

Hydrostatic Pressure Enhancement of Additively Manufactured Polymer Parts

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Introduction

- Benefits of Polymer Additive Manufacturing (AM):** lightweight parts, minimizes waste + cost, can produce complex geometries
- Pain Point:** AM polymer parts suffer from porosity and void networks
- Project Objective:** Improve AM polymer part microstructure and properties with pressure, time, and/or temperature treatments that reduce internal porosity and maintain geometry

Methods

Specimens

- ASTM D638 tensile dog bone specimens, print orientation according to ASTM 52921

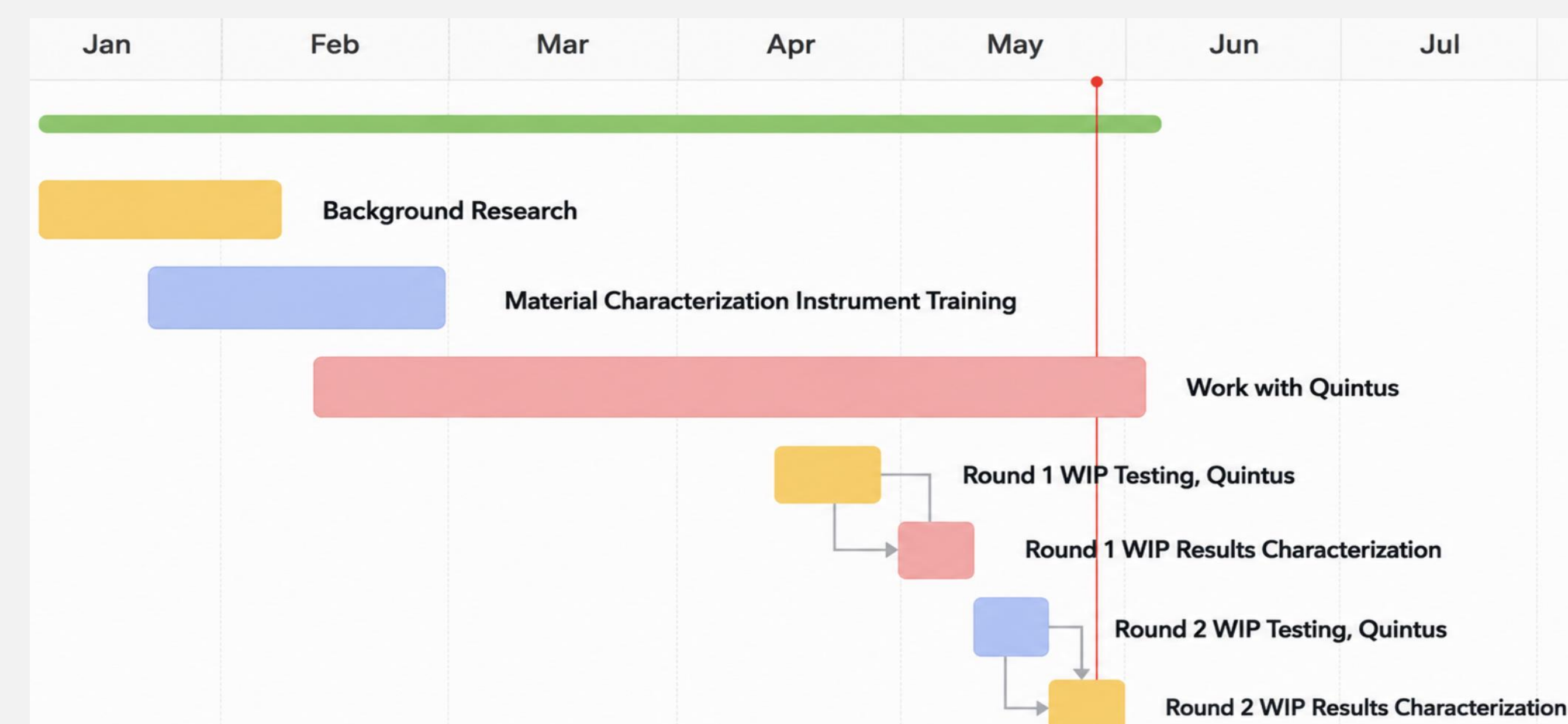
Pressure Treatments

- In partnership with Quintus Tech.
- Warm Isostatic Press (WIP) – elevated temp, extended time, pressurized liquid medium
- Autoclave uses gas medium

