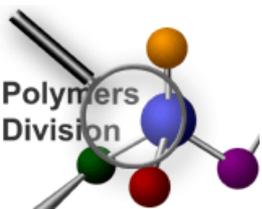
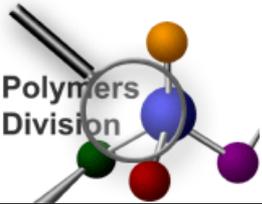


Fuel Cell Membrane Project Structure & Dynamics

Kirt A. Page
Alamgir Karim
Christopher Soles

Electronic Materials Group
November 6, 2008





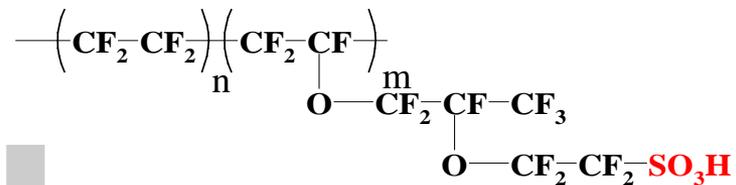
PEMFC Applications

Automotive

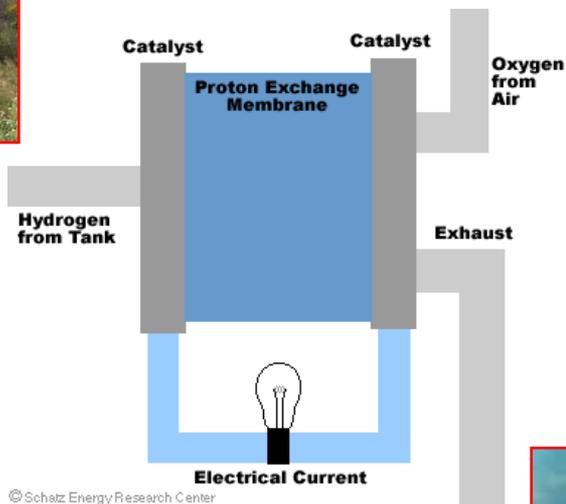


The best emissions strategy is a zero emissions strategy.

Perfluorosulfonate Ionomers (PFSI)



Portable Fuel Cells

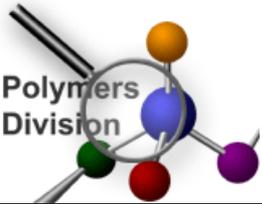


© Schatz Energy Research Center

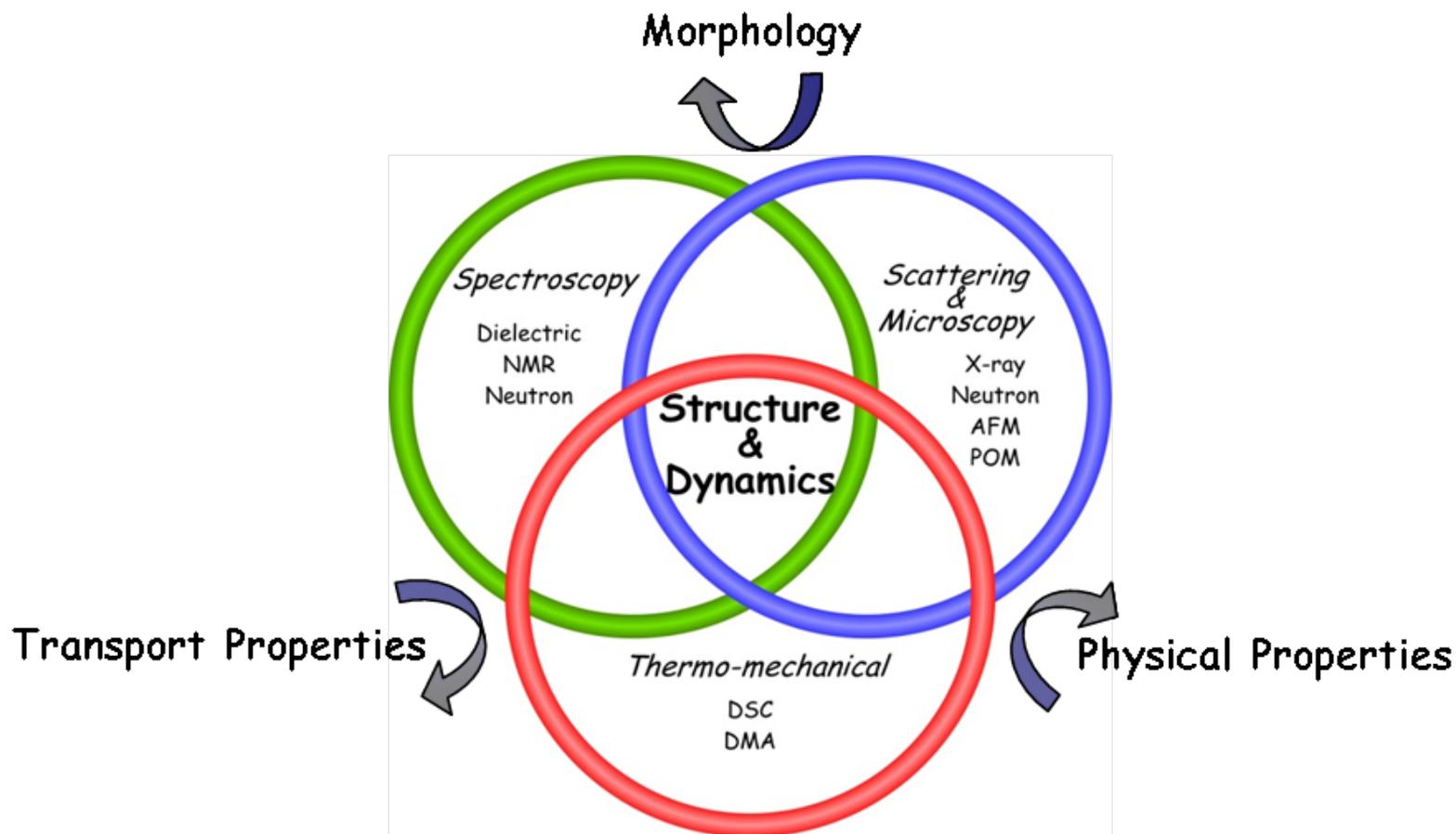
Aerospace

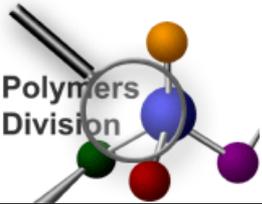


<http://americanhistory.si.edu/fuelcells/pem/pem4.htm>
<http://www.chevrolet.com/fuelcell/>



Multidisciplinary Approach





Fuel Cell Membrane Project Overview

Project Goal: To develop quantitative measurements to correlate the structural and dynamical properties of polymeric electrolyte membrane (PEM) materials with the transport of hydrogen ions through the PEM.

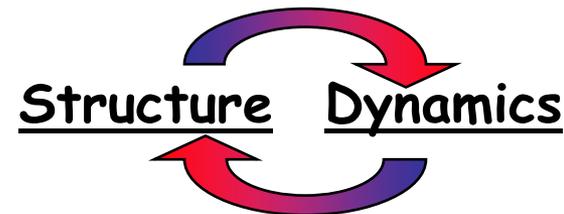
Measurement/Characterization

- Polymer Structure (scattering)
- Polymer/Water Dynamics (QENS)
- Catalyst ink structure
- MEA interface structure and diffusion
- *In situ* measure of water dynamics

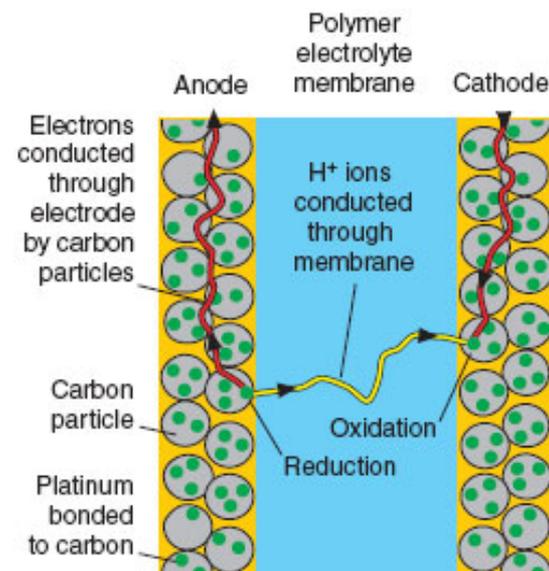
Focus Areas

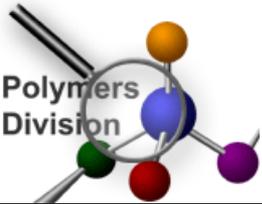
- Processing and Structure
- Polyelectrolyte Blends
- Catalyst ink structure
- Fundamental membrane structure
- Fundamental polyelectrolyte scattering
- New Materials (SNU)

Key Factors Influencing Structure Formation and Performance
How to measure!!



