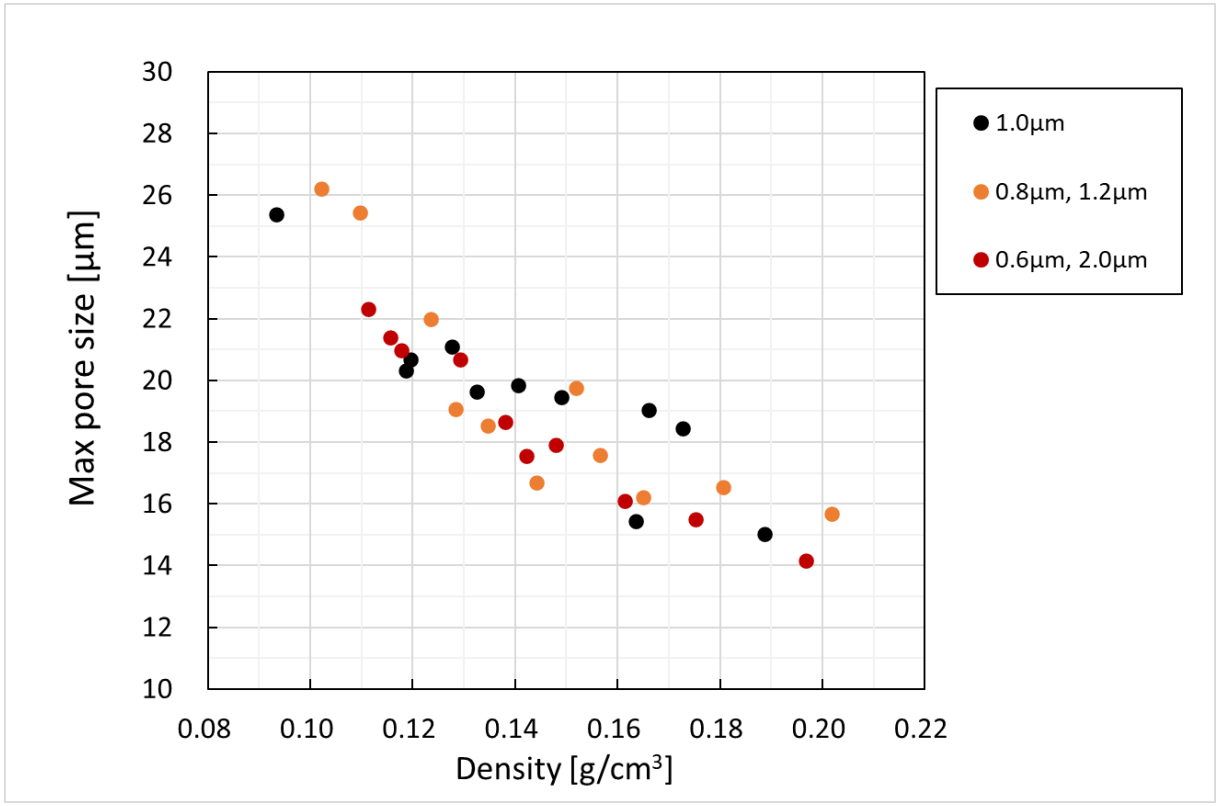


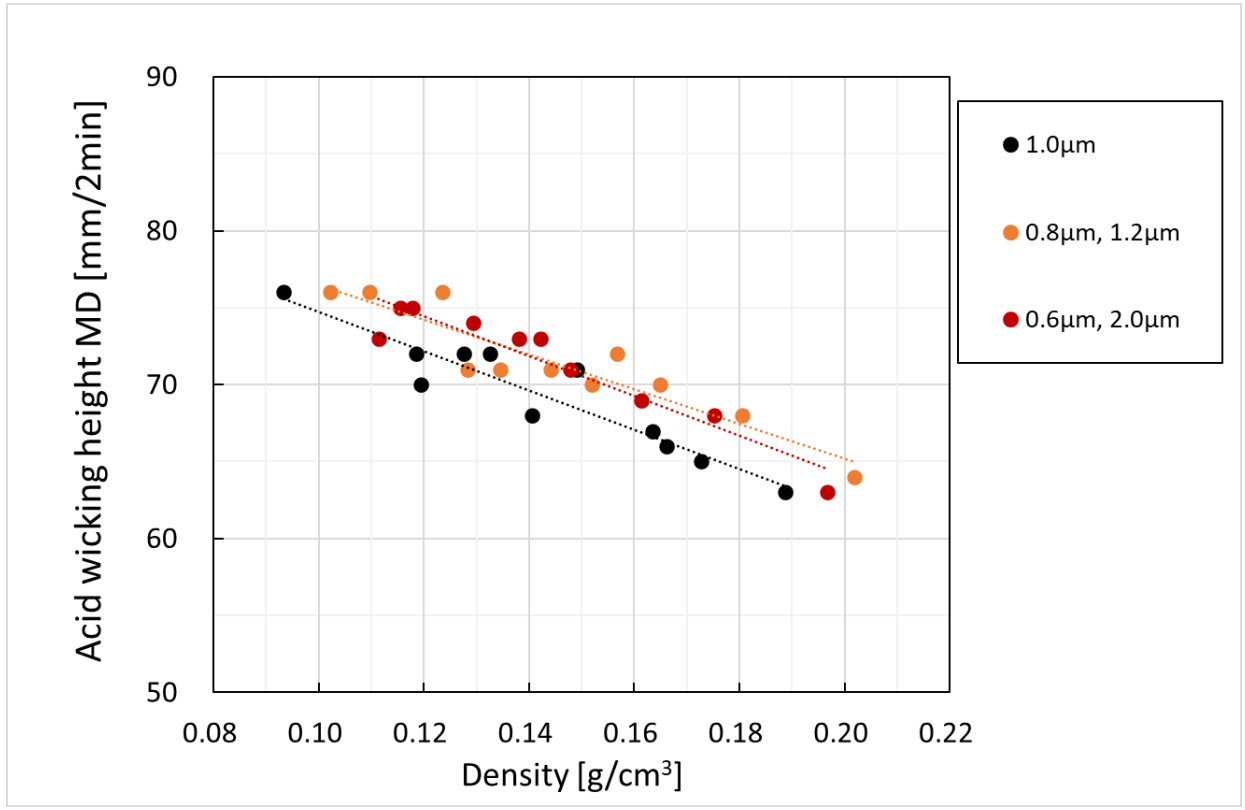
Puncture Strength



- Puncture strength decreased dramatically above a density of 0.17 g/cc for each formulation
- Evidence that localized stress becomes high enough to fracture glass fibers