Design Criteria

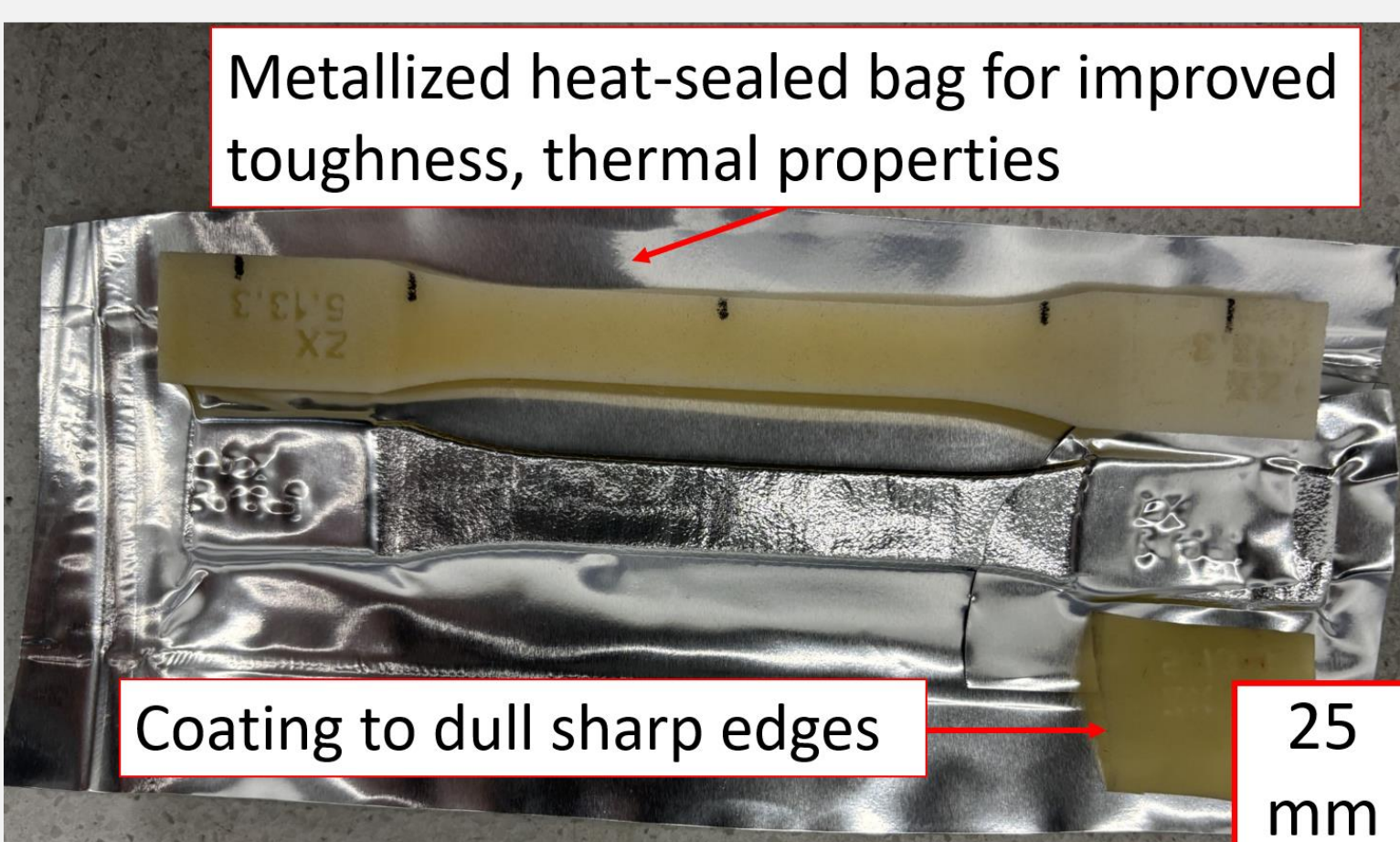
Constraint	Metric 1	Metric 2	Metric 3
Part Deformation	<2.5% change in part dimensions		
Cost & Repeatability	Total part cost increase <2.5%	Repeated runs return p-value ≥ 0.05	
Mechanical Properties	Elongation at break increases ≥5%	Average void size decreases ≥5%	UTS decreases ≤2.5%