Why are these things important?





Fuel Cell Membrane Project Overview

Project Goal: To develop quantitative measurements to correlate the structural and dynamical properties of polymeric electrolyte membrane (PEM) materials with the transport of hydrogen ions through the PEM.

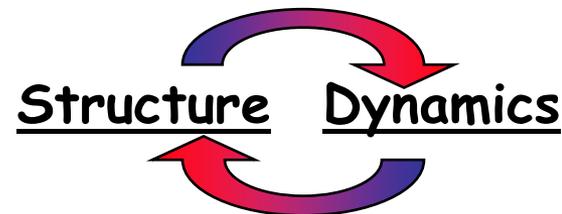
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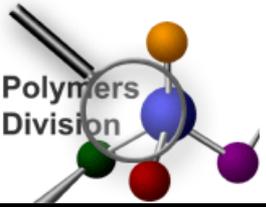
Key Factors Influencing Structure Formation and Performance
How to measure!!



Membrane Orientation: Probe of Morphology

Membrane Processing and Structure

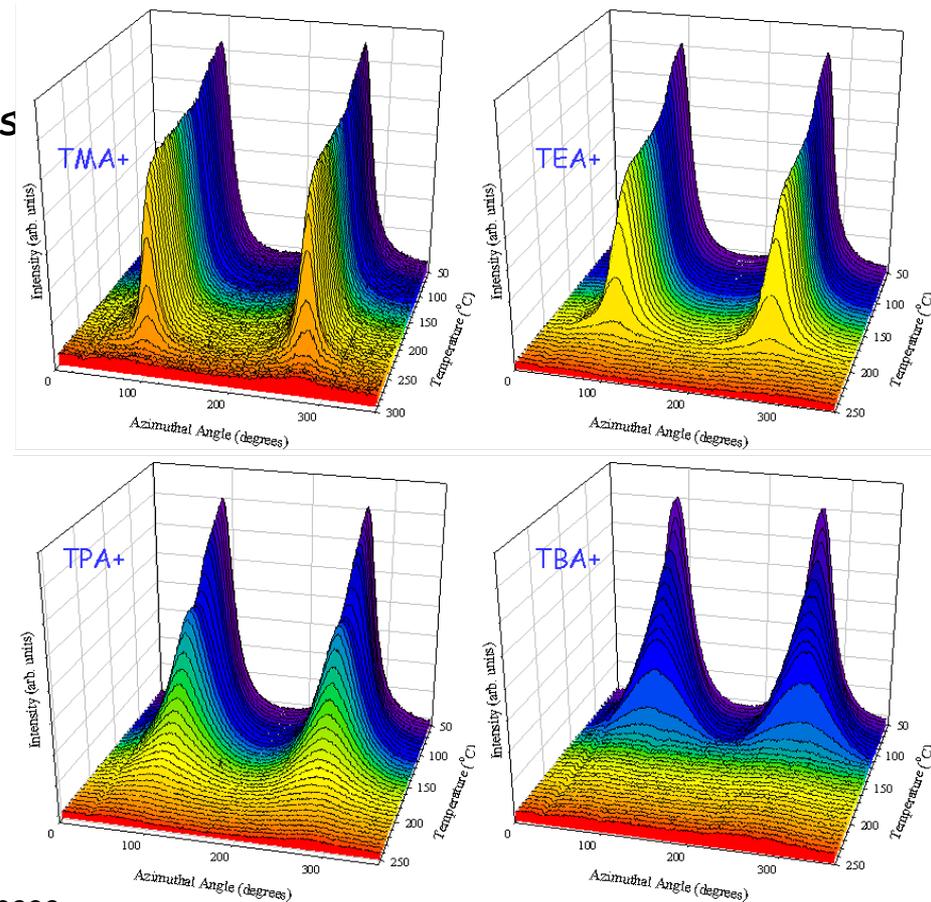
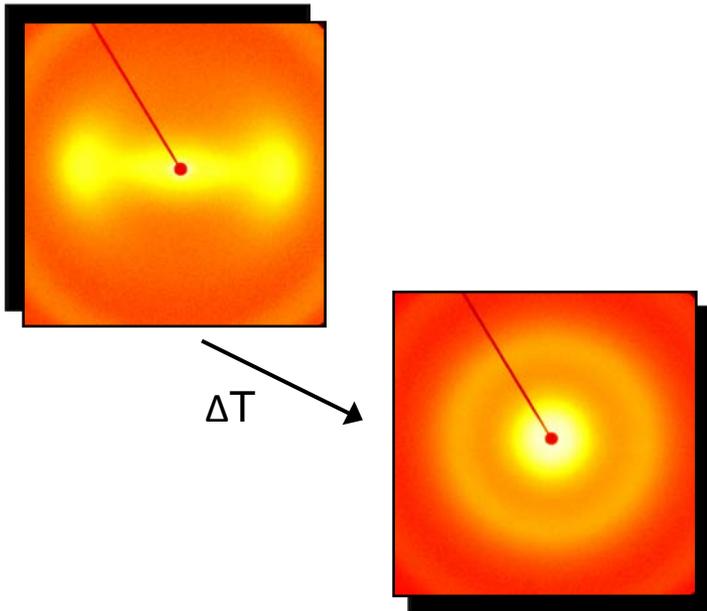
Polyelectrolyte Blends



Orientation as a Probe

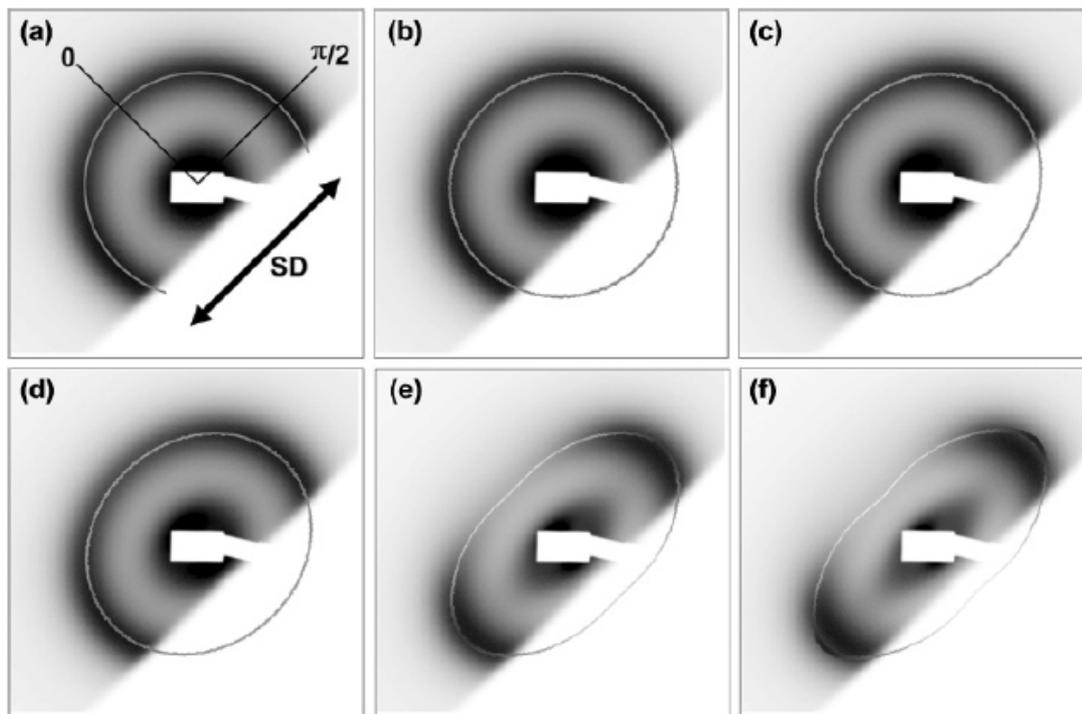
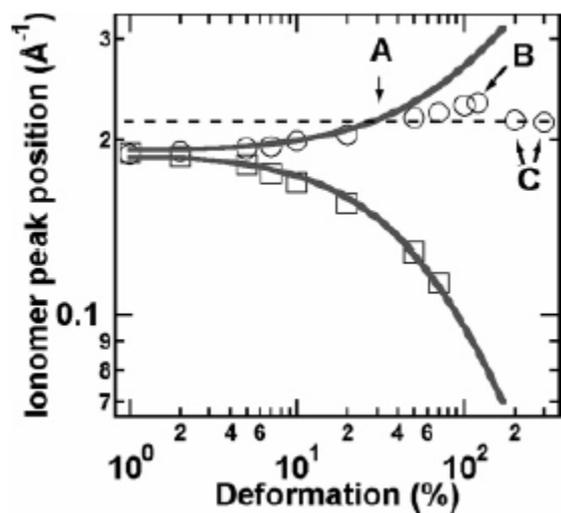
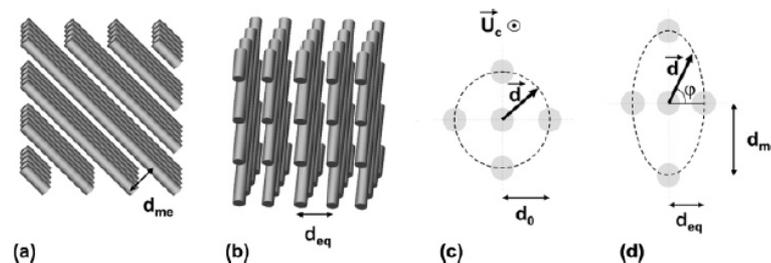
Why use orientation of a membrane?

