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Chemical-mechanical effects on subcritical fracture initiation and propagation in fused quartz

Presented by

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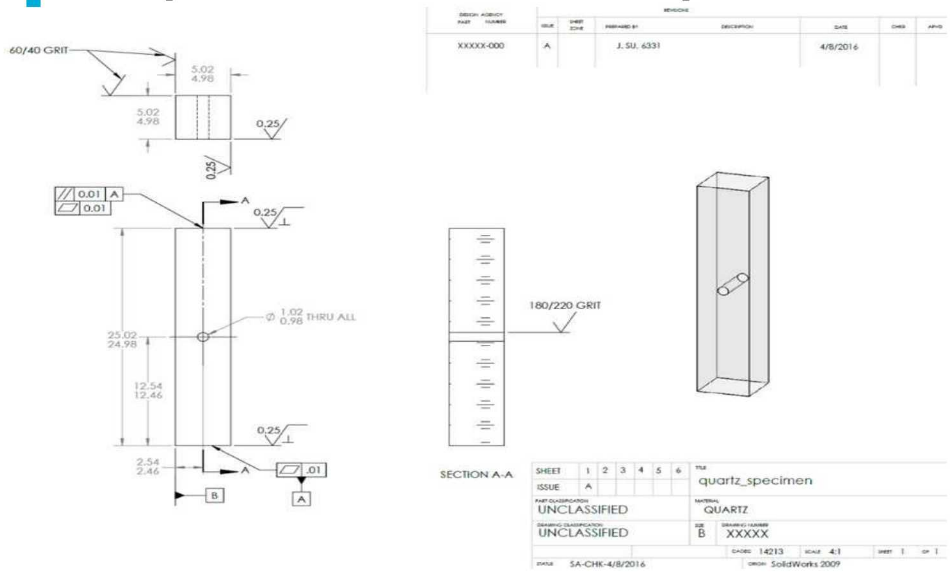
Summary

- Motivation
- Experimental setup
- Load to initial fracture
- Fracture propagation
- Load relaxation
- Summary and Conclusions

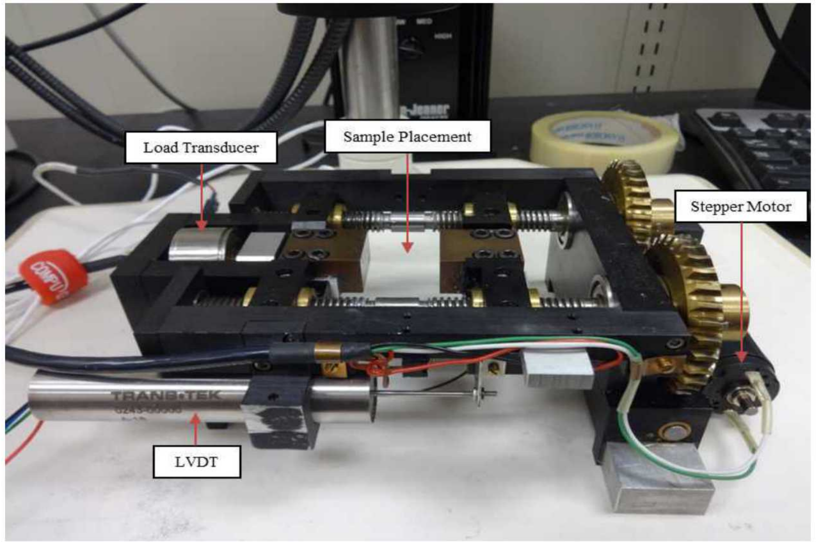
Motivation

- Predicting fracture initiation and propagation is a critical yet unsolved problem for various applications
  - Assessing shale cap rocks at CO2 sequestration sites
  - Maximizing/controlling fracturing for gas and oil extraction
  - Predicting the corrosion and embrittlement of metals and ceramics
- Determine the validity of molecular modeling at the macroscale
- Background (based on studies by Celarie et al. [1, 2])
  - Double cleavage drilled compression (DCDC) performed on soda-silicate glasses
  - Fracture observed via Atomic Force Microscopy (AFM)
- Primary focus of current experiments
  - Chemical environment effects on the fracture initiation and propagation
  - Fracture observed via light microscope