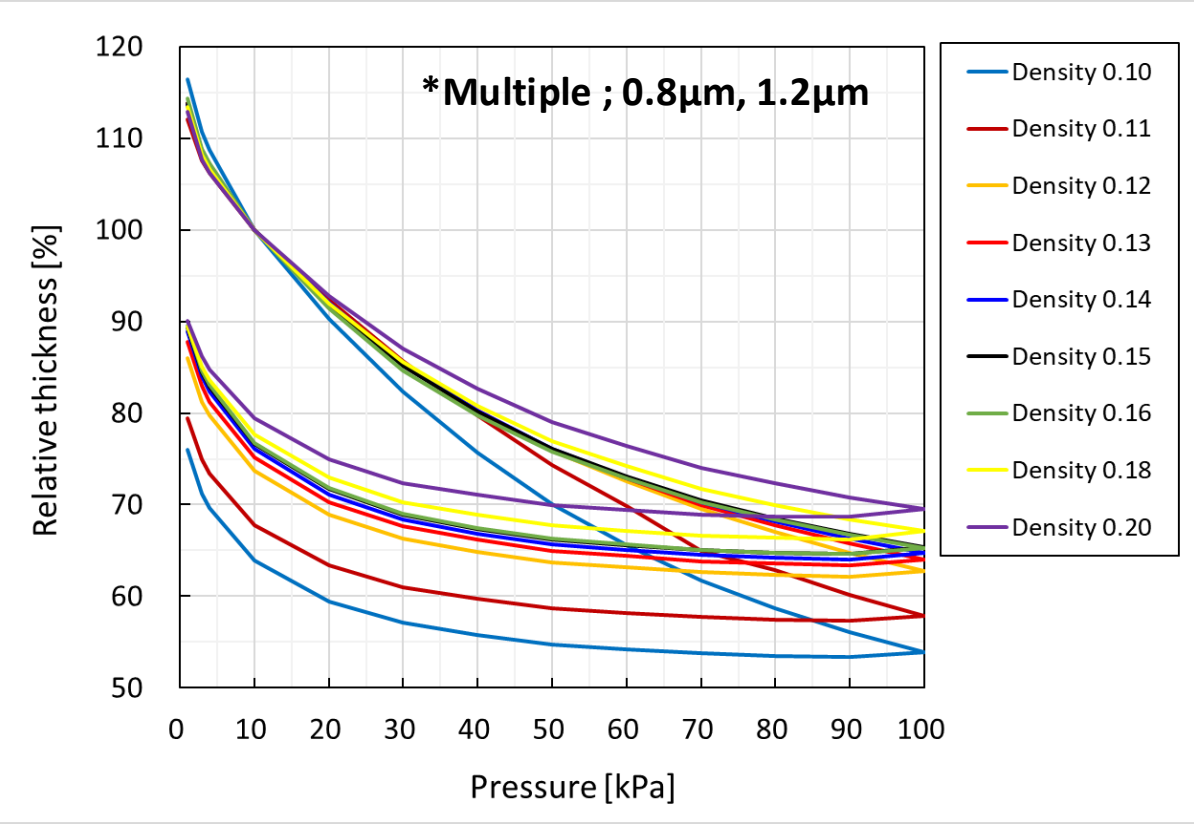
Bubble Point and Wicking Behavior

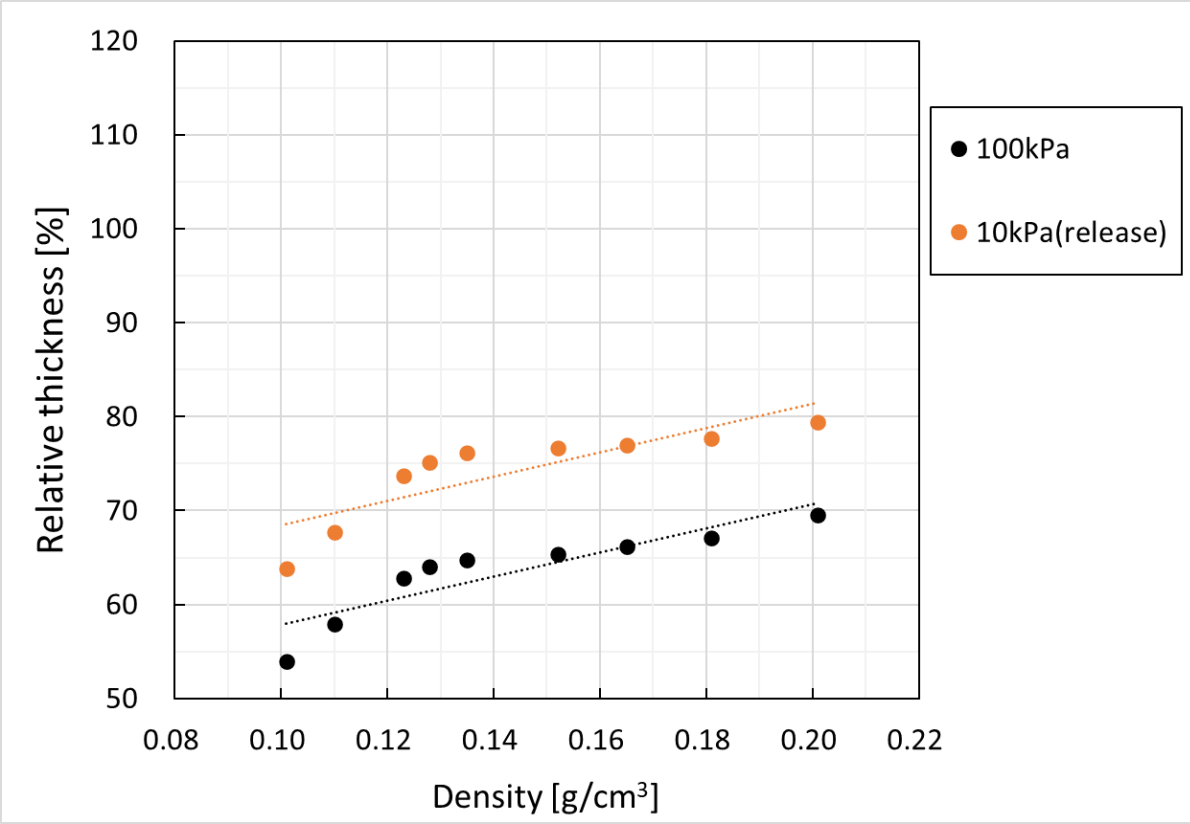




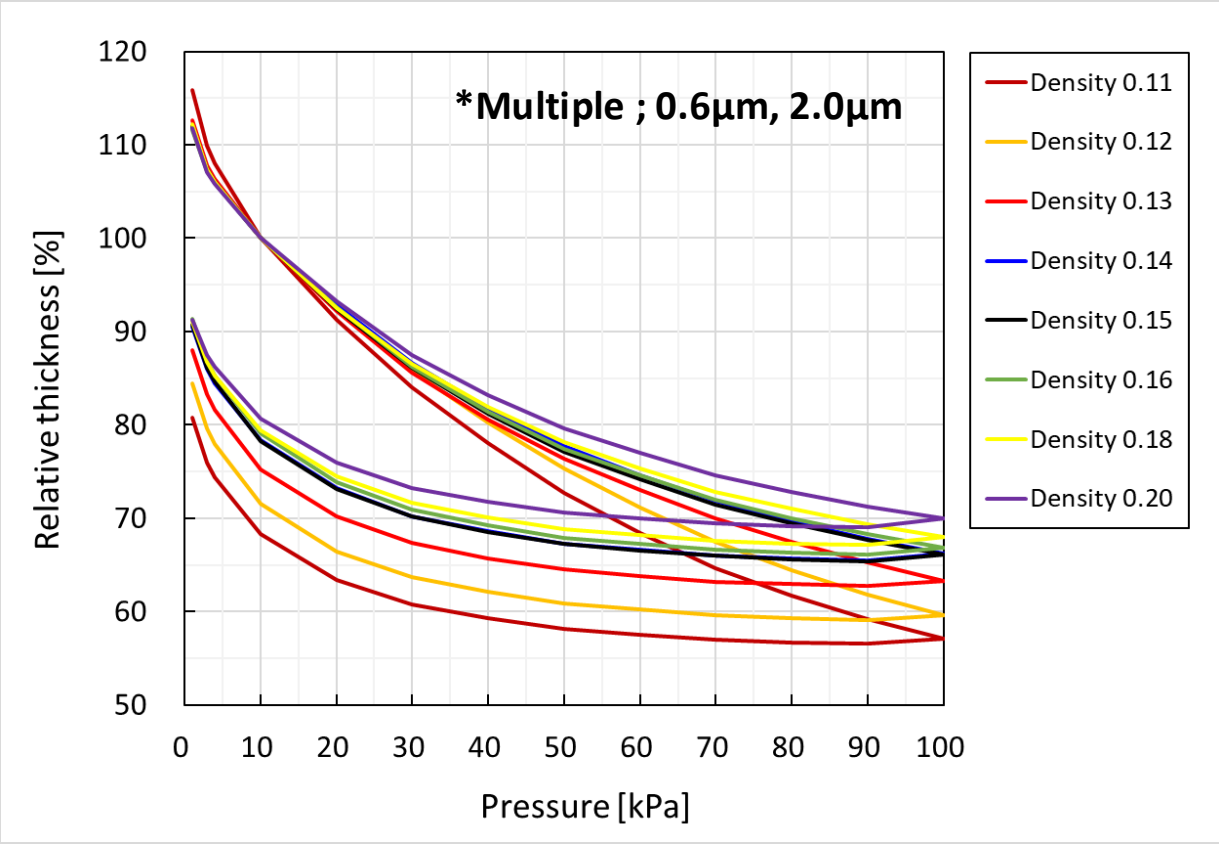
- No significant difference between the formulations.
- Recall that average fiber diameter and specific surface area were designed to be the same in each case.