- Can aid in understanding relaxation behavior
- Probe the morphology
- Elucidate structure-property relationships

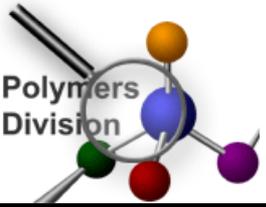


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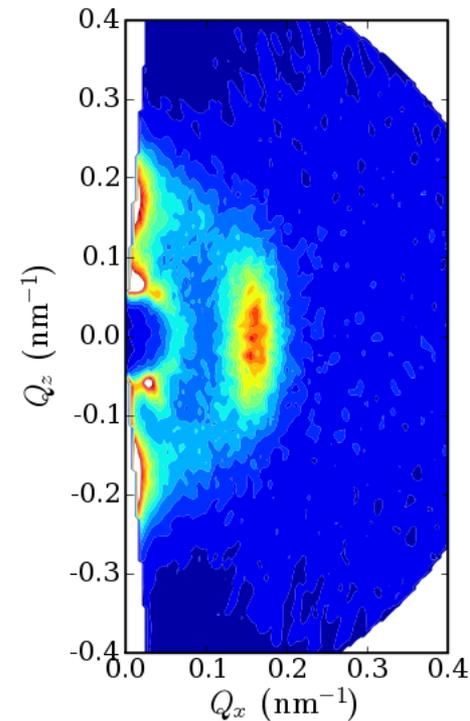
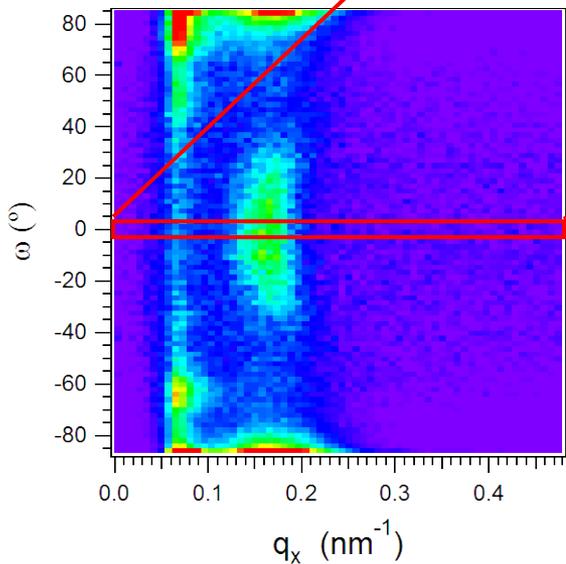
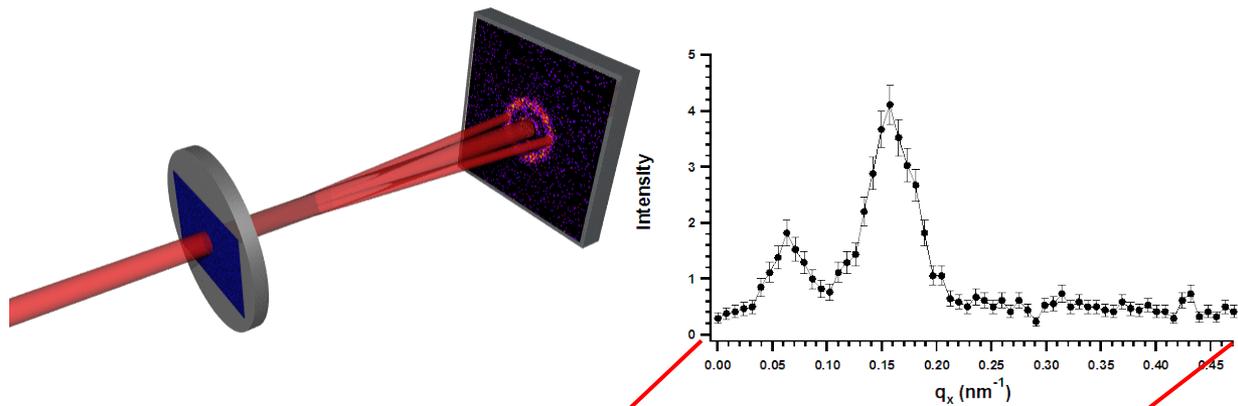
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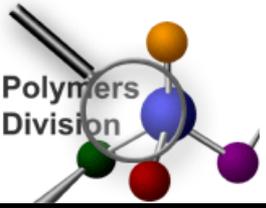


Rubatat and Diat. *Macromolecules* 2007, 40, 9455.

