Characterization of Swelling of Liquid Crystal Elastomers

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Outline

- Introduction
  - Liquid crystal elastomers (LCE)
  - New Liquid Crystal Materials Facility
- Experiment
  - Swelling/Deswelling
  - Dynamic Swelling
- Results

INTRODUCTION: LIQUID CRYSTAL ELASTOMERS (LCE)

- LCE:
  - combination of polymer rubber with anisotropic liquid crystal[1]
  - coupling of orientational order and mechanical strain[2]
  - sample orientation can be achieved by applying mechanical stretching[3,4] or by cross-linking[5]

Introduction: Liquid Crystal Materials Facility (NLCMF)

- NLCMF
  - Provide LCE samples developed by different groups to community
- Duties
  - Aided in the construction of smectic LCE
  - Development of NLCMF Website
  - Characterization of Nematic LCE
    - measured strain of sample versus toluene concentration

Introduction: Diffusion

$$D = \nabla^2 \rho = \frac{\partial \rho}{\partial t}$$

D=diffusion coefficient
ρ=density
t=time

$$t = \frac{L^2}{D}$$

thickness of elastomer

$$L = 300 * 10^{-6}\, m$$

for liquids:

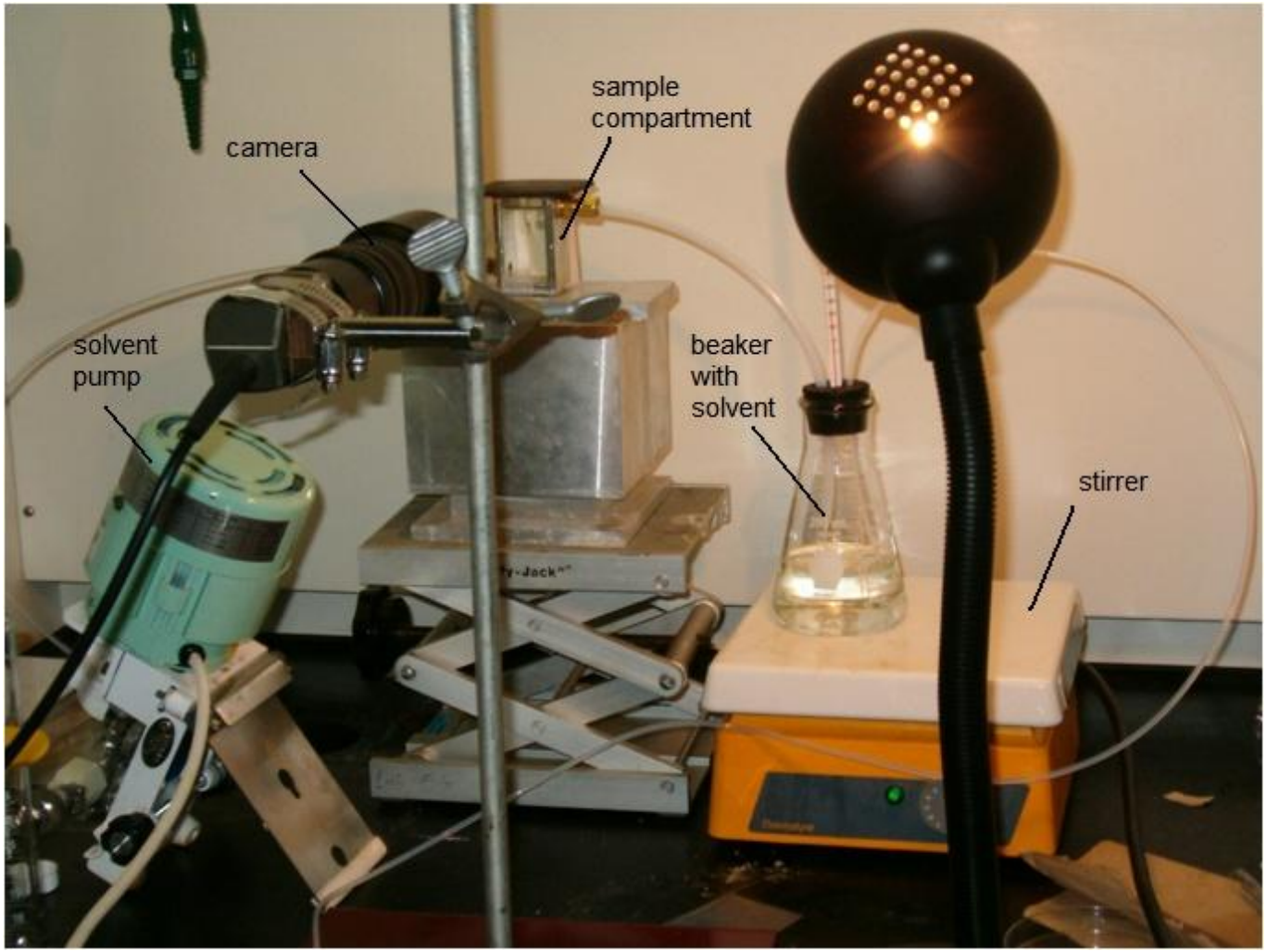
$$D = 10^{-9}\, \frac{m^2}{s}$$

So,
t = 90 s

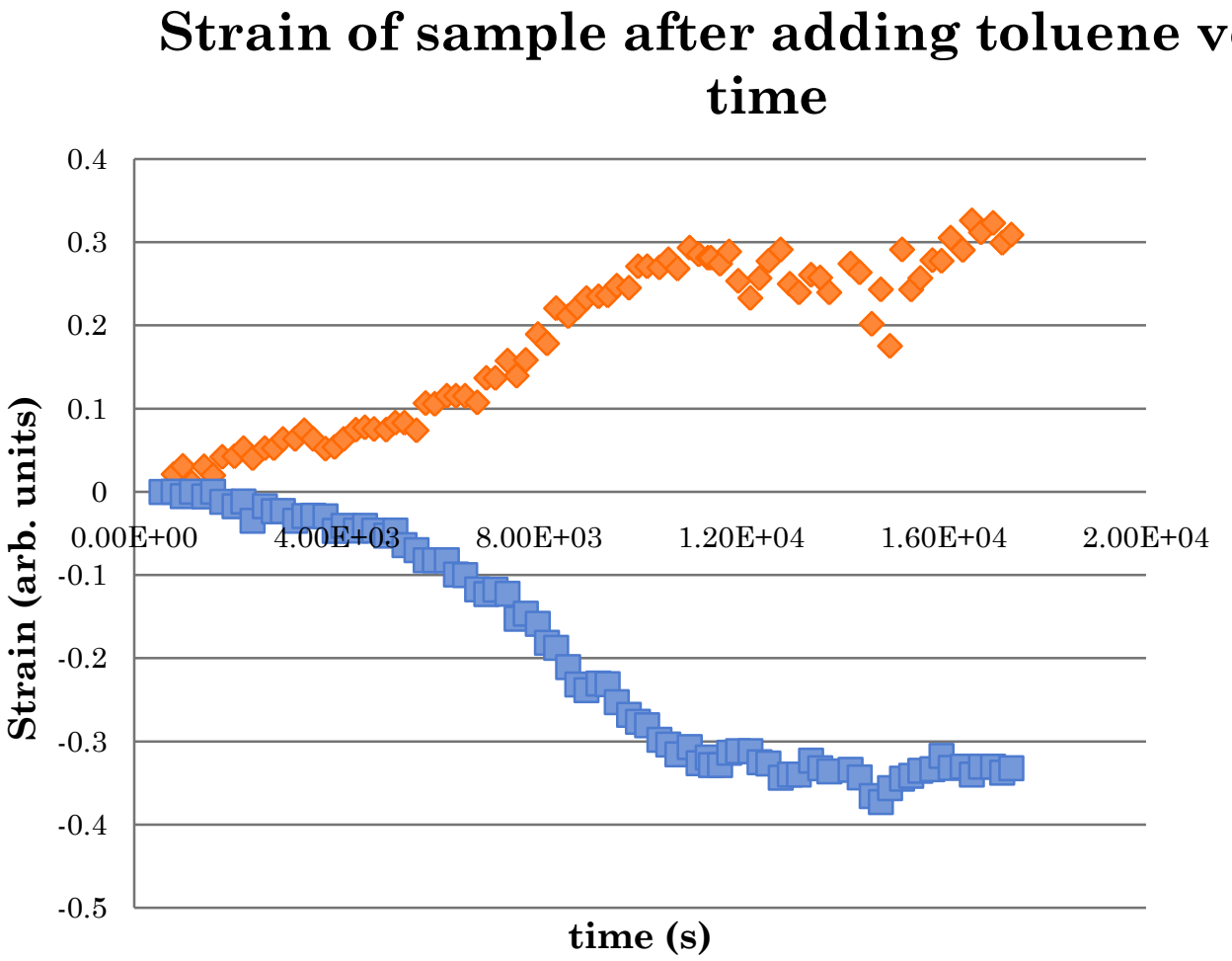
Experiment: Swelling/Deswelling

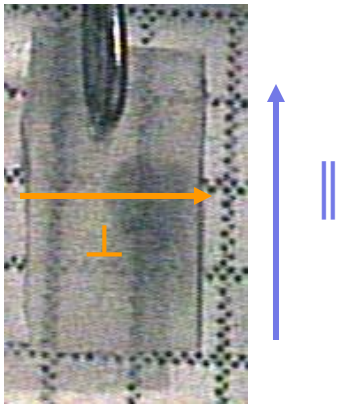
- Sample: 10% cross-linked nematic liquid crystal elastomer
- Procedure: Circulate hexane solvent into sample. Add toluene in to hexane. Record strain as a function of toluene concentration and time. Decrease toluene concentration. Record changes in sample.