Timeline



Sealing Challenges

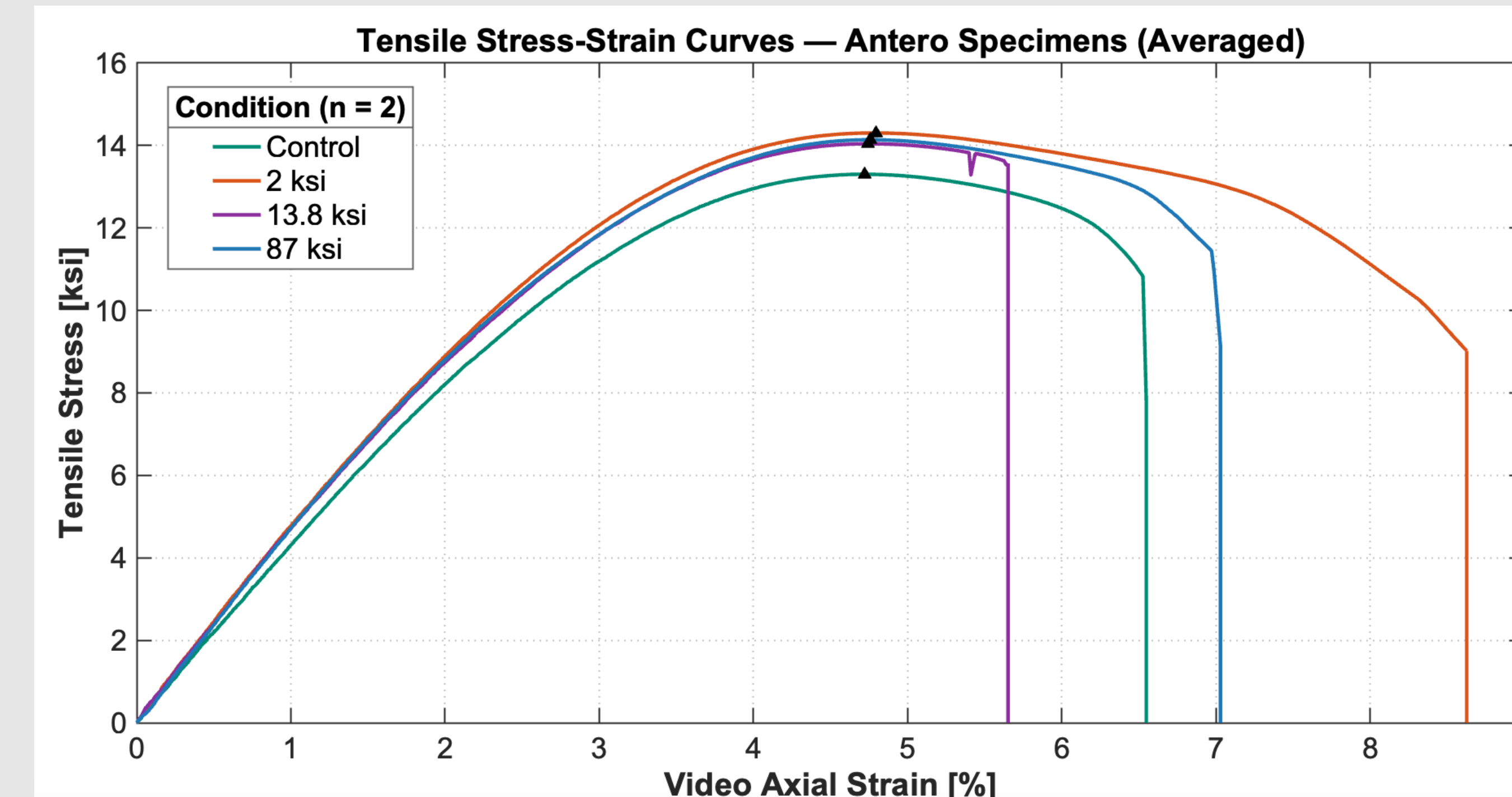
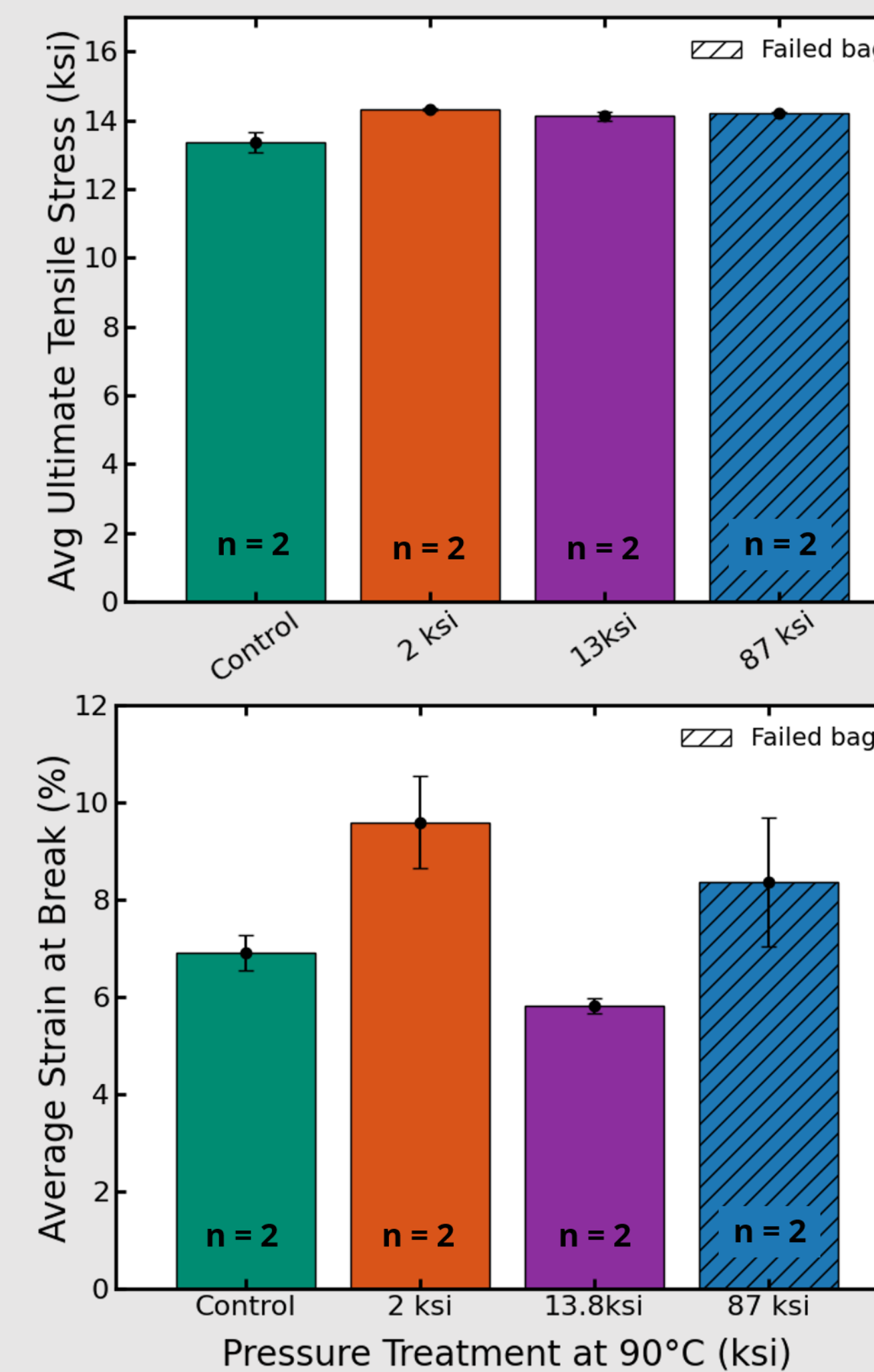
- WIP requires samples with <95% surface density sealed via vacuum bag
- Sharp sample corners → bag failure under high pressure
- Mitigate via coating to dull sharp edges, double-bagging