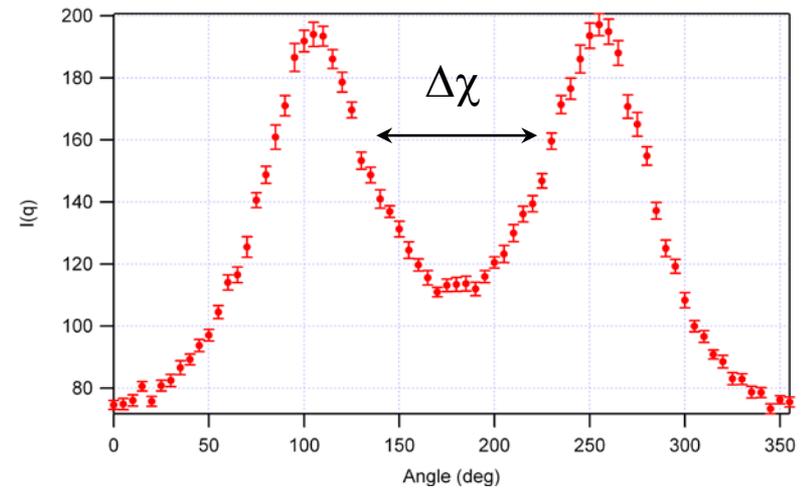
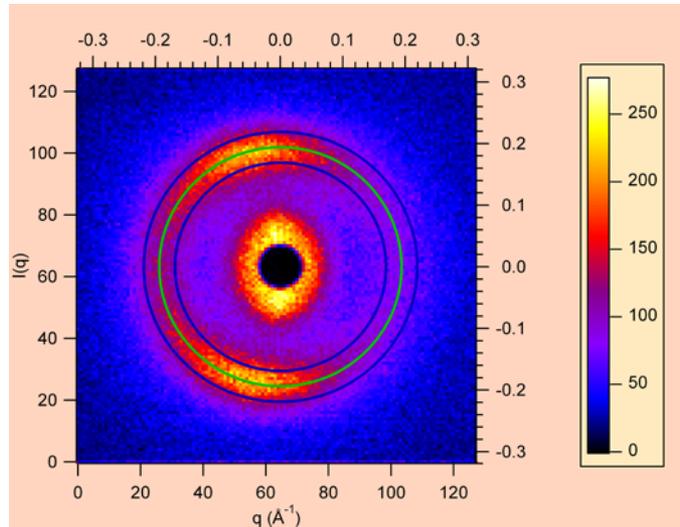
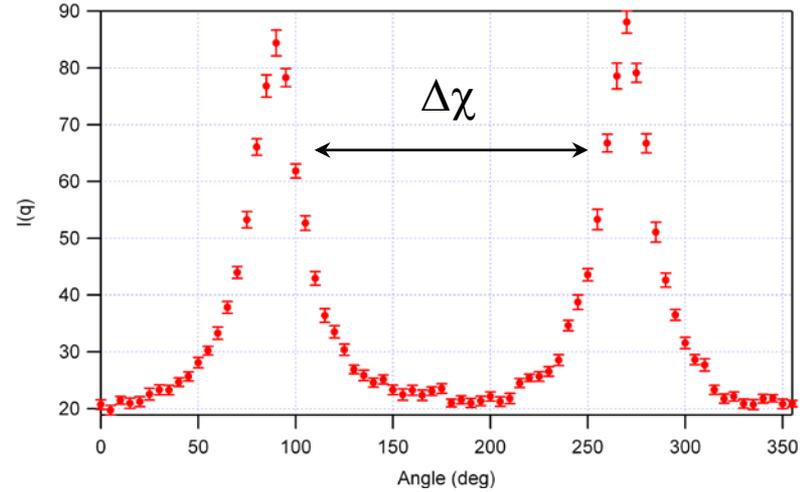
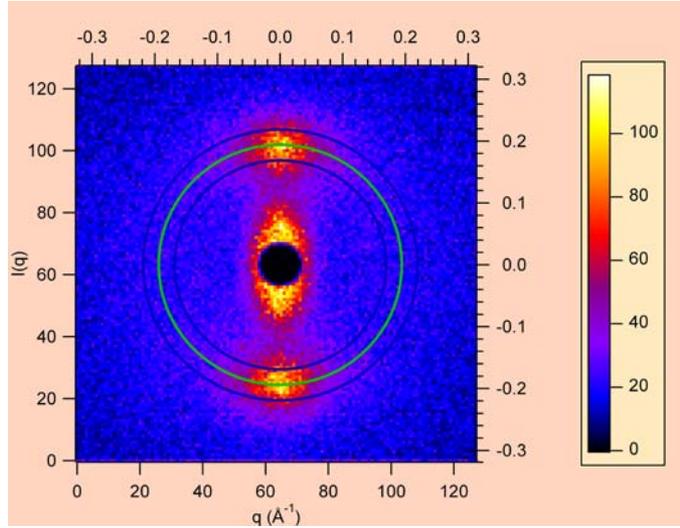


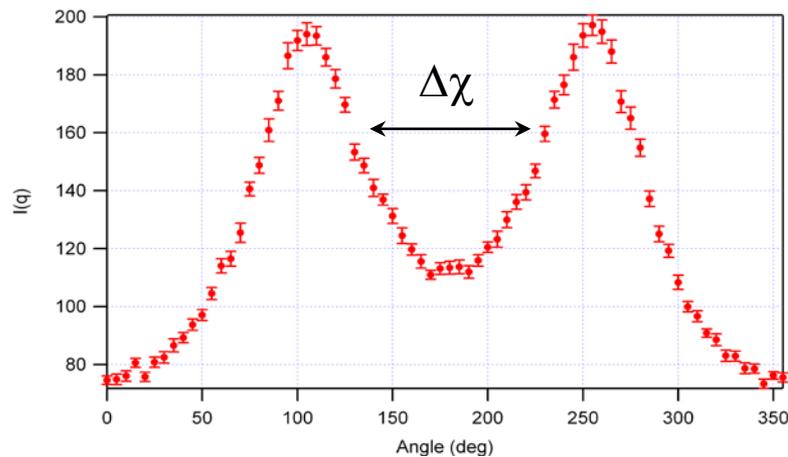
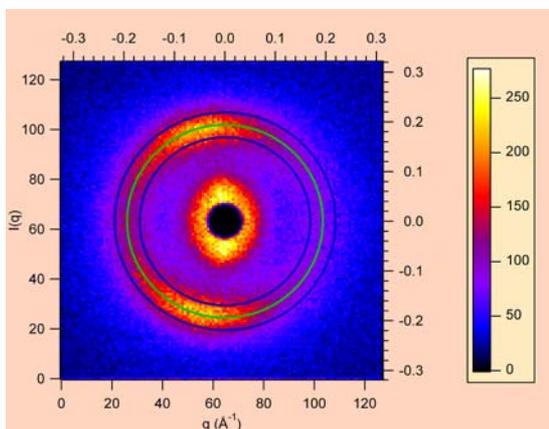
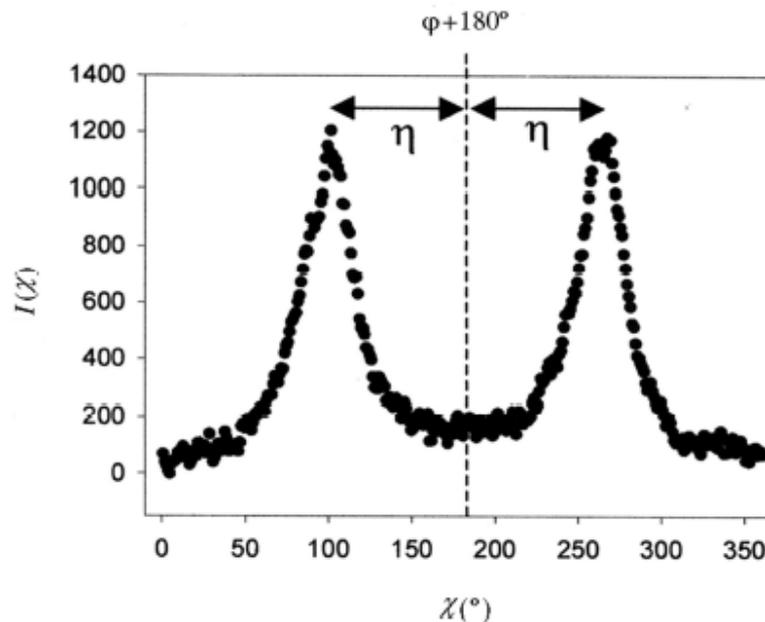
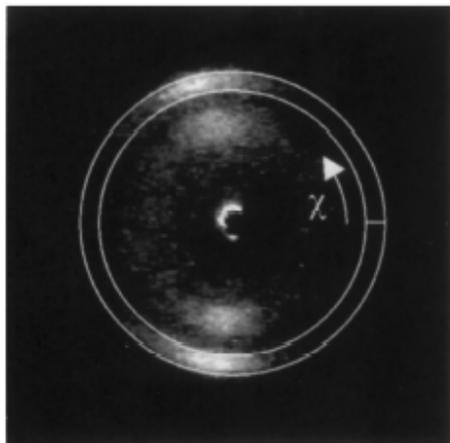
Rotational SANS Techniques