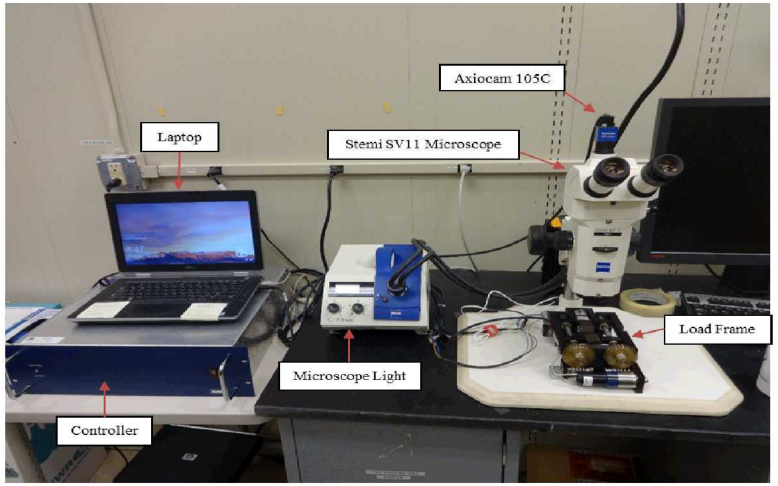
Experimental Setup



Fused Quartz Sample



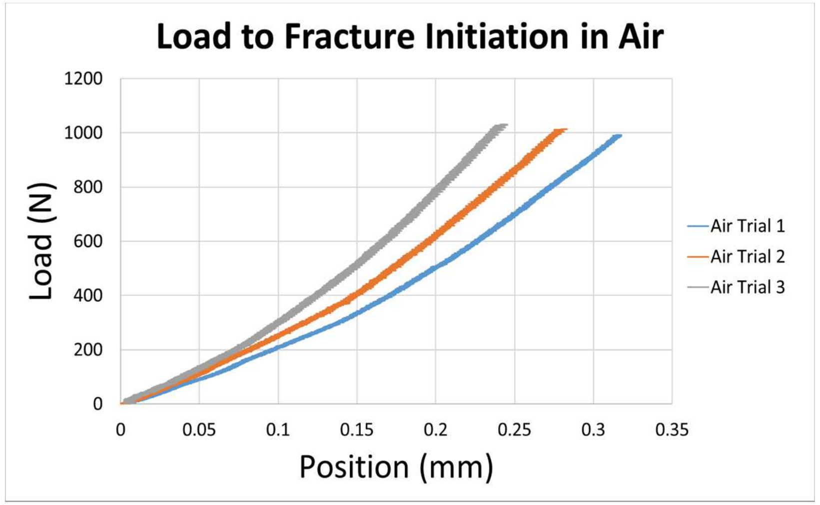
MTI Load Frame

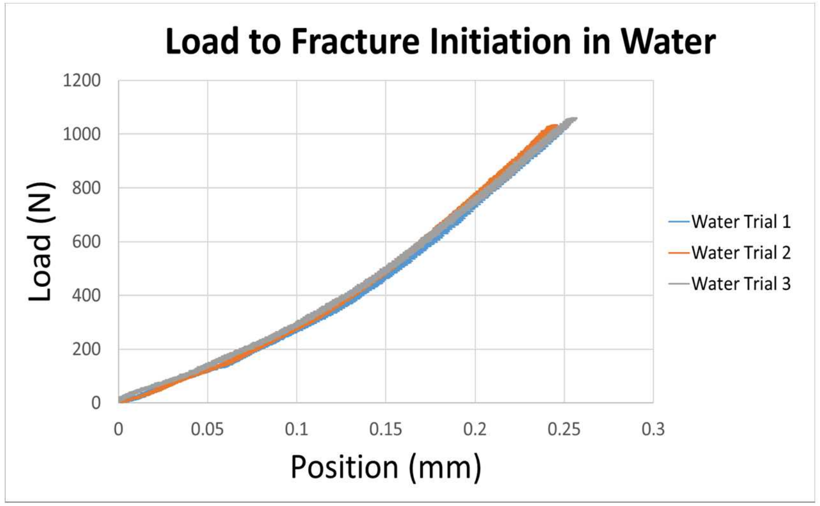


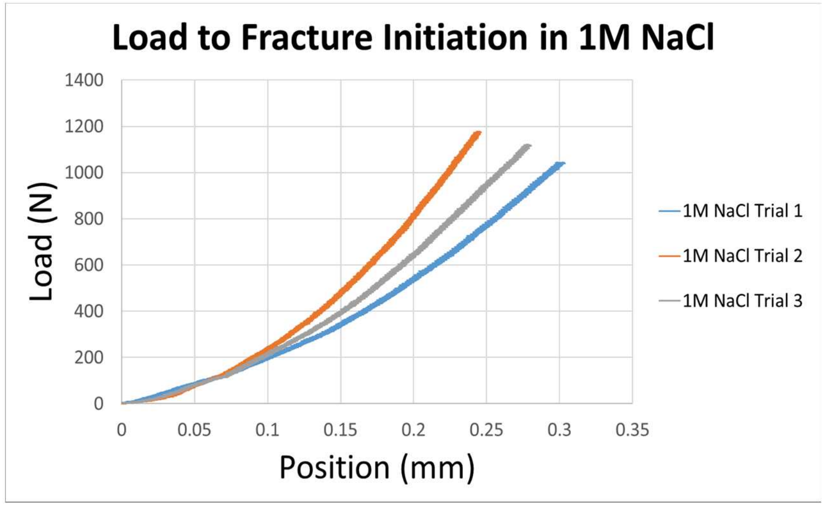
Experimental Setup

Chemical Environmental Chamber

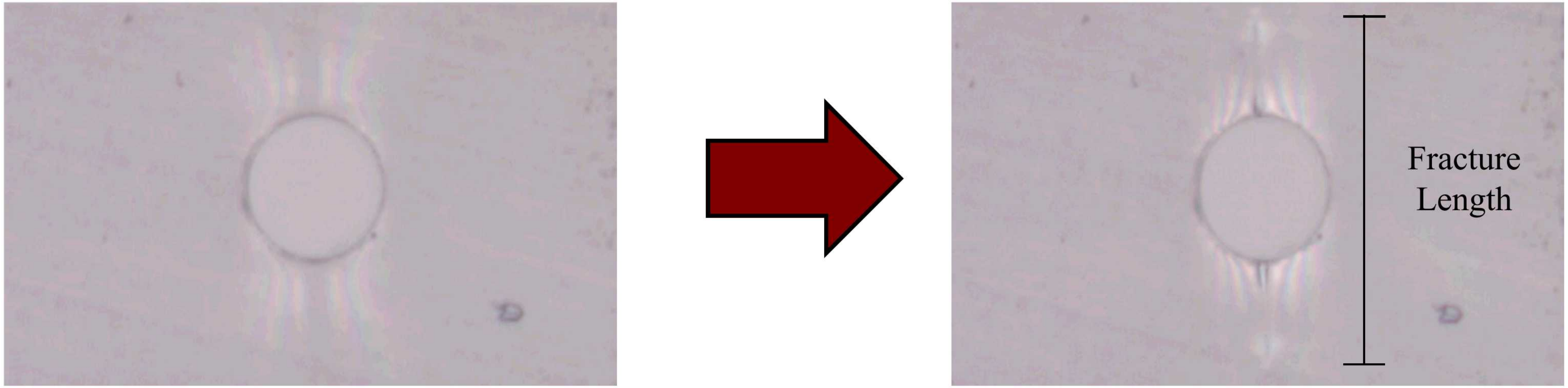
Initial Load to Fracture



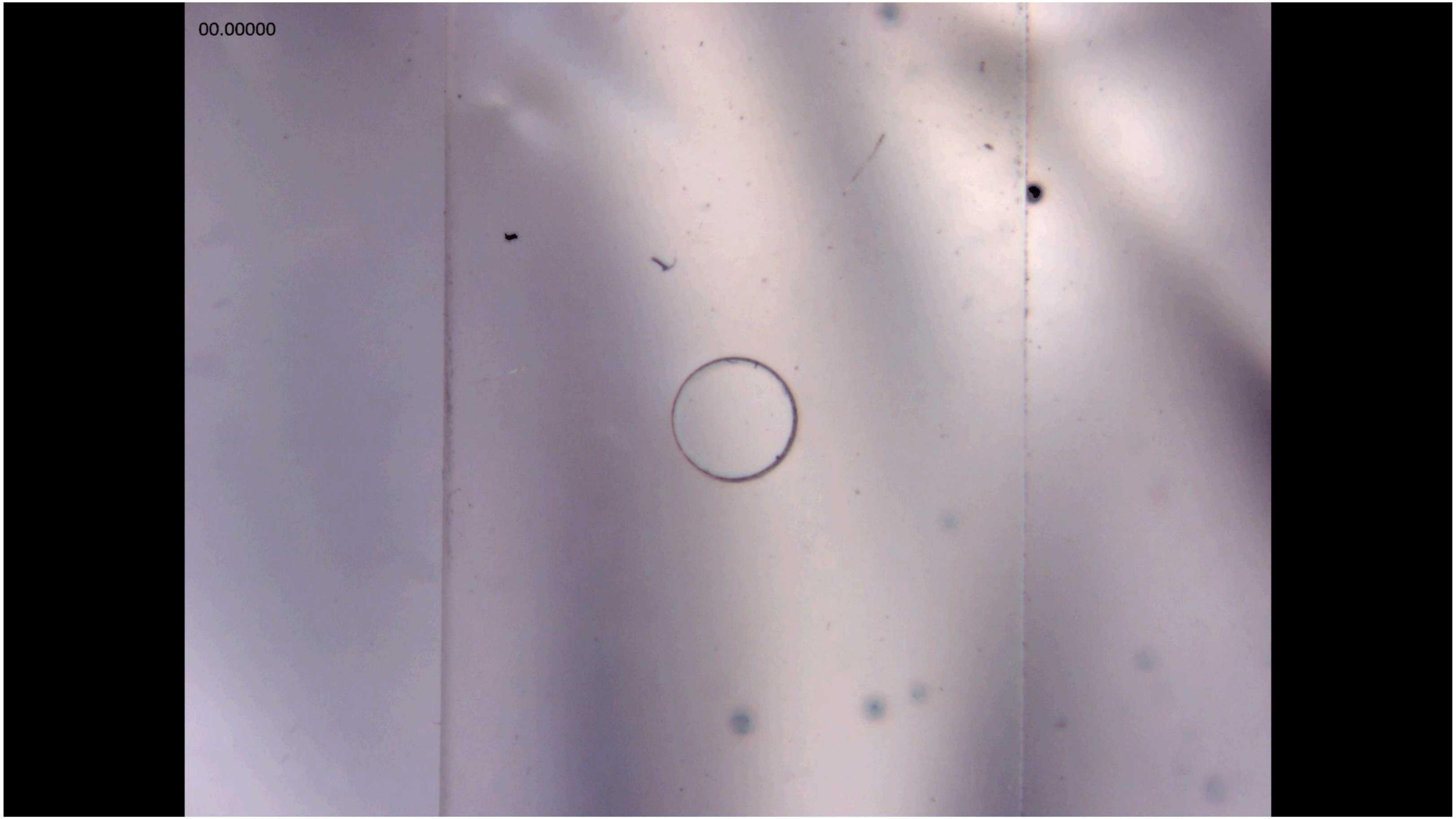