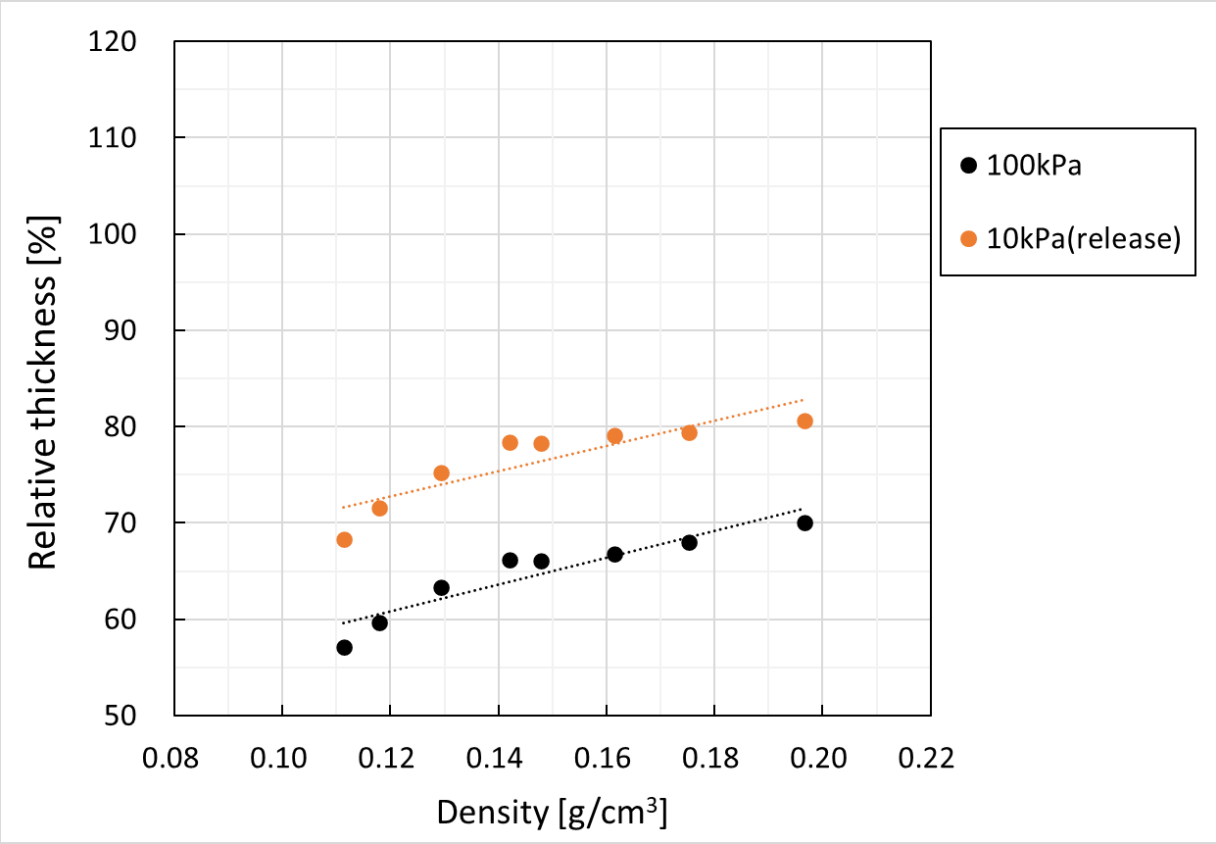
Compression - Recovery (Dry)



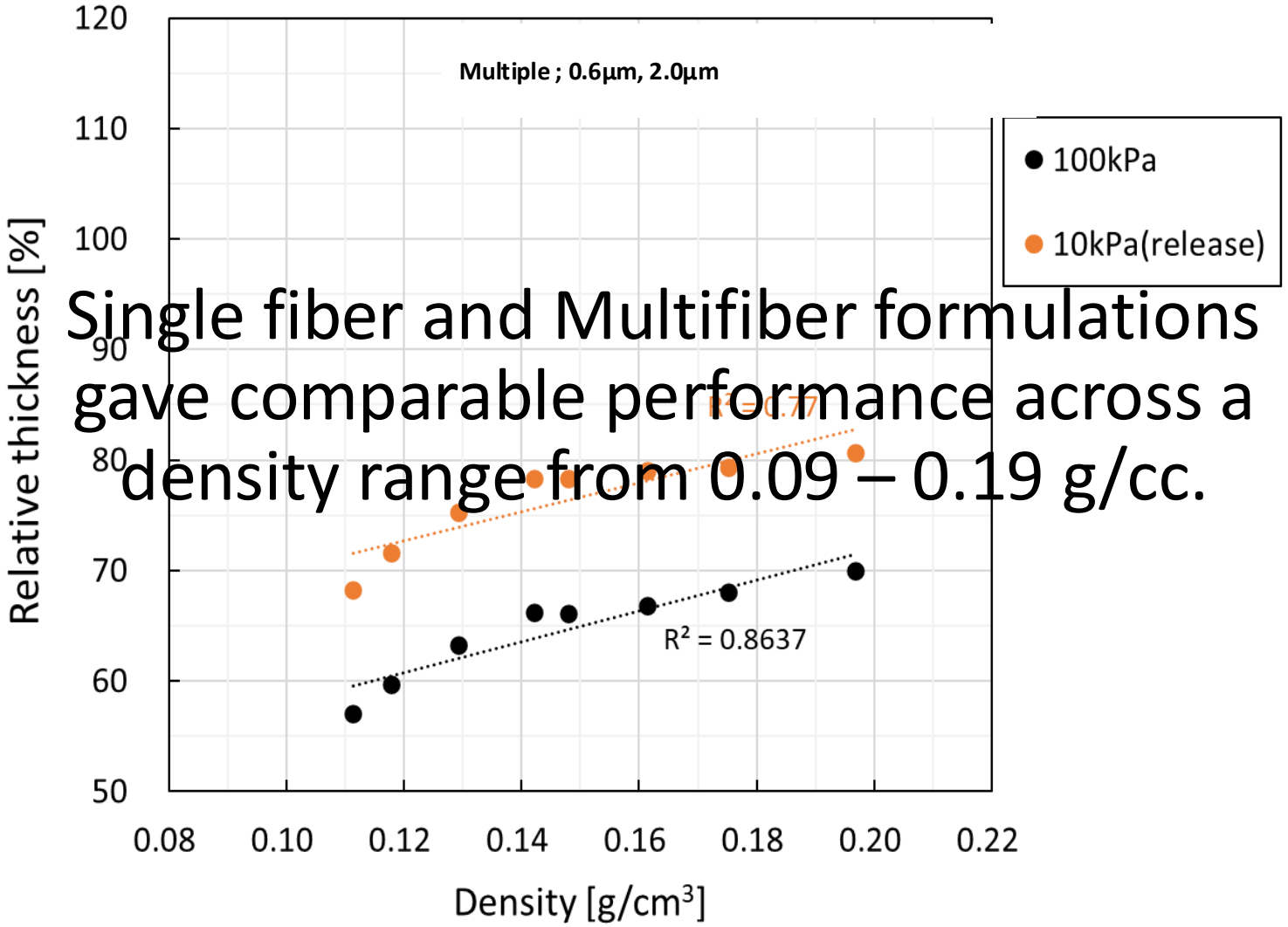


Compression - Recovery (Dry)