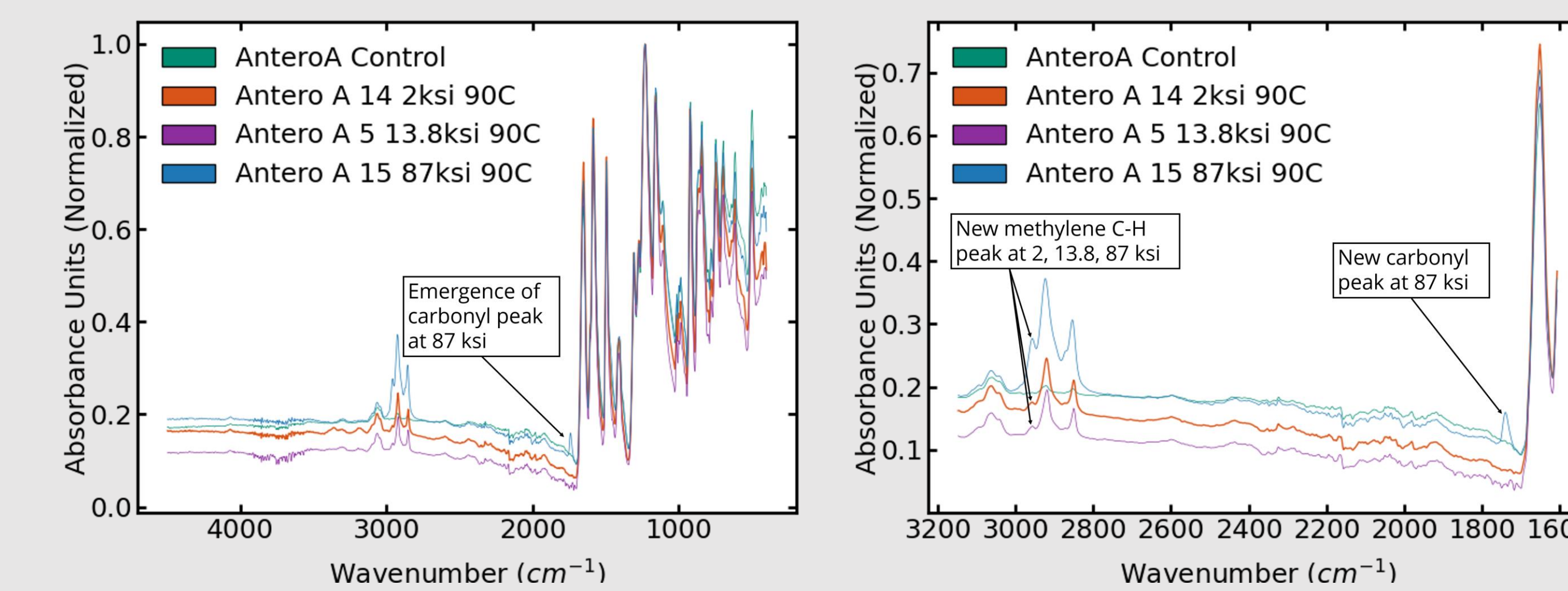
- Bag thermal properties limit cycle parameters → round 1 limited to 194 °F
- Mitigate using metallized bags to improve toughness, thermal properties
- Recommend future research on use of liquid sealers, silicone casting to seal more complex sample geometries

Mechanical Results

- Most consistent + complete data in Antero A specimens
- 10% increase in tensile strength with pressure treatment
- 2% increase in elongation at break with pressure treatment
- Bag failure occurred at 87 ksi treatment condition, likely contributing to inconsistent mechanical response
- Results suggest treatment effectiveness depends strongly on material type, treatment temperature, pressure, print orientation, and effectiveness of surface sealing
- ULTEM and Nylon saw negative changes in elongation at break with pressure treatment



FTIR



Methylene peak in treated samples likely solvent used for cleaning post-treatment, while new carbonyl peak indicates change in microstructure, oil contamination, or degradation