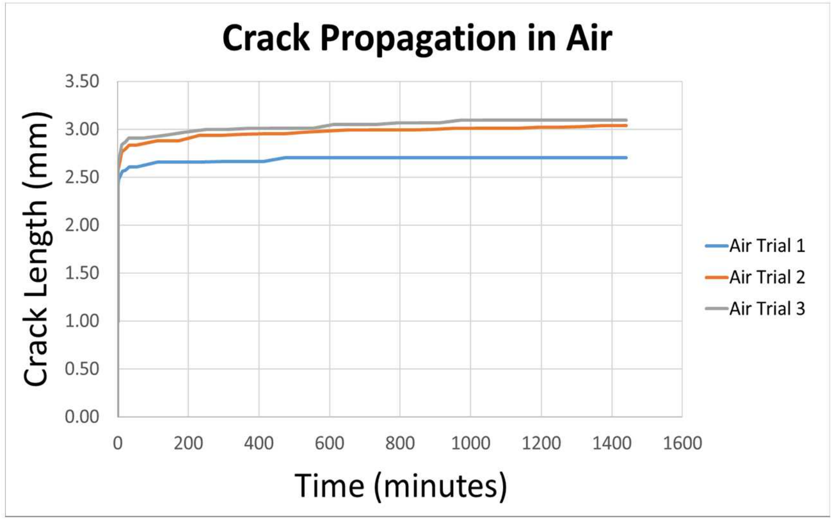
Fracture Initiation

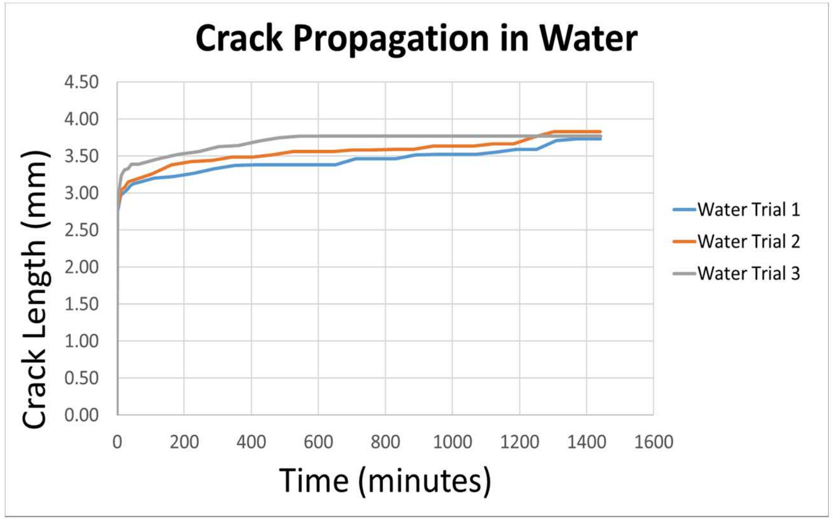


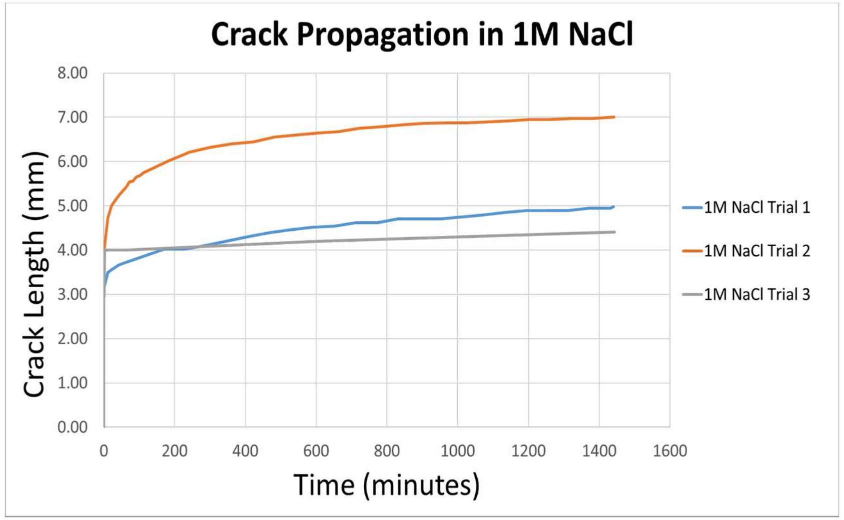
Fracture Propagation in 1M NaCl

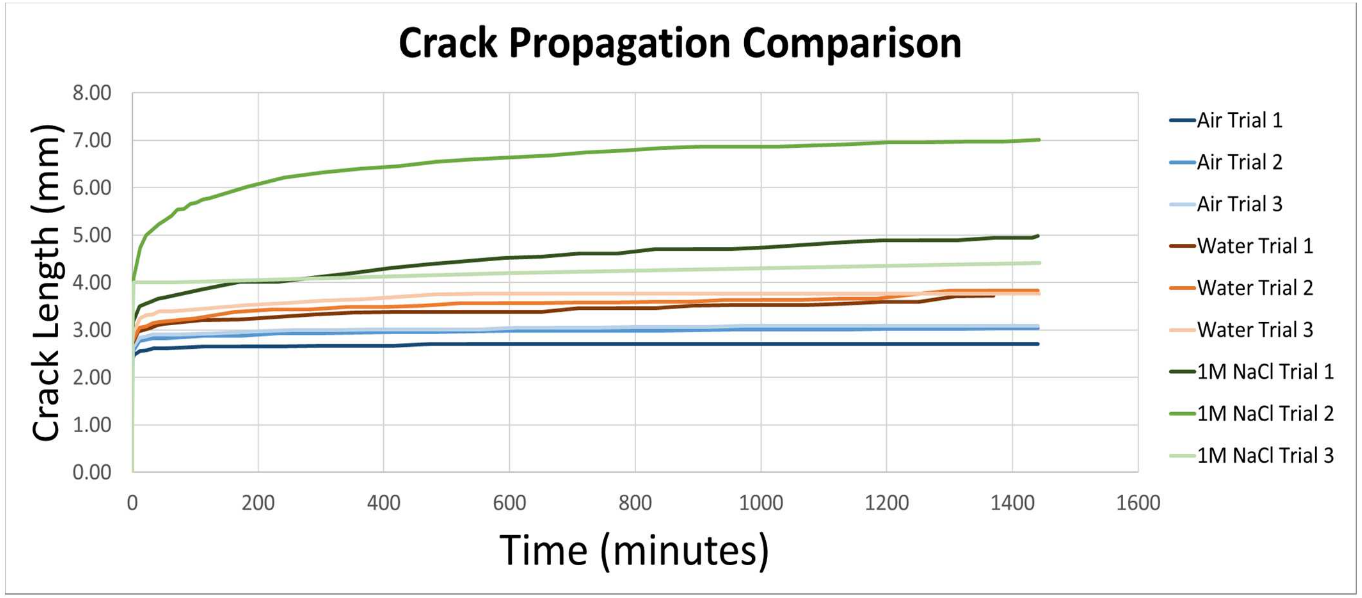


Fracture Propagation



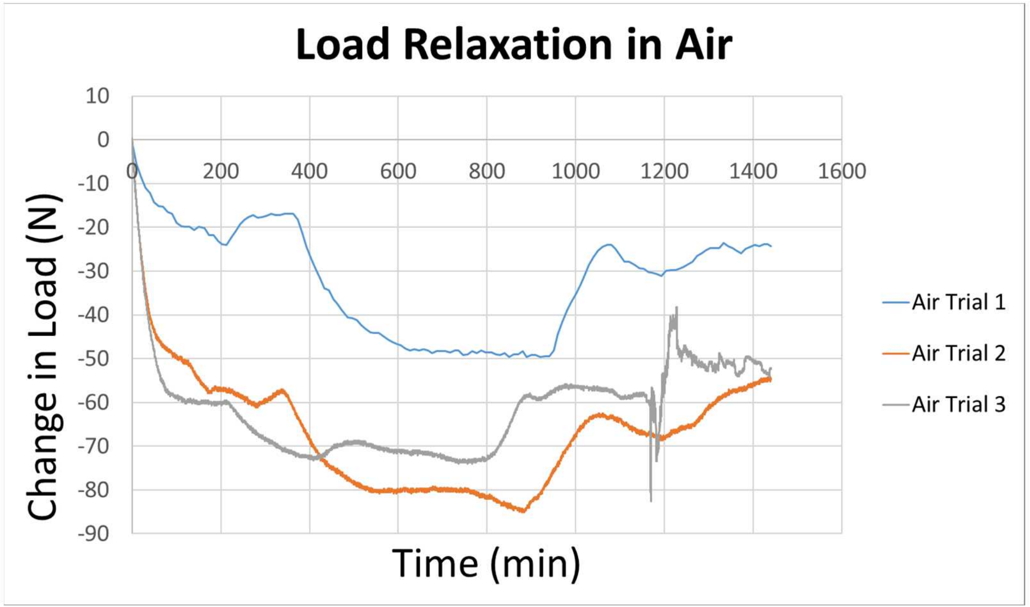


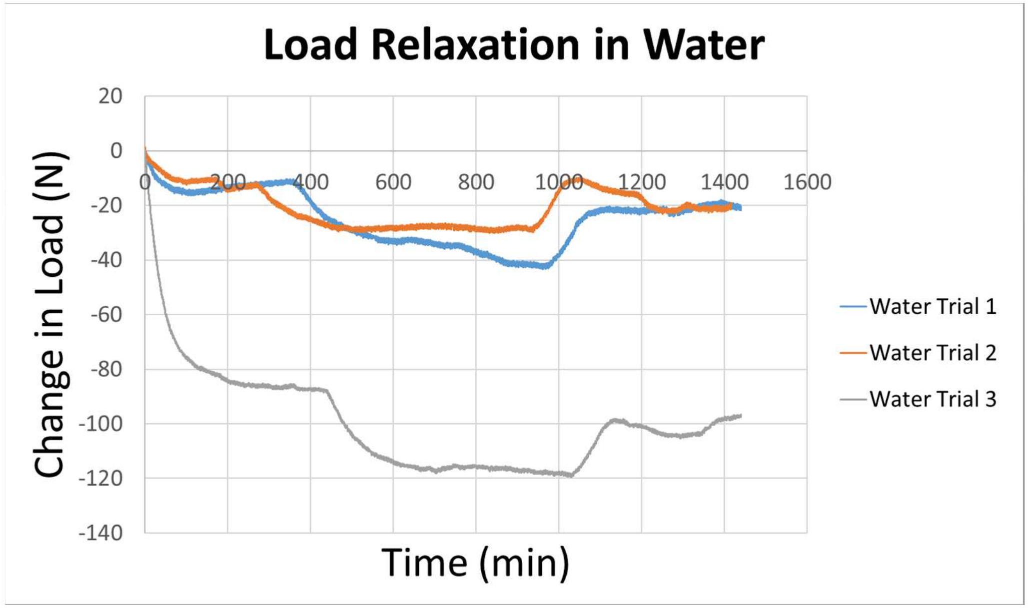


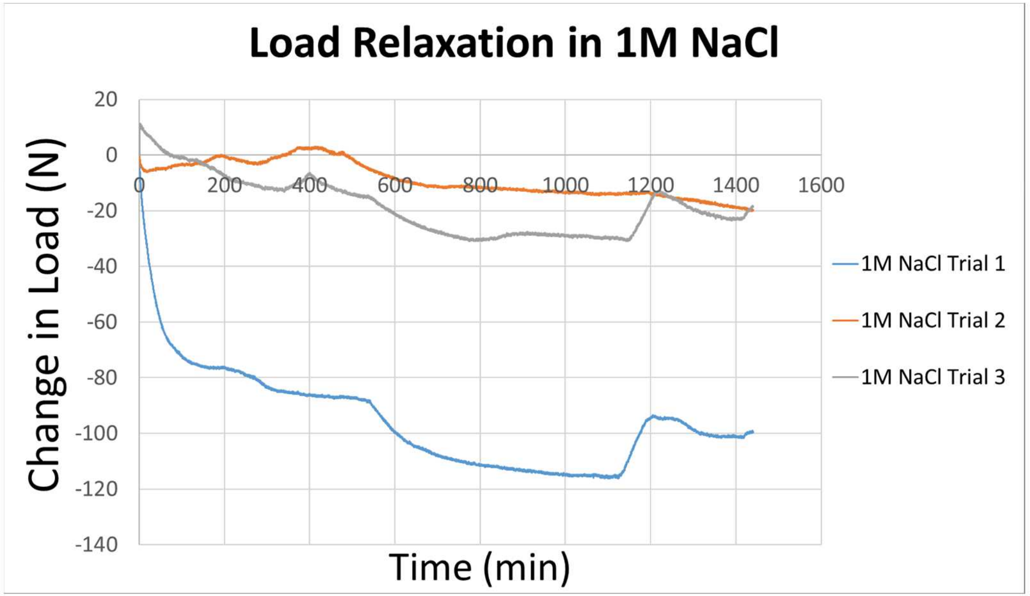


- Crack lengths examined over 24 hour period