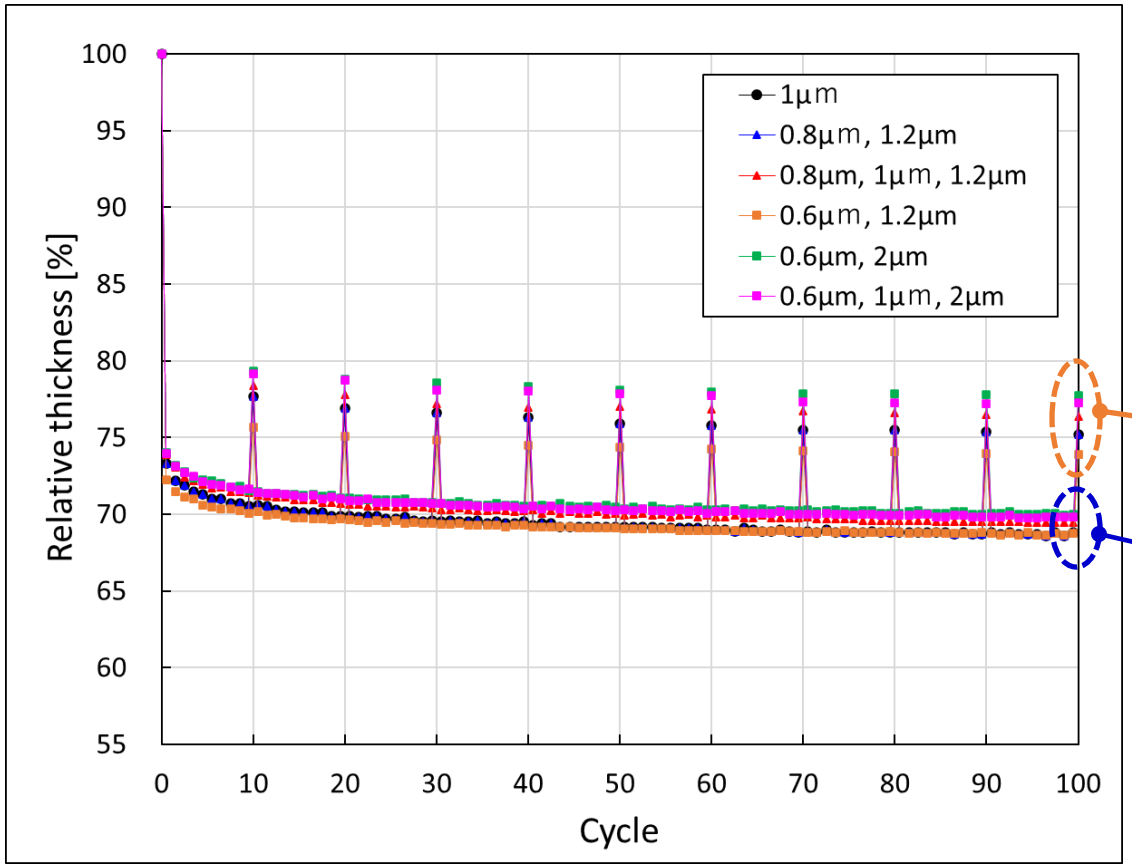


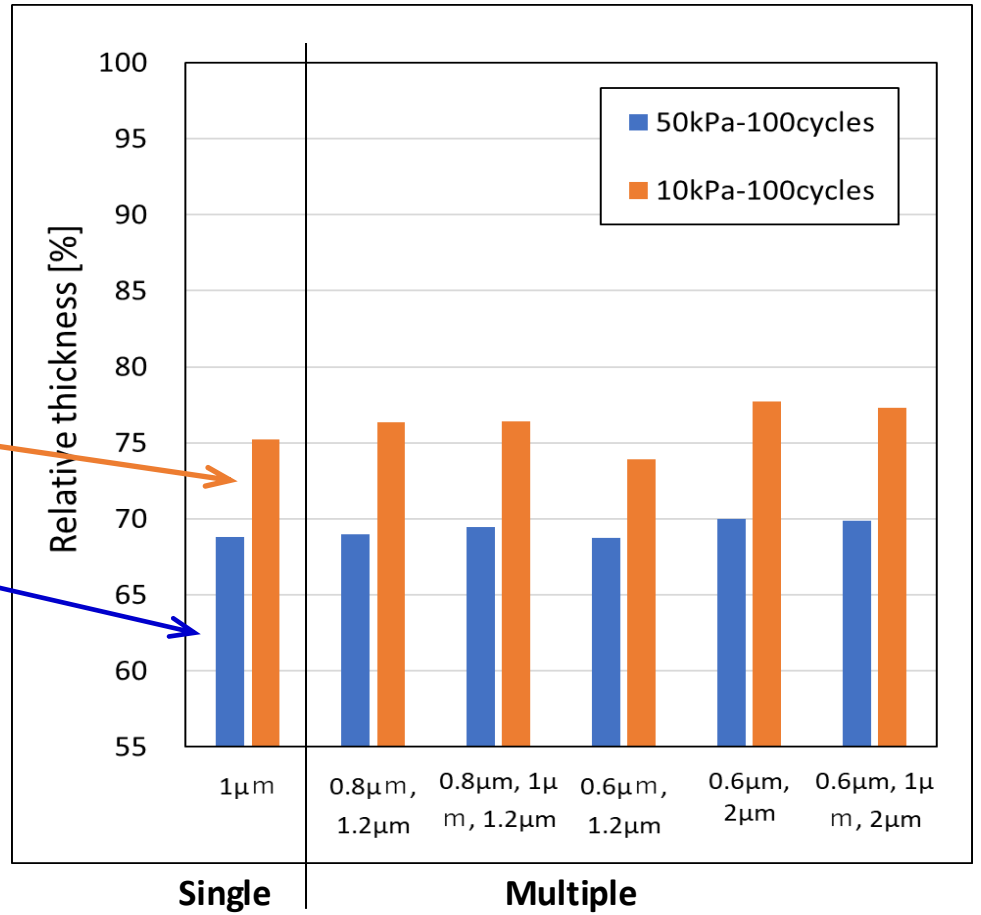
Compression - Recovery (Dry)



Single fiber and Multifiber formulations gave comparable performance across a density range from 0.09 – 0.19 g/cc.