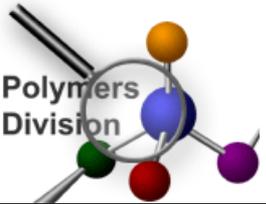


Asymmetric Scattering

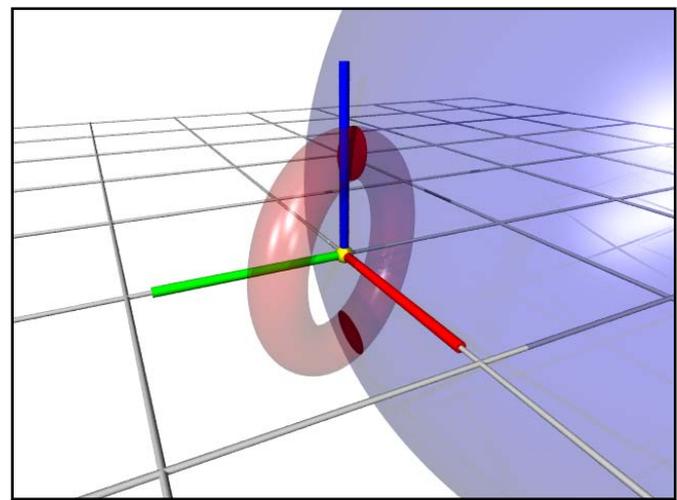
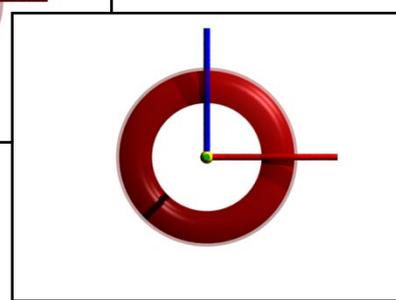
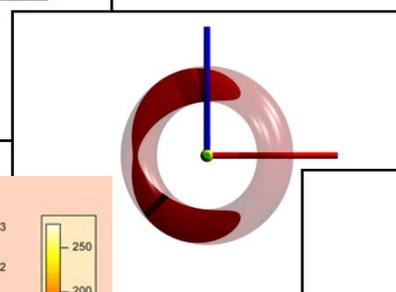
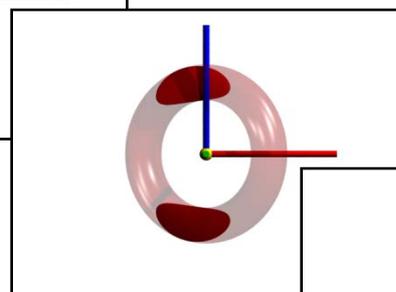
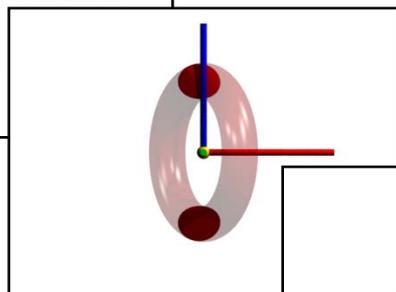
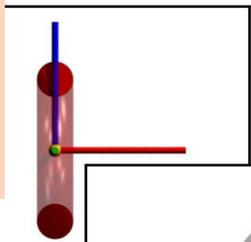
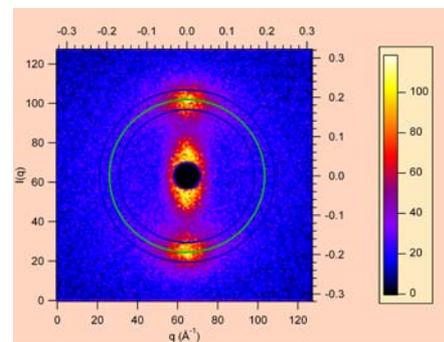




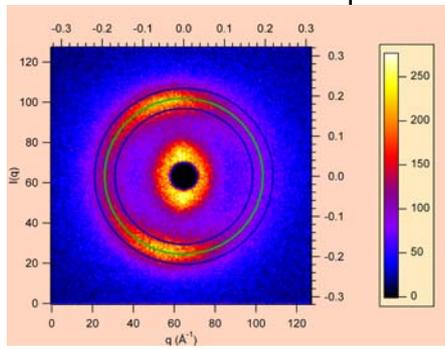
Lichtenegger, Mueller, Paris, Riekel, & Fratzl *J. Appl. Cryst.* (1999). **32**, 1127-1133



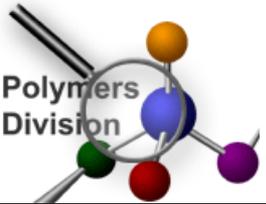
Angular Dependent Scattering



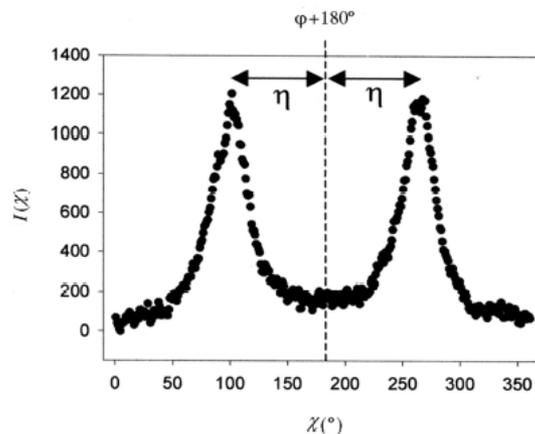
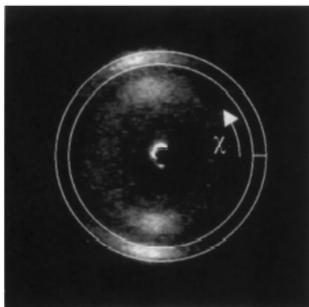
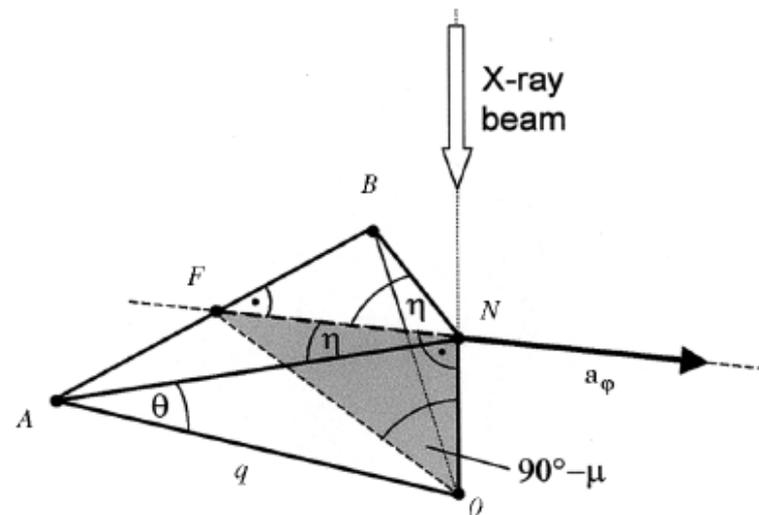
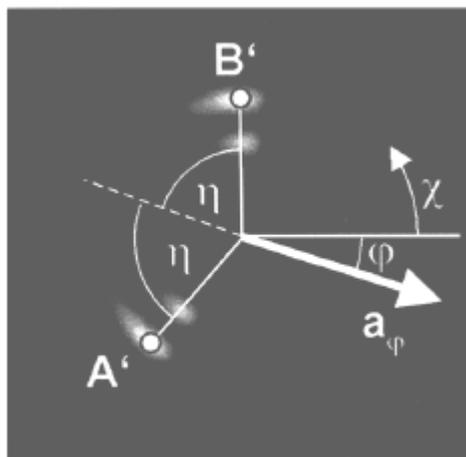
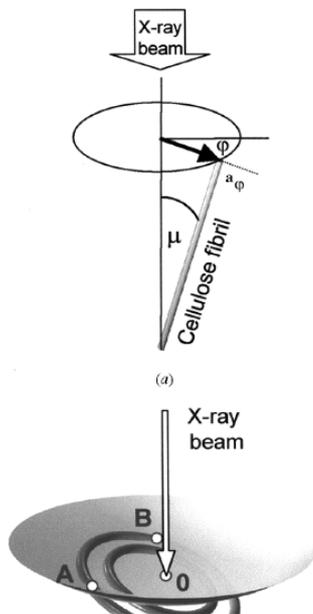
The cartoon images show the simulated intersection of the scattering ring with the Ewald Sphere as the ring is rotated. These are compared with detector images taken from oriented membranes with different rotational angles.



Simulation courtesy of Kevin Yager



Geometric Framework : Oriented Fibrillar Structures

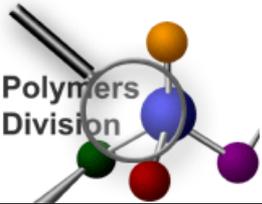


$$\overline{NF} = \overline{NA} \cos \eta = q \cos \theta \cos \eta$$

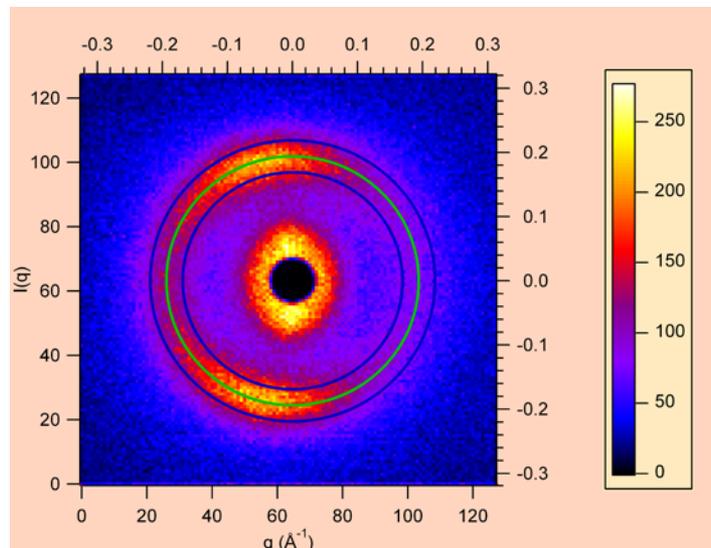
$$\overline{NF} = \overline{ON} \tan \eta = \frac{q \sin \theta}{\tan \mu}$$