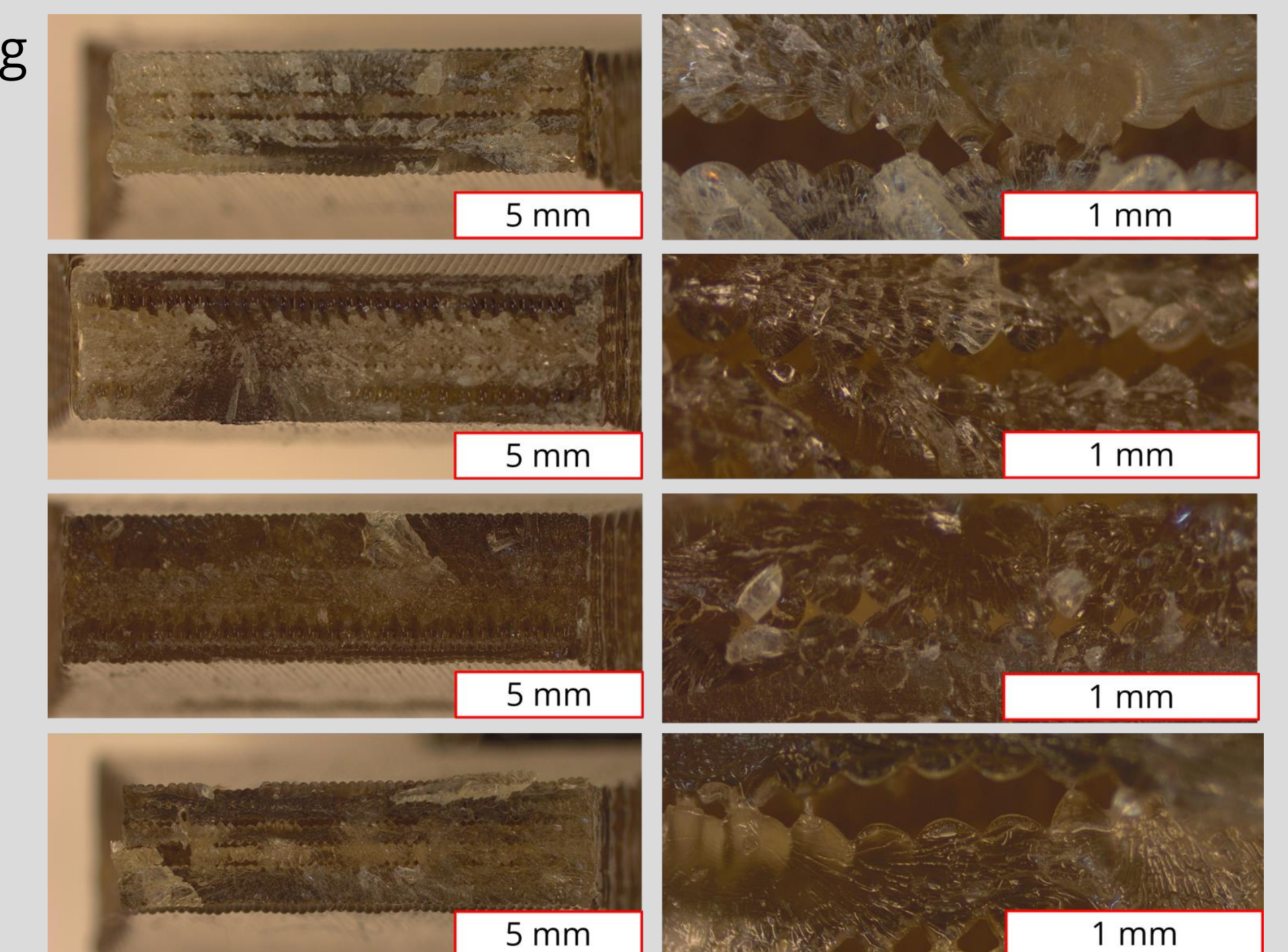
DSC

- No significant change in T_g or T_m
- Small increase in degree of crystallinity with pressure