Experiment: Set-Up



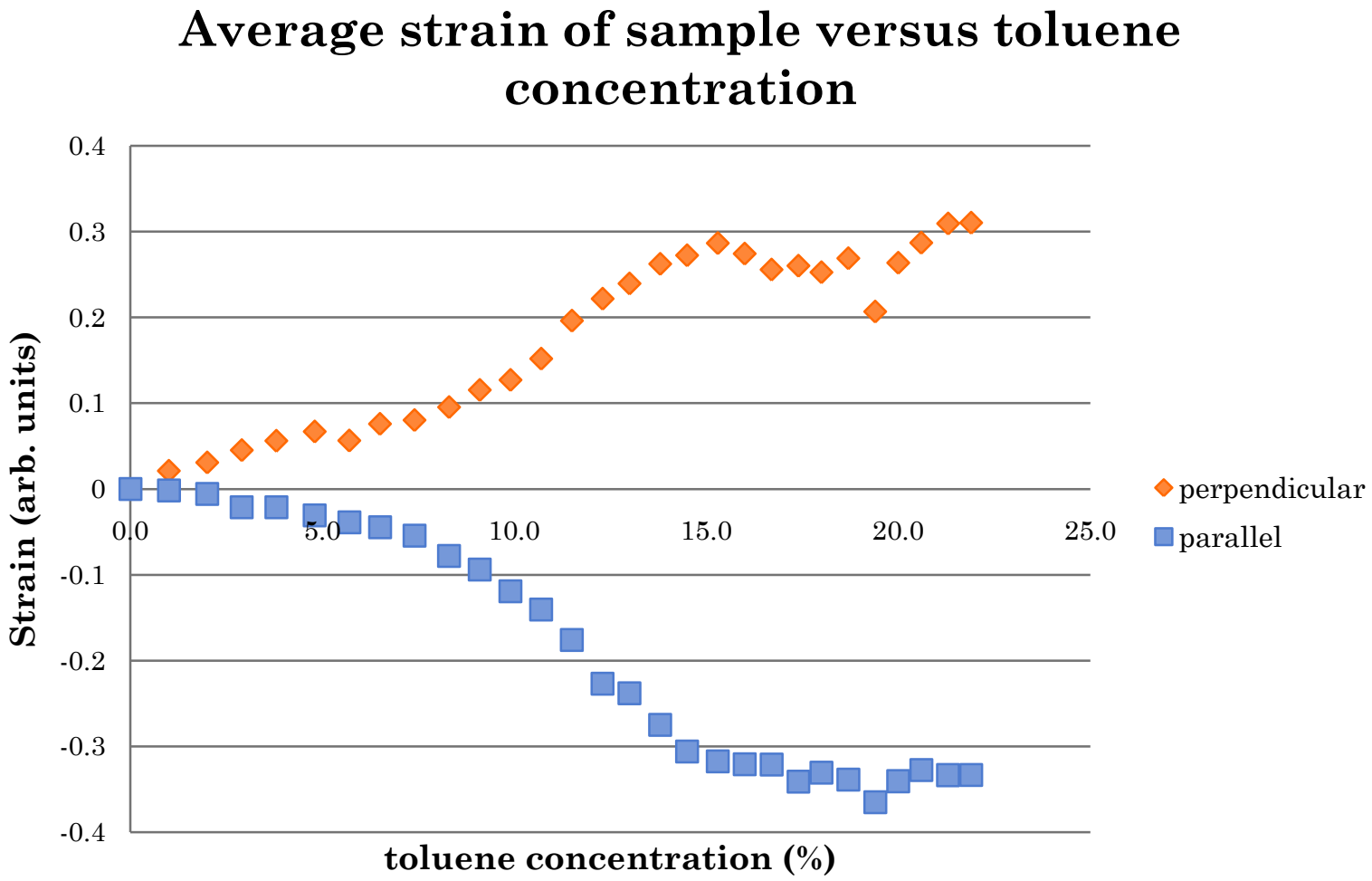
Results: Swelling



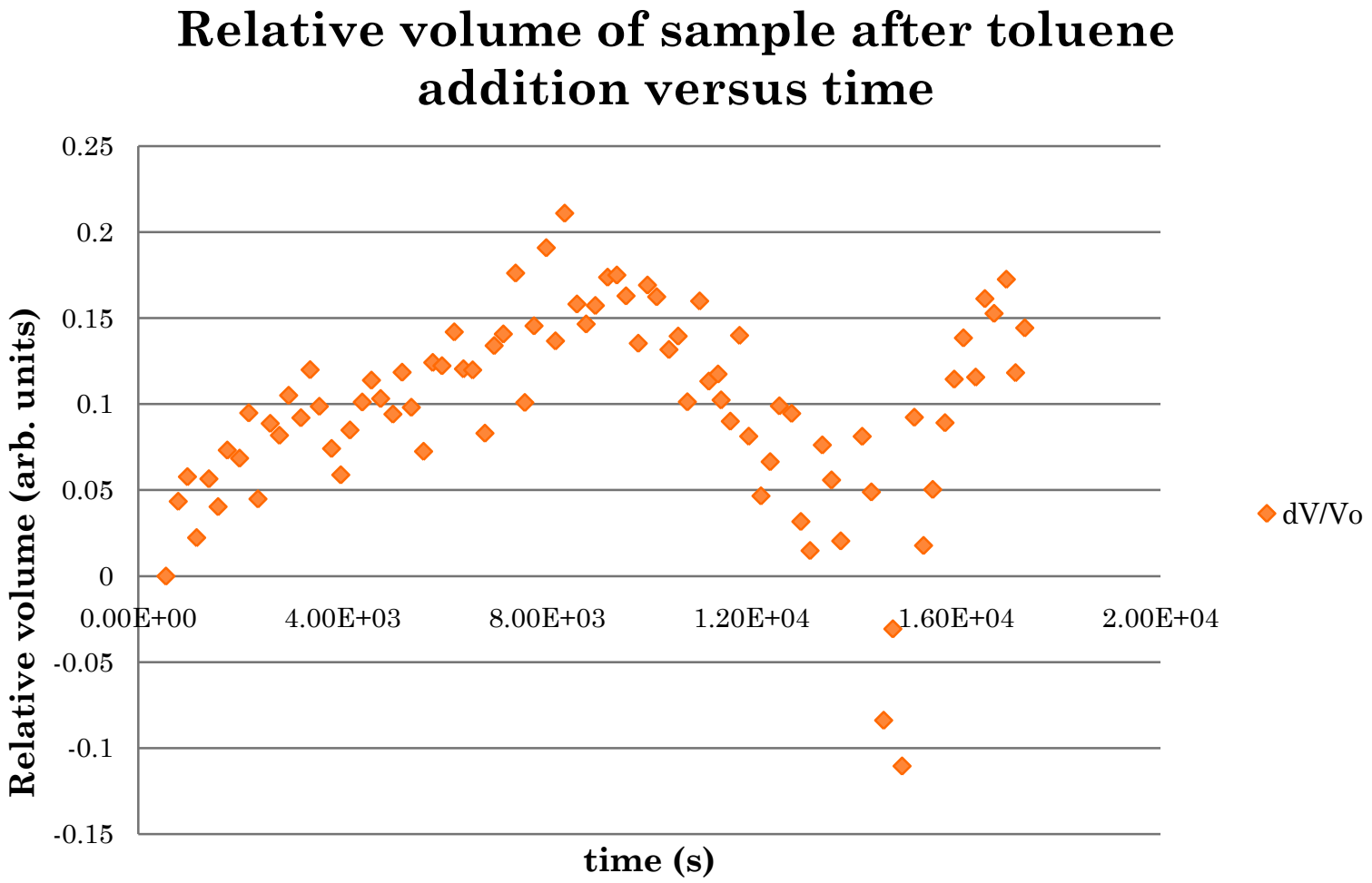


perpendicular

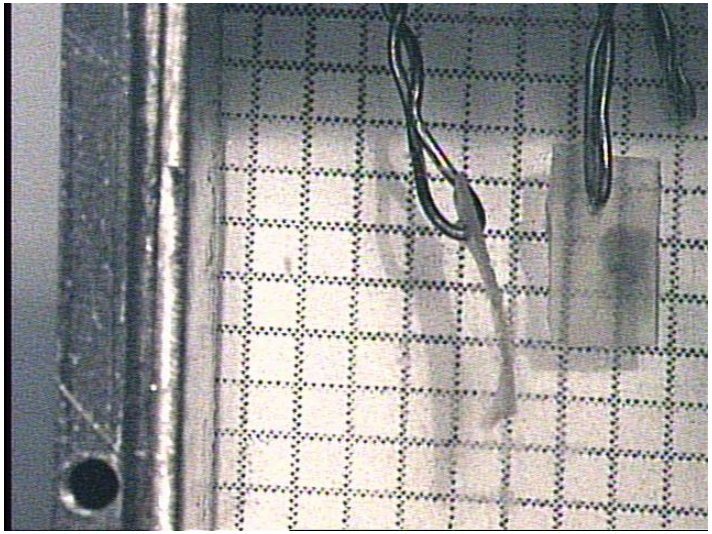
Results: Swelling



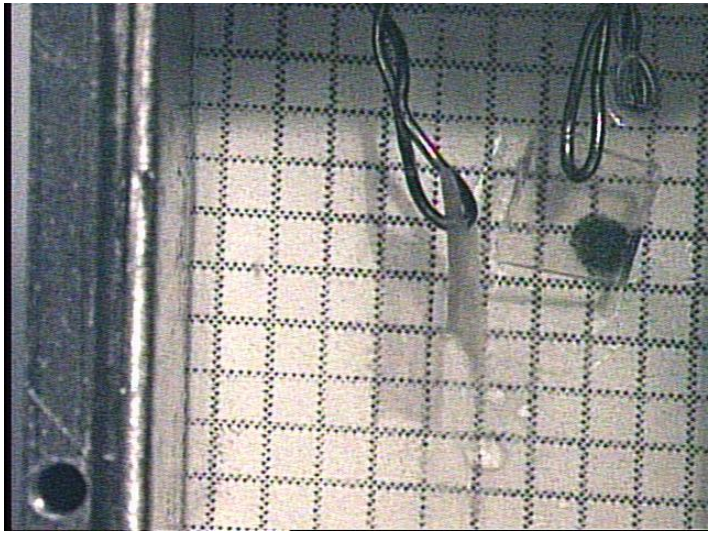
Results: Swelling



Results: Swelling

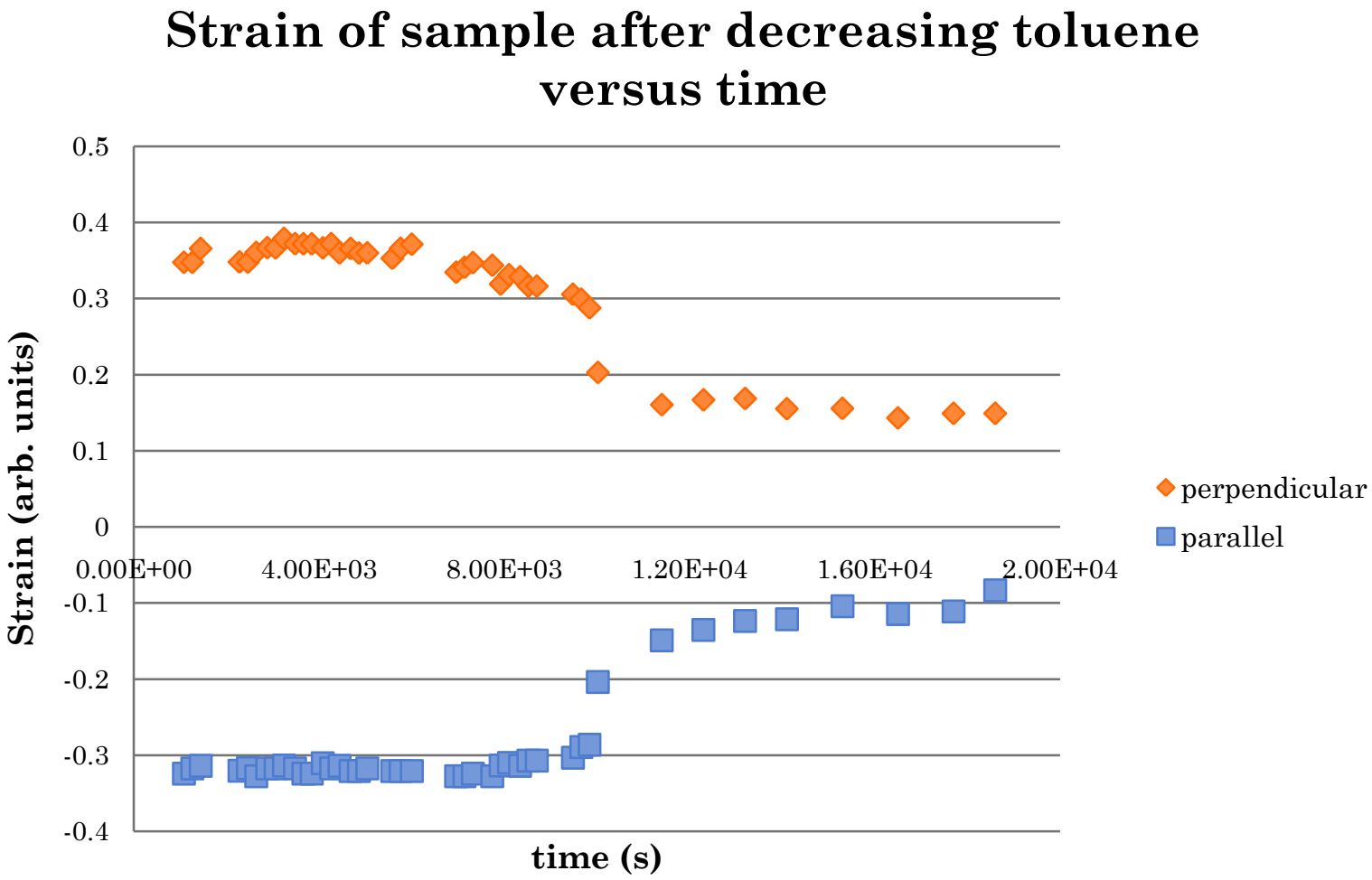


Sample at 0% toluene