Compression - Recovery (wet) vs. Cycle Life



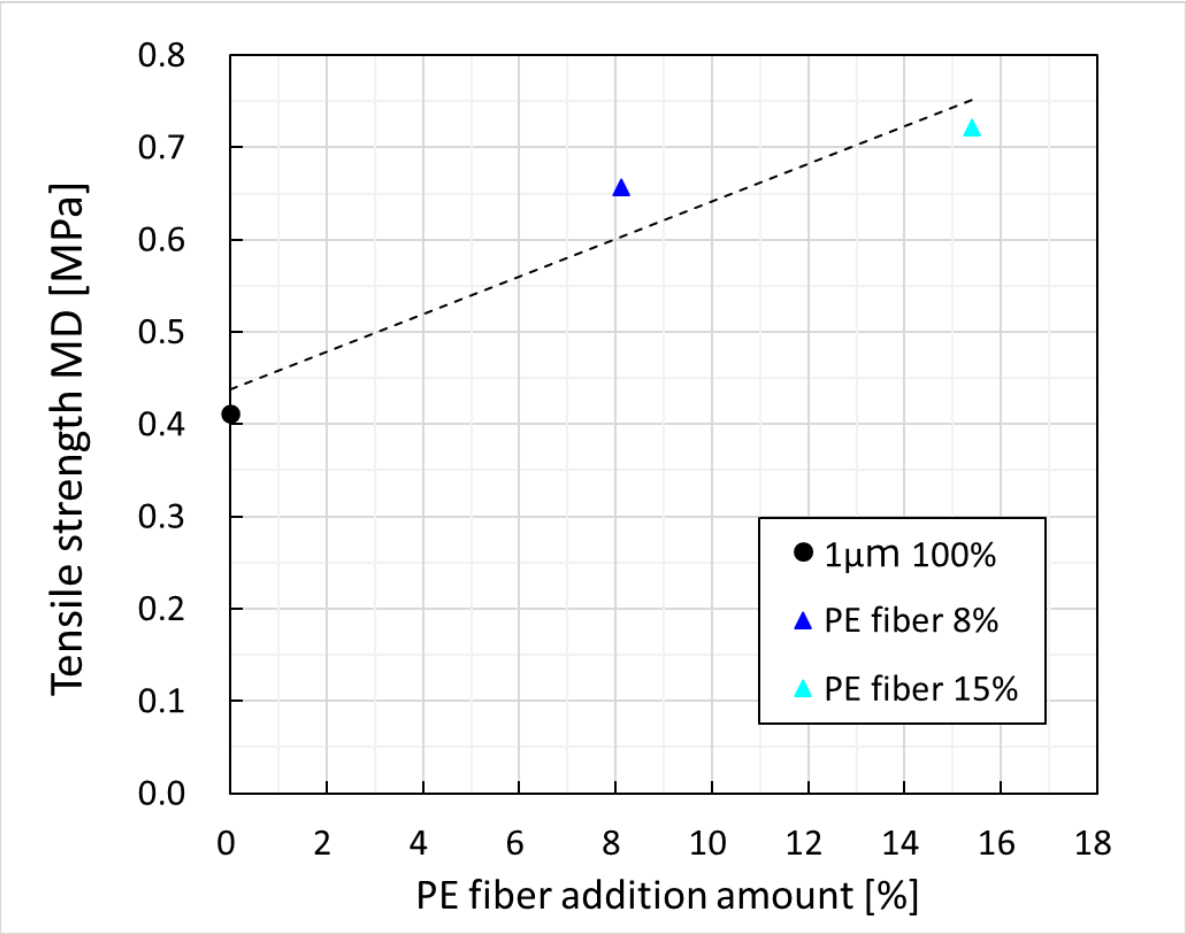


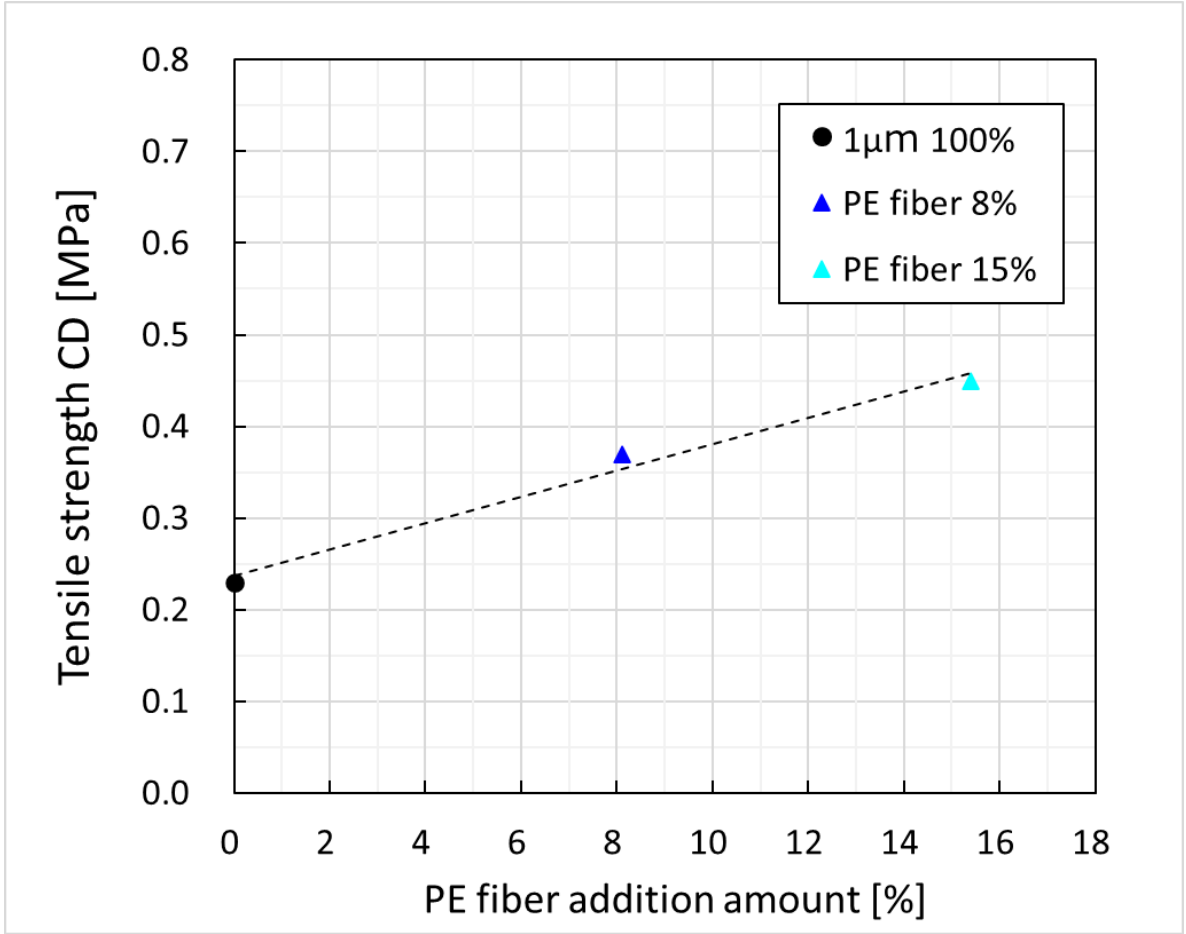
- All samples at 0.15 g/cc

Question

Are we able to change AGM properties and behavior at a fixed density ??