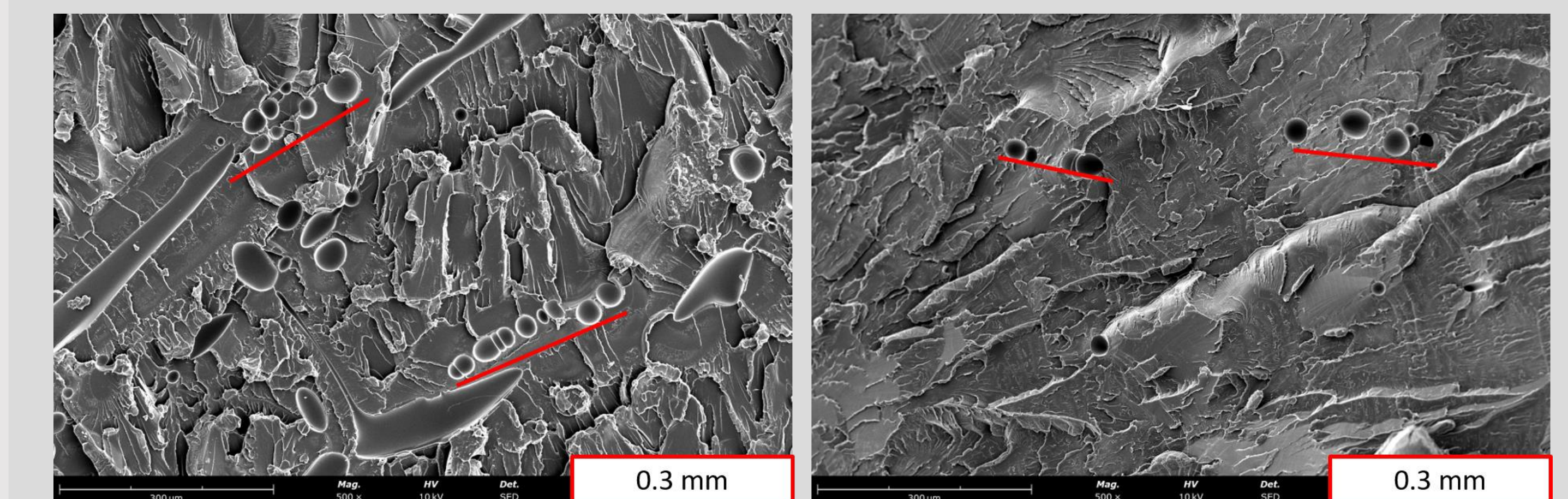
Antero A Sample Type	Degree of Crystallinity
Control	2 %
2 ksi	2.2 %
13.8 ksi	3.15 %
87 ksi	3.85 %

Microscopy Results

- Visible filament fusing with increasing pressure treatments
- Increased polymer diffusion between filaments at higher magnifications
- Reduction in void size, quantity with increased pressure treatment
- Bag failure + oil intrusion in 87 ksi samples interferes with microstructure change



Antero specimen cross sections, control, 2 ksi, 13.8 ksi, 87 ksi (top to bottom), at 0.67x (left) and 4x (right)



SEM 500x, Antero control with 25 pores avg. diameter 29 microns (left), Antero 13.8ksi with 12 pores avg. diameter 28 microns (right)

Conclusions

- Effective sealing of sample surface is challenging due to sample geometry, complex temperature + pressure + compatibility requirements
- Limited commercial heat-seal vacuum bags suited to required WIP temperatures
- WIP treatment caused microstructural changes, evidence of diffusion, improvement in tensile strength, elongation at break
- Higher temperatures, longer pressing times, change in sealing conditions could improve changes in sample properties further

Recommendations

- Print orientations → distinct treatment groups
- Increase pressing temperature to facilitate greater diffusion
- Investigate sealing alternatives to reduce constraints on part geometry & treatment parameters, including:
 - Thermoplastic films
 - Cast silicones
 - Liquid sealers

Materials	
Polyamide (Nylon 11) PEKK (ANTERO 800NA) PEI (ULTEM 9085)	
Pressures	
2 ksi, 13.8 ksi, 87 ksi	
Temperature	Duration
284 °F (140°C)	60 min
Print Methods	
SLS (Polyamide), FFF (PEKK + PEI)	

Next Steps

- The team is currently repeating the test matrix at higher temperatures

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