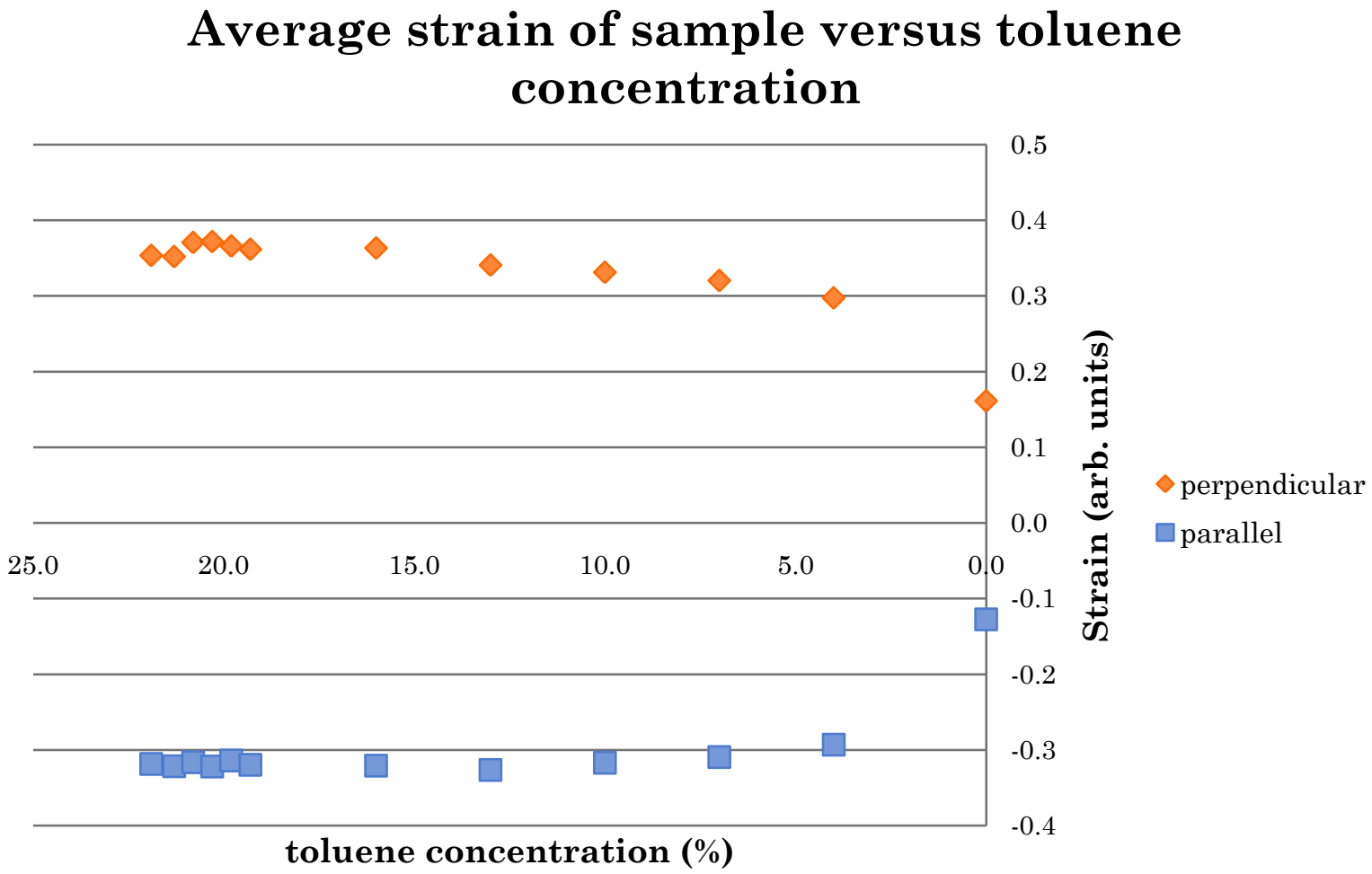


Sample at 22% toluene

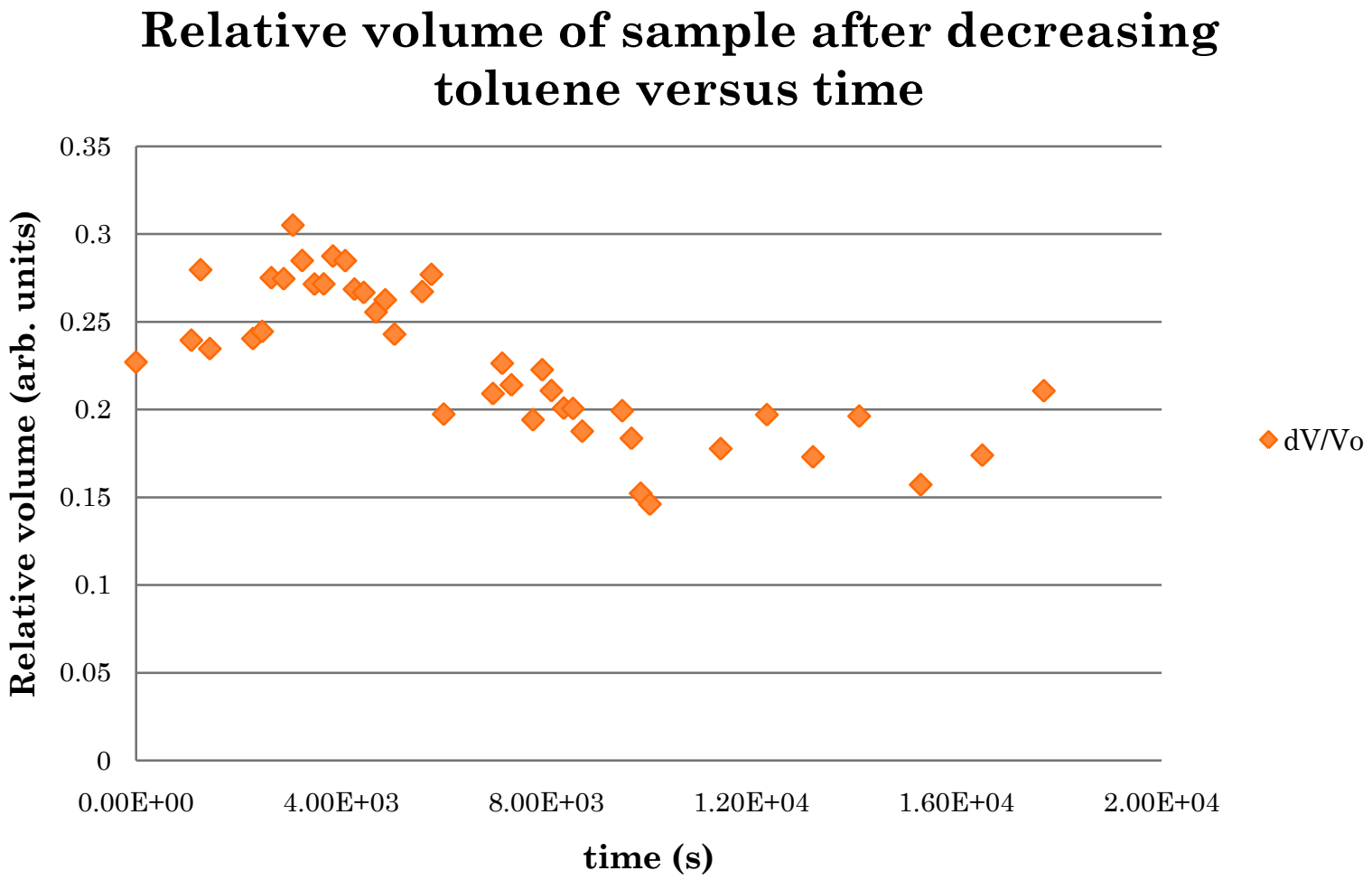
Results: Deswelling



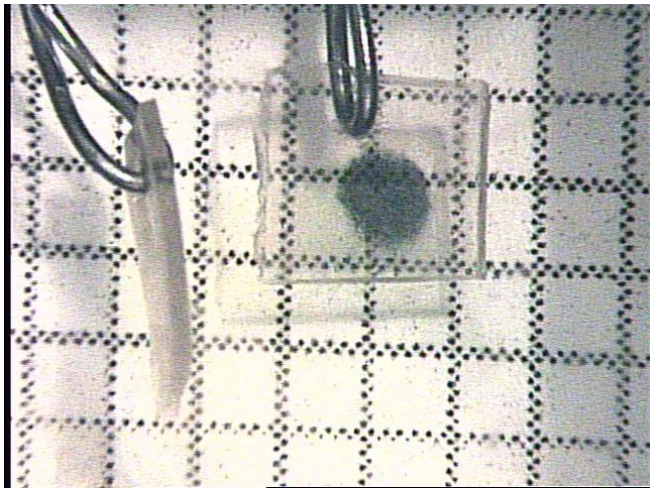
Results: Deswelling



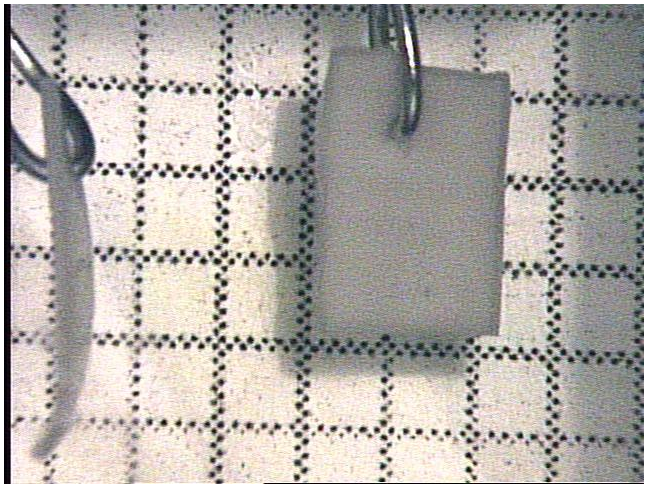
Results: Deswelling



Results: Deswelling



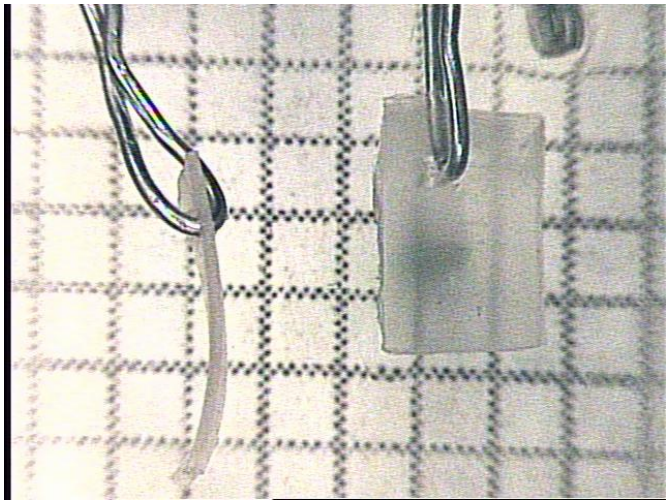
Sample at 22% toluene



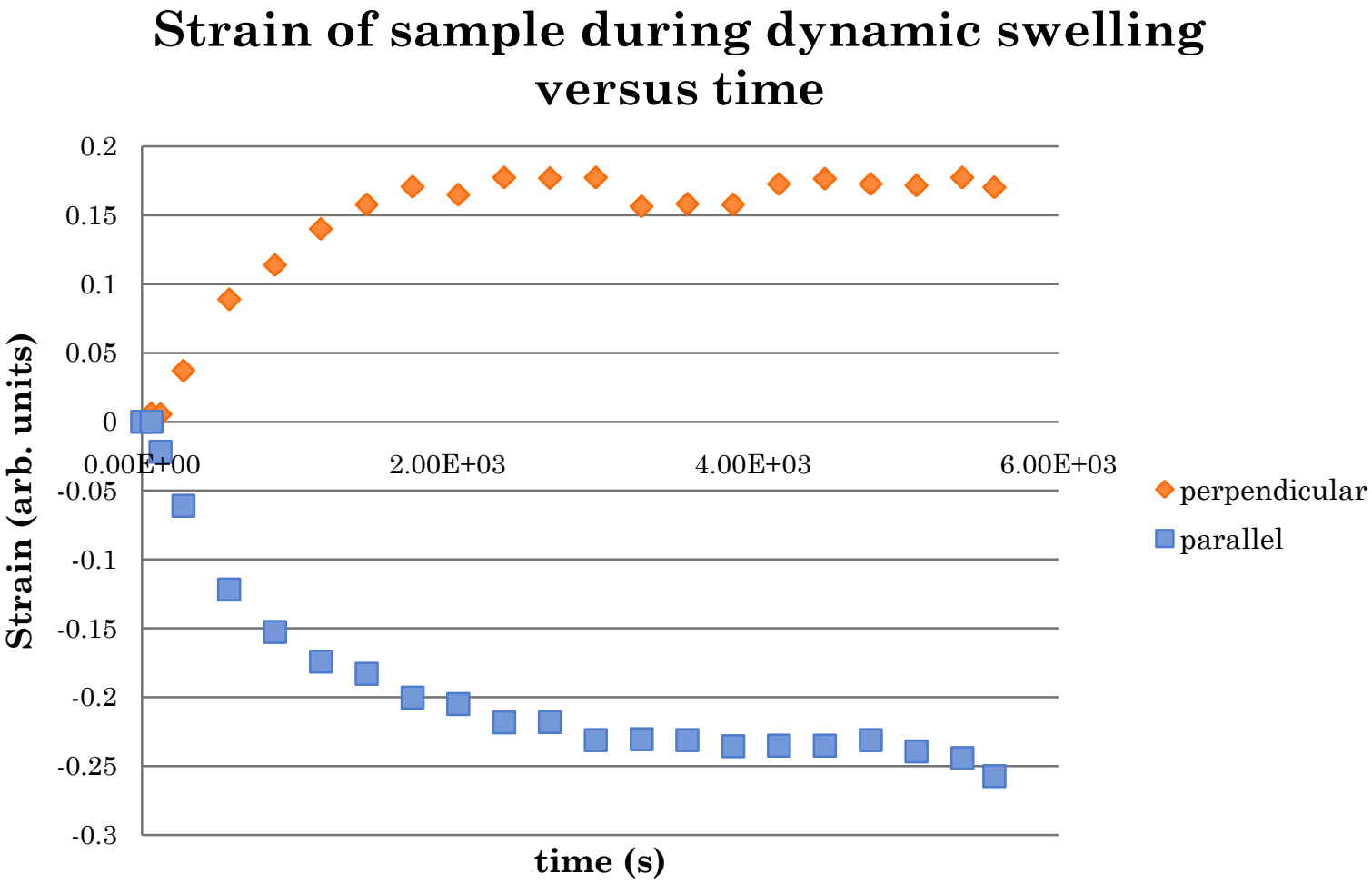