- Average final crack lengths
  - 2.94 ± 0.2 mm
  - 3.77 ± 0.04 mm
  - 5.47 ± 1 mm

Load Relaxation







- Change in load varied between trials and chemical environments
- Decrease in load is expected for the entirety of the observational period
- Each trial demonstrated short period of increasing load during a zero displacement static hold
- Possible transducer drift

Summary and Conclusions

Chemical Environment	Initial Crack Length (mm)	Final Crack Length (mm)	% of total Crack Length @(60 sec)	Peak Load (N)
Ambient Air	1.42 ± 0.6	2.94 ± 0.2	86%	1011 ± 15
DI Water	2.02 ± 0.7	3.77 ± 0.04	75%	1040 ± 14
1M NaCl	2.35 ± 0.7	5.47 ± 1	62%	1113 ± 54

- 1M NaCl demonstrated highest peak load for fracture initiation 1113 N
- 1M NaCl demonstrated largest average initial crack length at 2.35 mm
- 1M NaCl demonstrated largest average final crack at 5.47 mm
- 38% of the crack growth occurred after the load frame was in static hold in 1M NaCl as compared to 25% in DI H_2O and 14% in ambient air
- Results indicate that 1M NaCl environment promotes subcritical crack propagation in the fused quartz
  - Possibly due to enhanced quartz dissolution in ionic environment [3]

References

1. Celarie, F., M. Ciccotti, and C. Marliere. 2007. “Stress-enhanced ion diffusion at the vicinity of a crack tip as evidenced by atomic force microscopy in silicate glasses,” *Journal of Non-Crystalline Solids*, **353**, 51-68.
2. Celarie, F., S. Prades, D. Bonamy, A. Dickele, E. Bouchaud, C. Guillot, and C. Marliere. 2003. “Surface fracture of glassy materials as detected by real-time atomic force microscopy (AFM) experiments,” *Applied Surface Science*, **212**, 92-96.
3. Icenhower, Jonathan P., and Patricia M. Dove. “The Dissolution Kinetics of Amorphous Silica into Sodium Chloride Solutions: Effects of Temperature and Ionic Strength.” *Geochimica Et Cosmochimica Acta*, vol. 64, no. 24, 2000, pp. 4193–4203., doi:10.1016/s0016-7037(00)00487-7.

Thank You

Questions?