$$\cos \eta = \frac{\tan \theta}{\tan \mu}$$

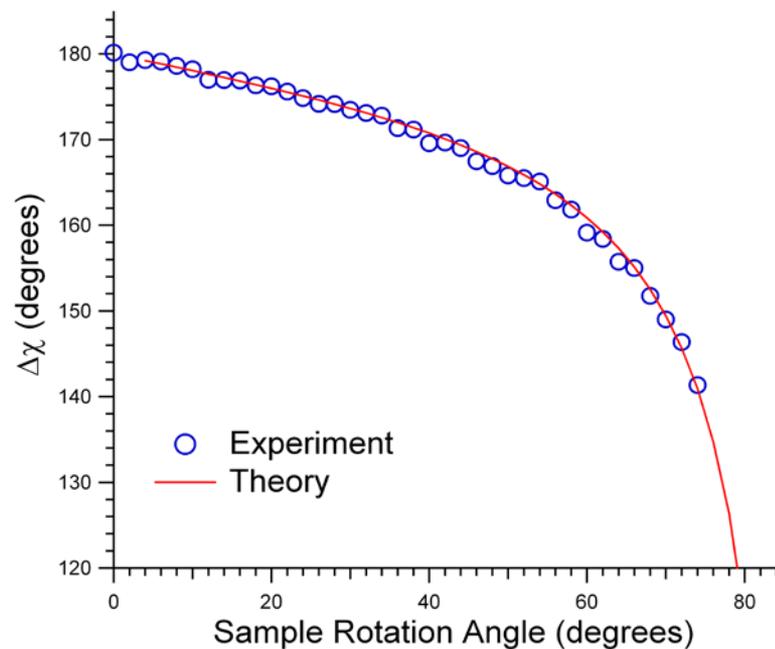
Lichtenegger, Mueller, Paris, Riekell, & Fratzi *J. Appl. Cryst.* (1999). **32**, 1127-1133



Angular Dependent Scattering



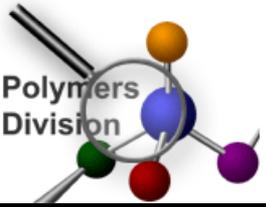
Ionomer Peak Scattering



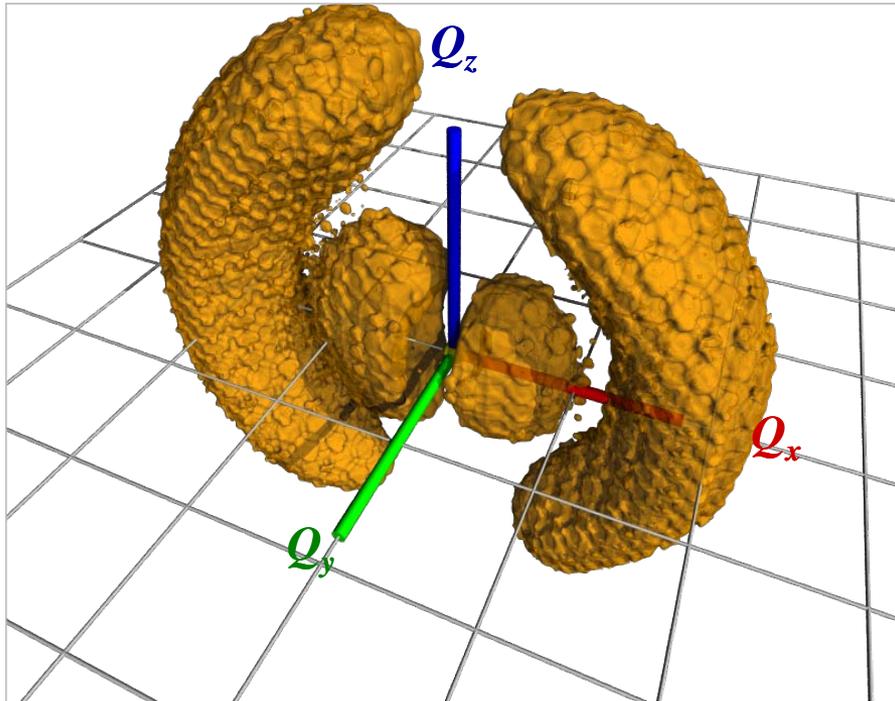
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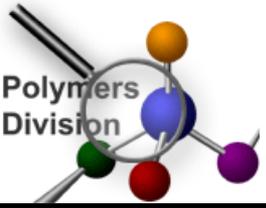
3-Dimensional Neutron Scattering



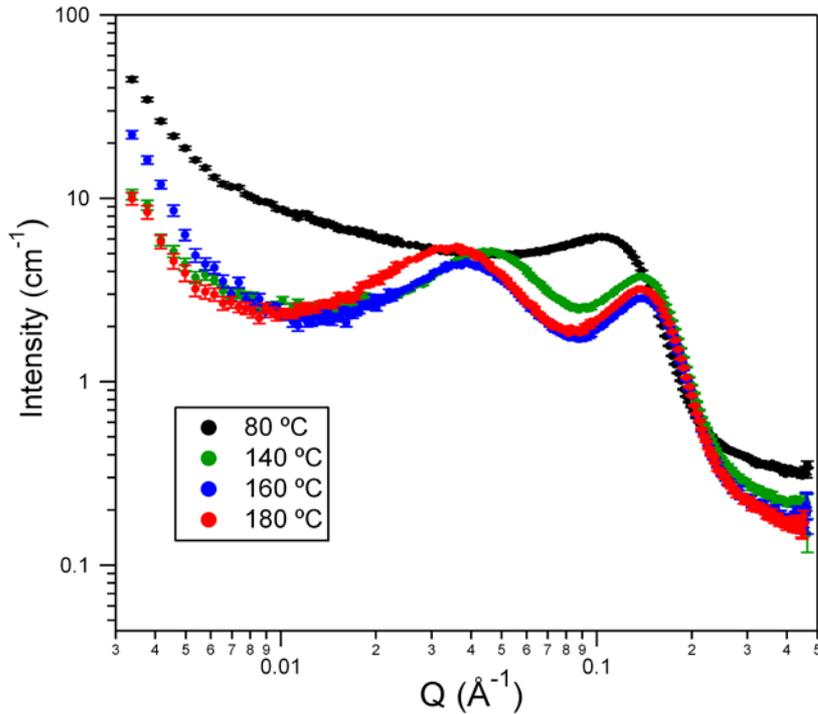
Potential Benefits

- Determination of "true" structure
 - Shape of clusters?
 - Distribution of crystallinity?
 - Large scale heterogeneities?
- Through-film structure?