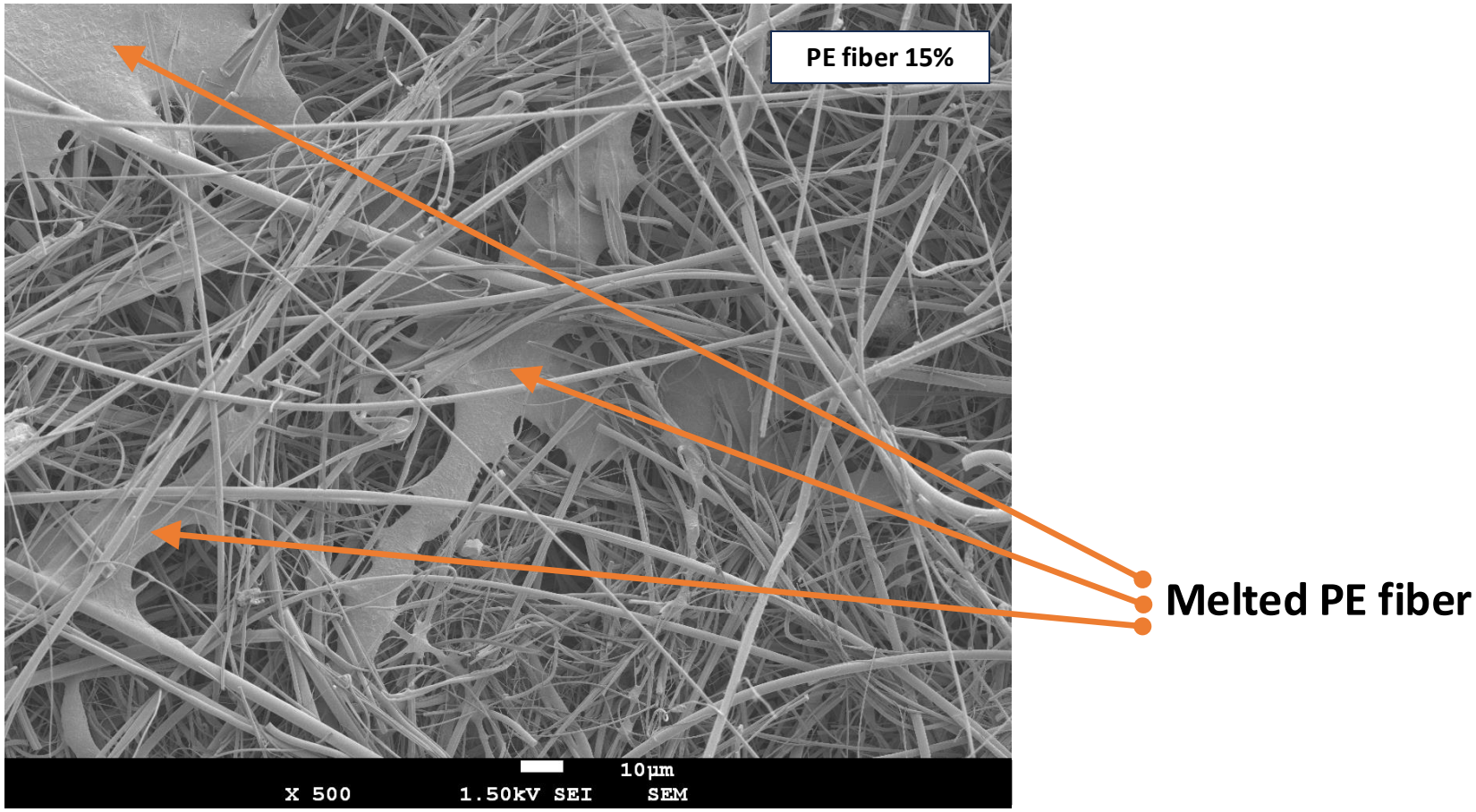
Addition of PE Fiber





- PE fiber was added to AGM formulation which included only 1µm diameter glass fiber.
- Density equaled 0.15 g/cc
- Heat treatment: 200 C.