Sample at 0% toluene
after 3 hours and 20 minutes

Experiment: Dynamic Swelling

- Sample was soaked in a mixture of 15% toluene and the change in dimensions were recorded using a camera.
- Sample was in the mixture for approximately 90 minutes.



Results: Dynamic Swelling



Conclusion

- With increasing toluene concentration, the strain perpendicular to the nematic director increased while the strain parallel to director decreased. It was vice versa as the concentration was decreased. The perpendicular component was positive and the parallel component was negative.
- Also, the sample transitioned into the isotropic phase as concentration increased. As the toluene concentration decreased, the sample transitioned back to nematic phase.
- With the concentration kept constant, the strain perpendicular to the director increased while the strain parallel to director decreased as time progressed before reaching an equilibrium.

References

- 1. W. Gleim and H. Finklemann, *Side Chain Liquid Crystalline Polymers*, edited by C. B. McArdle, Glasgow: Blackie (1989).
- 2. H. Schuring, R. Stannarius, C. Tolksdorf, R. Zentel. *Macromolecules* **34** 3962 (2001).
- 3. T. Eckert, H. Finkelmann. *Macromol. rapid Commum.*, **17** 767 (1996).
- 4. K. Semmler, H. Finkelmann, *Macromol. Chem. Phys.*, **196** 3197 (1995).
- 5. R. Kohler, R. Stannarius, C. Tolksdorf, R. Zentel. *Appl. Phys. A* **80** 381 (2005).