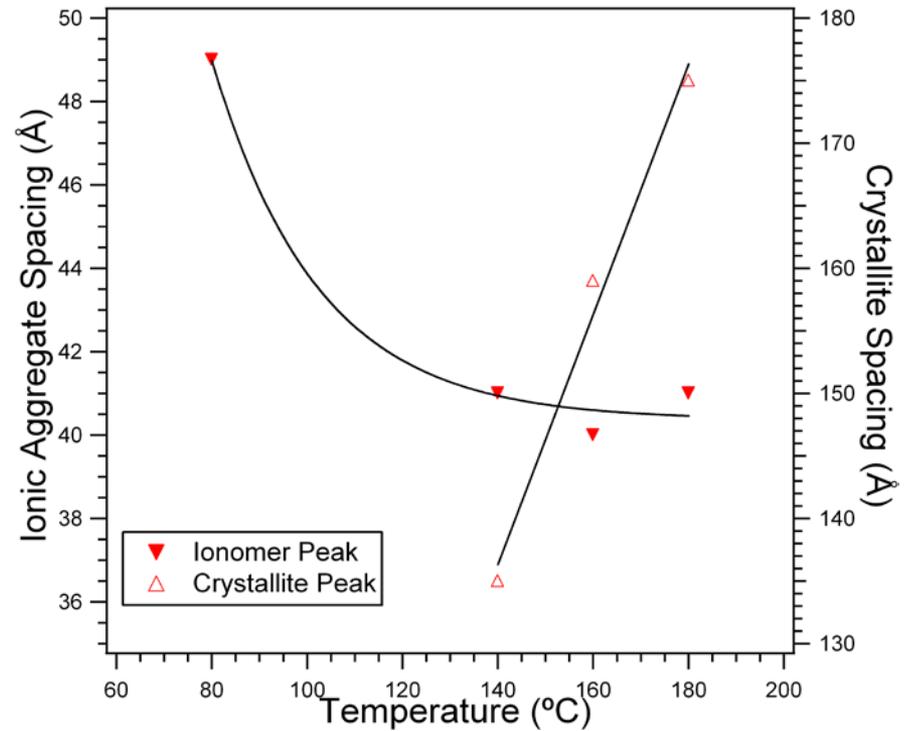
3-D image courtesy of Kevin Yager

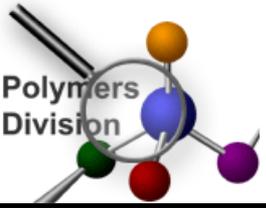


Processing and Structure

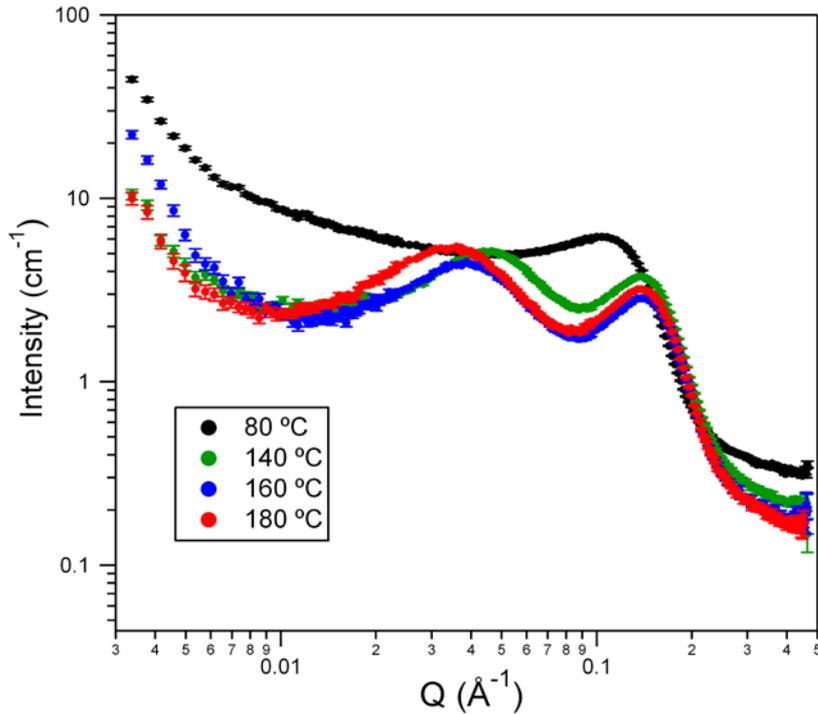


- Membrane casting and annealing
 - changes in crystallinity
 - ionomer structure
 - water uptake