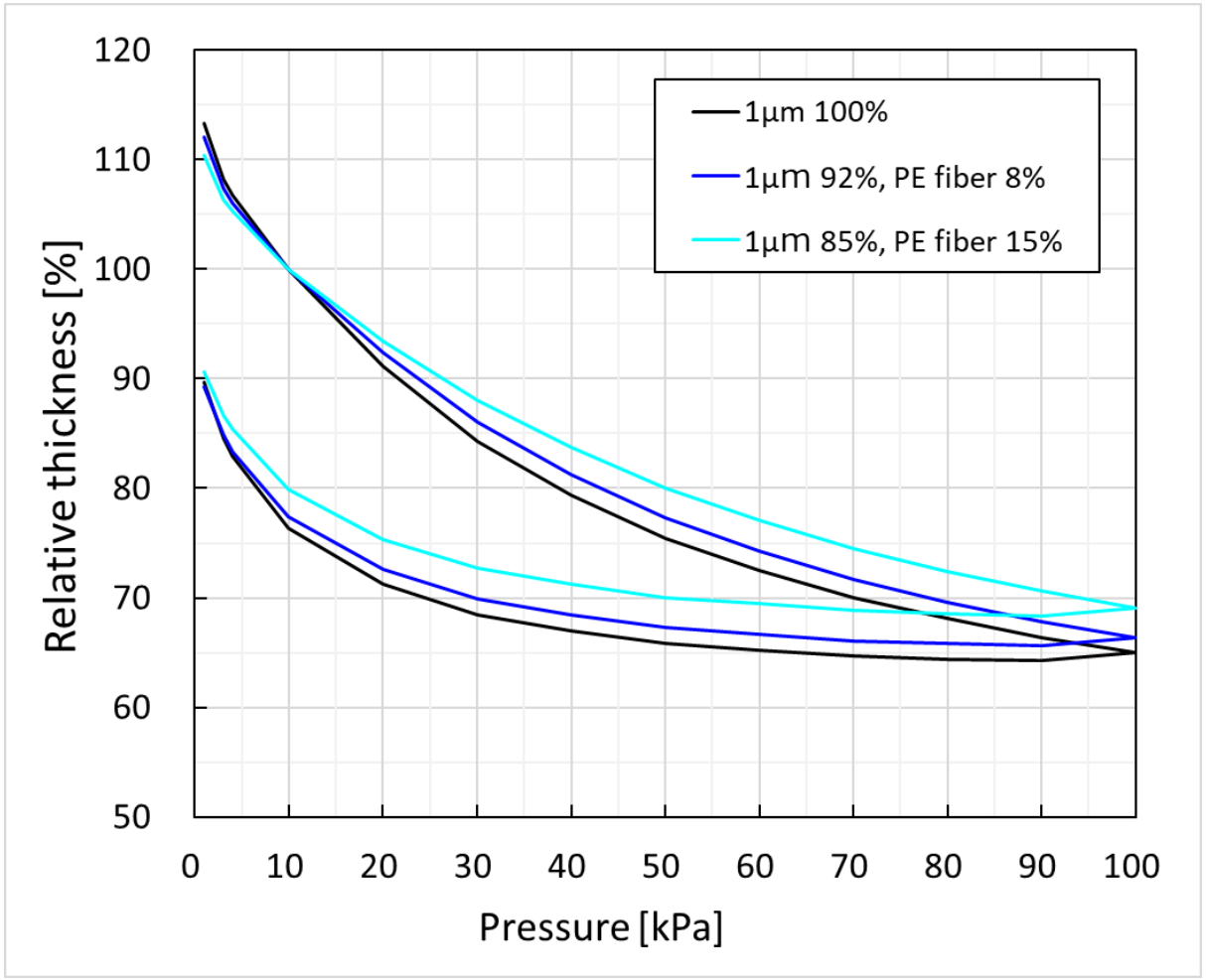
PE/Glass Morphology

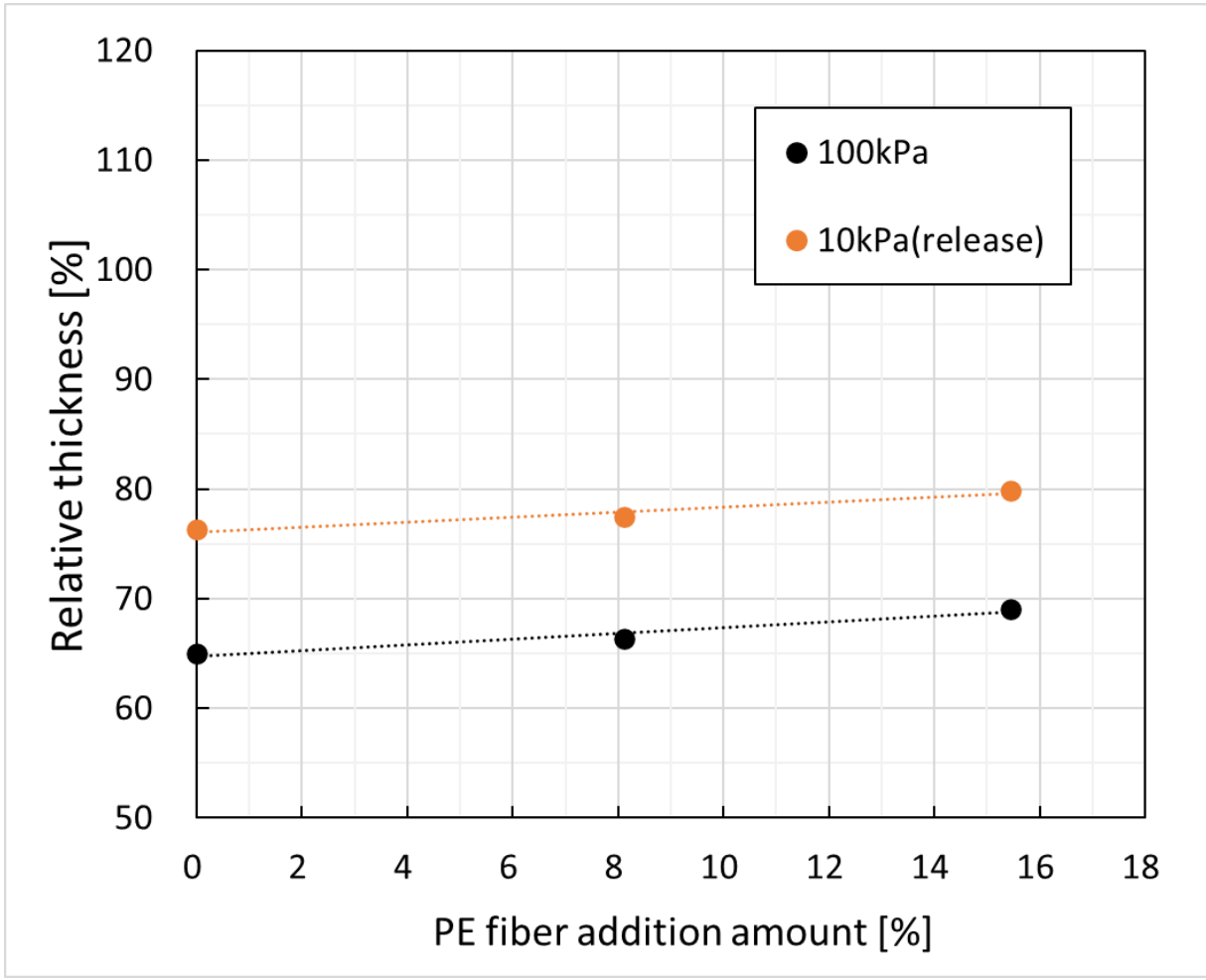


*Magnification 500, SEM bar size = 10um

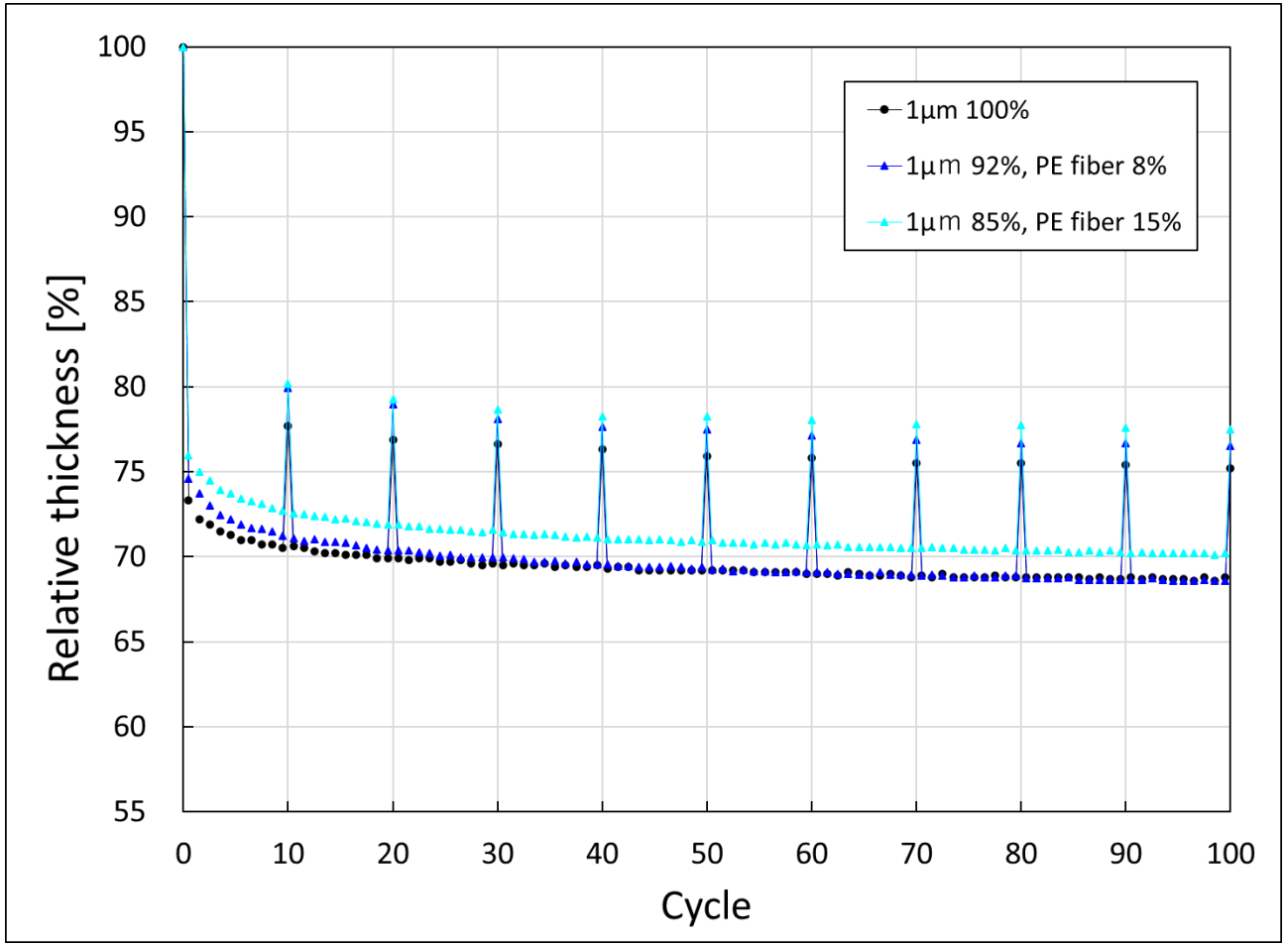
- Scanning electron micrographs show the PE fiber is melted and adheres with glass fibers, thereby increasing tensile strength.

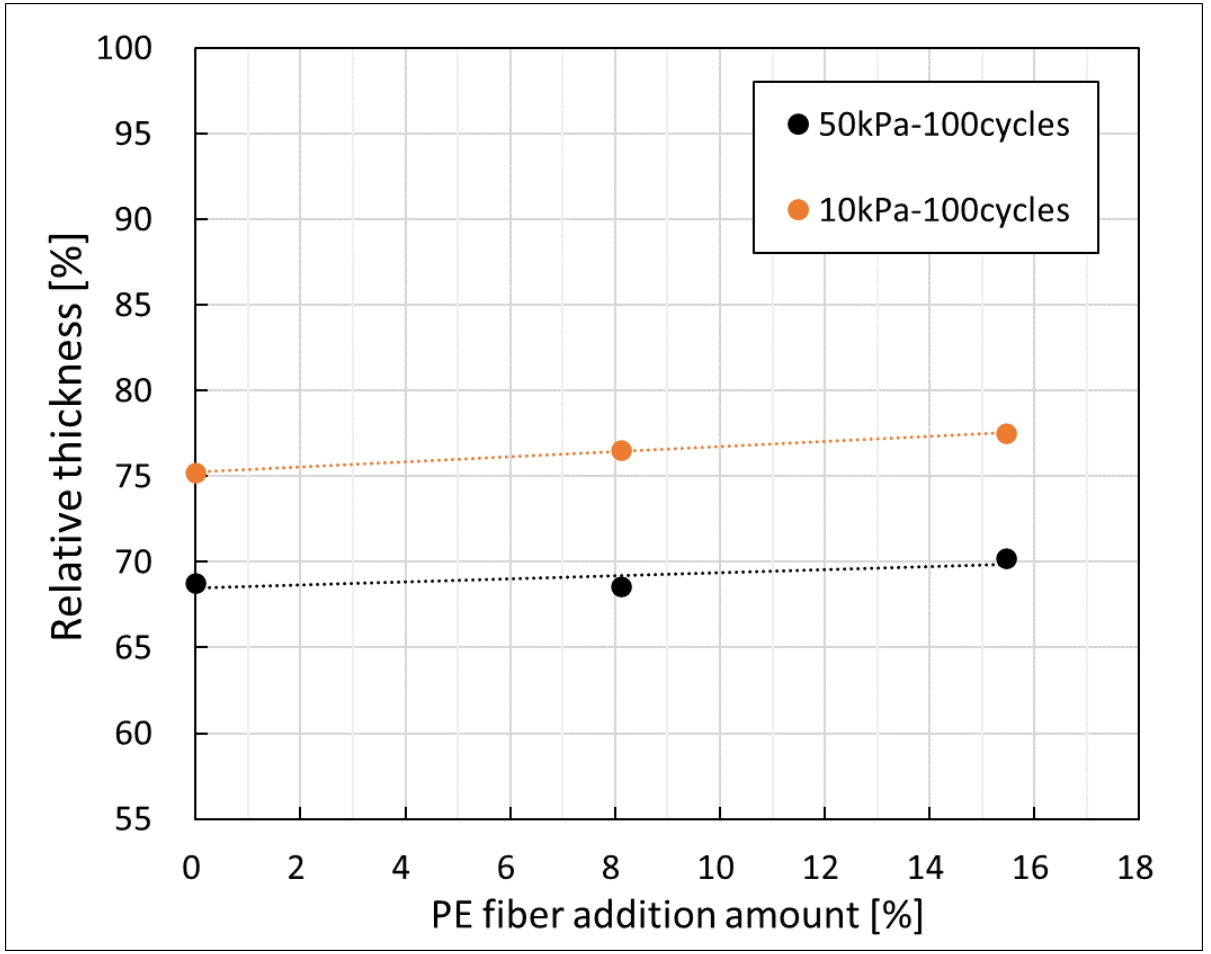
Compression - Recovery (Dry)





Compression - Recovery (Wet)

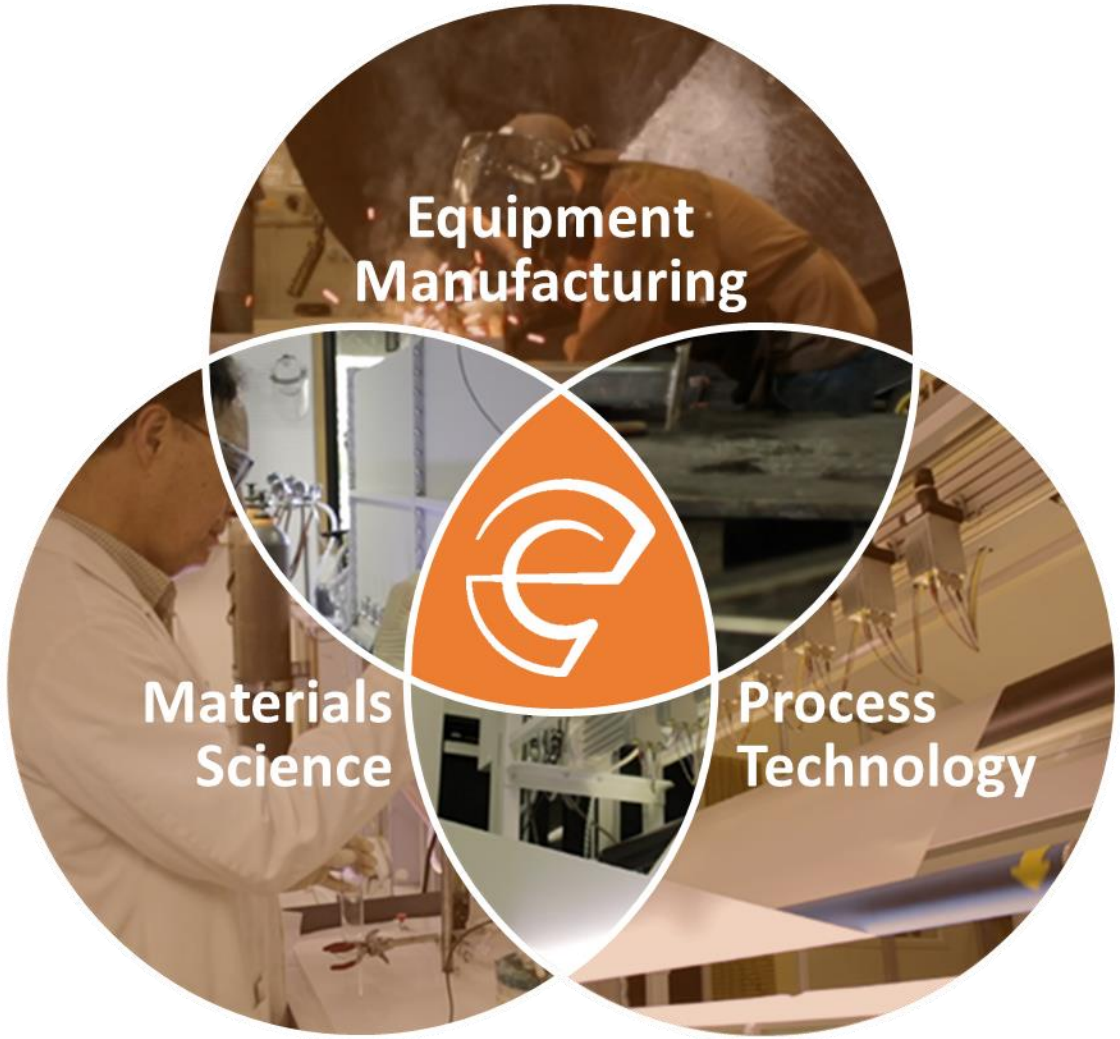




Summary

- AGM does not follow the classic power law relationship between material properties and relative density exhibited by other porous materials
- AGM manufactured with multi-diameter glass fiber formulations has higher tensile strength compared with single diameter formulations over a density range of 0.09 – 0.19 g/cc
- Wicking behavior is dominated by larger pores at short times (2 mins.) and smaller pores at long times (24 hr.)
- There is much to learn about controlling glass fiber compositions and contact points to further improve compression-recovery behavior

Thank you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