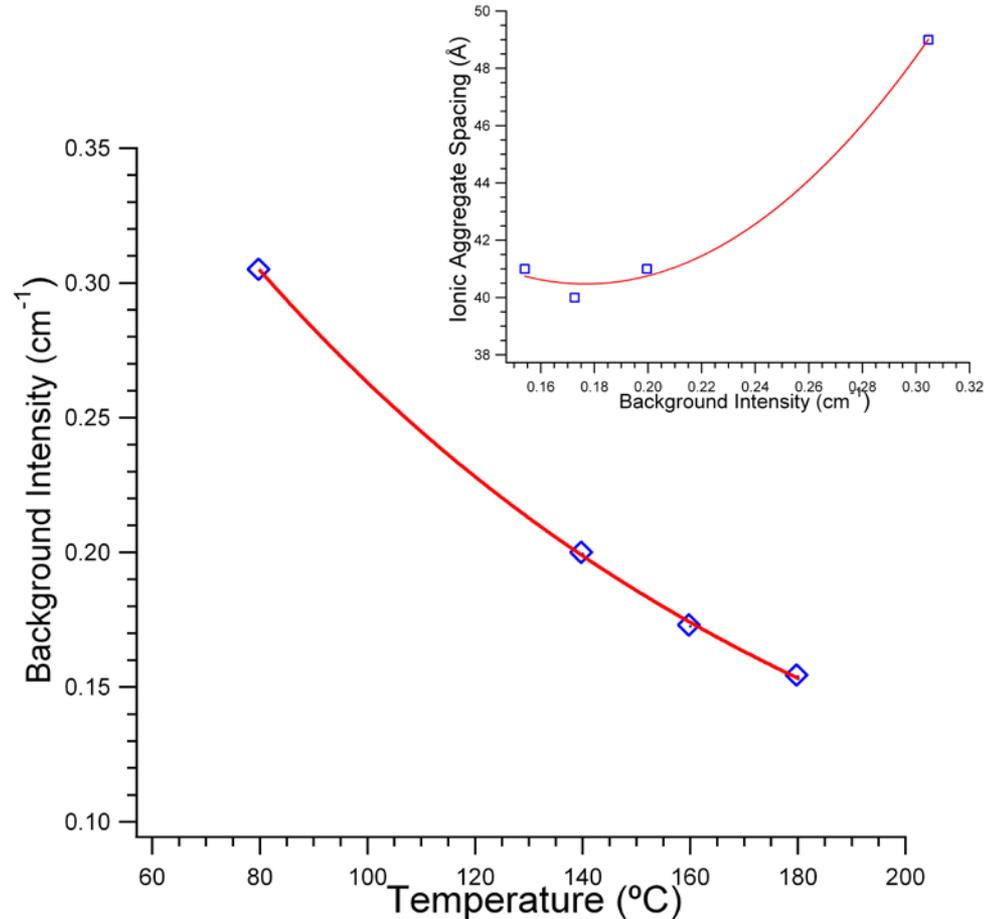


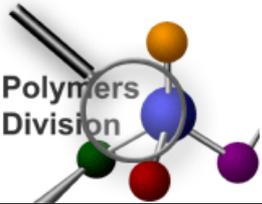


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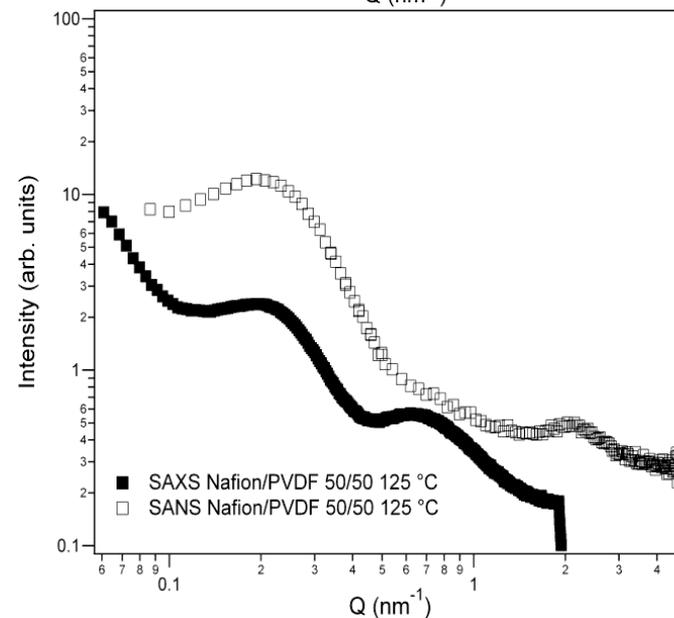
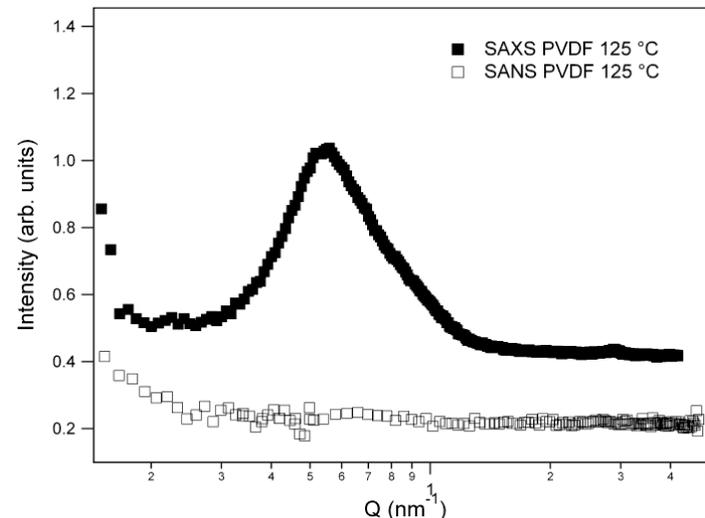
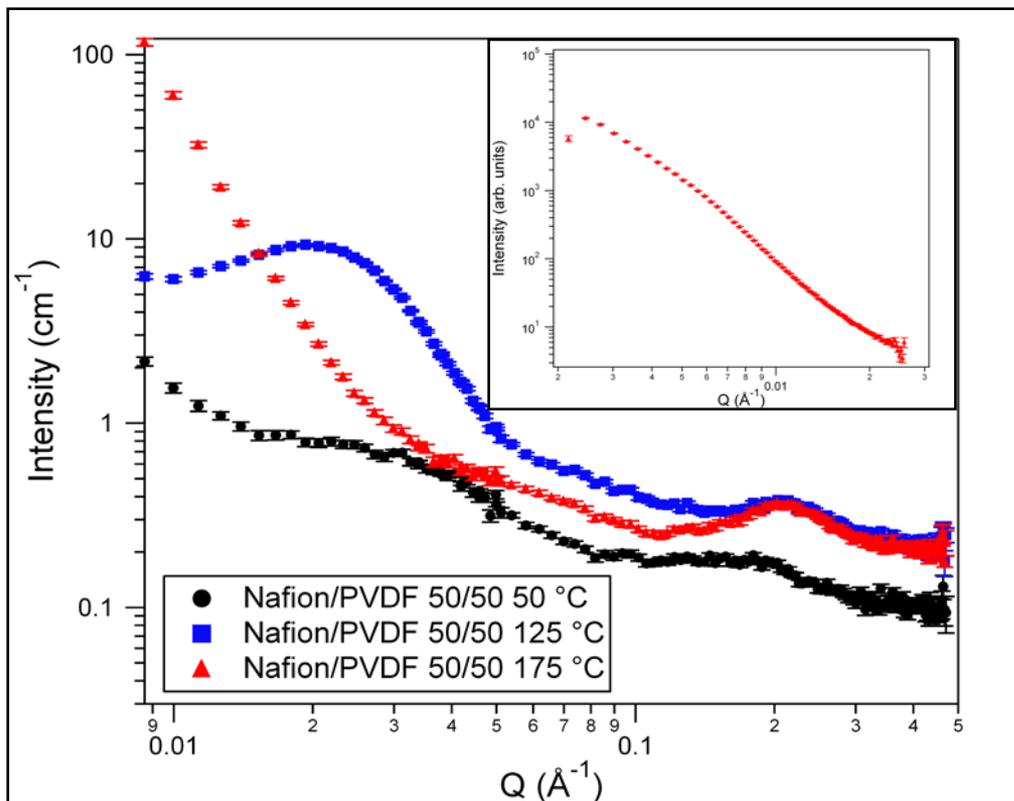


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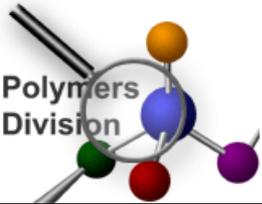




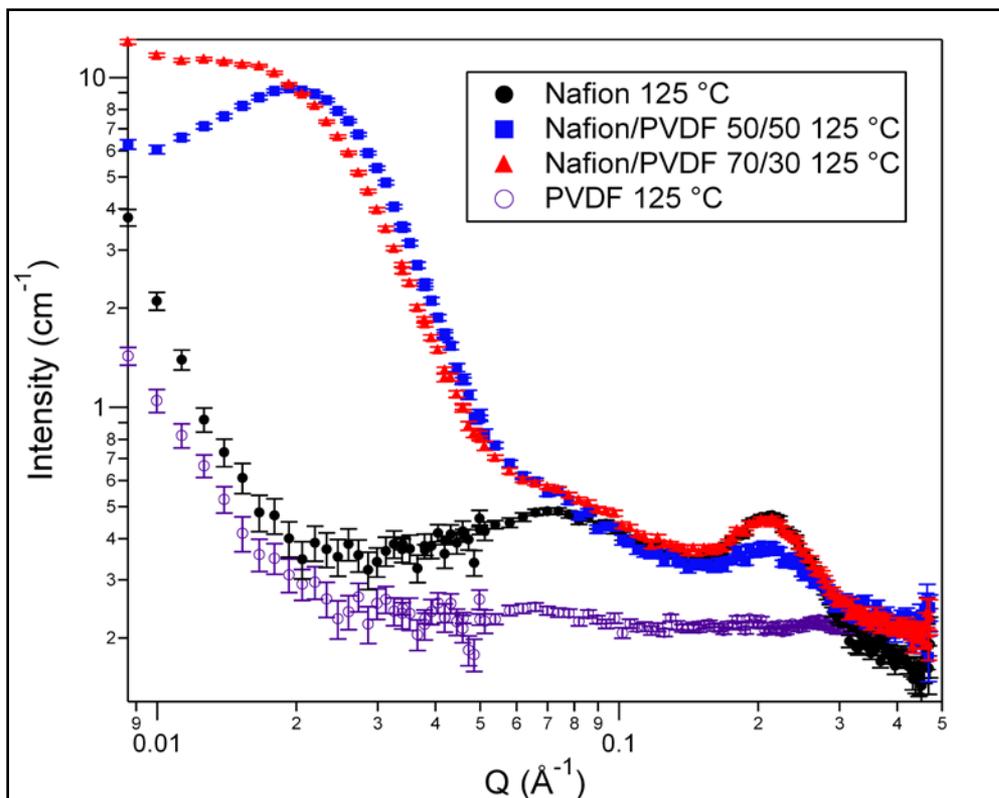
Morphology of Polymer Blends



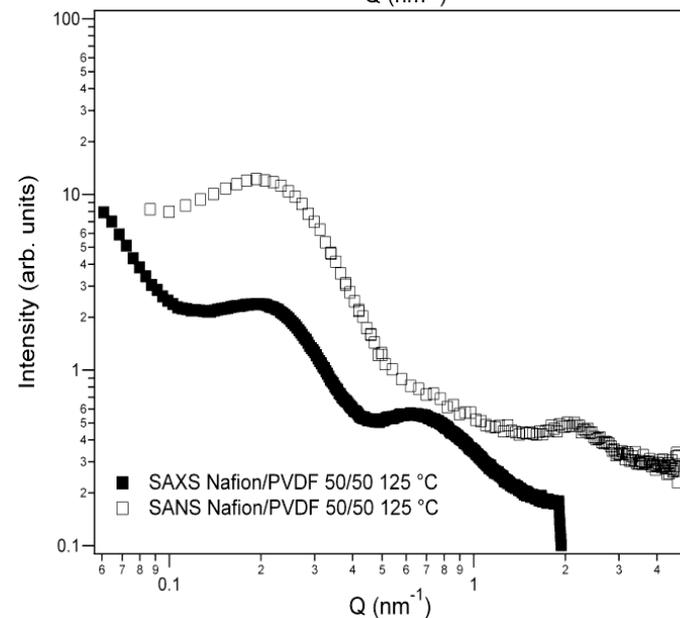
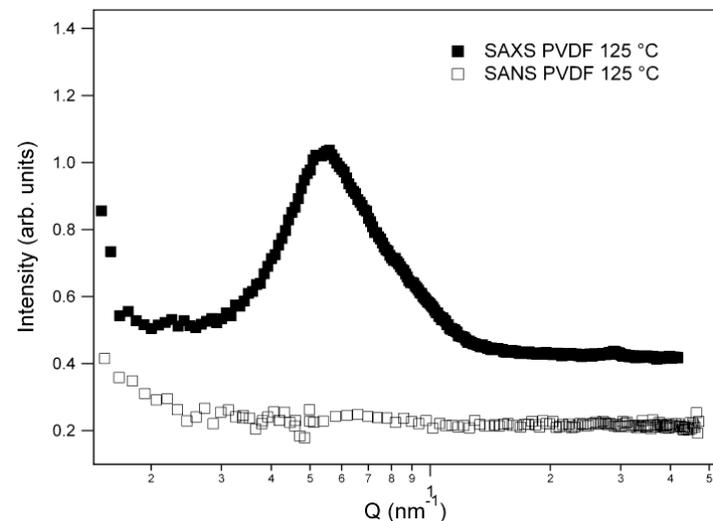
- Blend behavior revealed by SANS/SAXS
 - ionomer structure relatively unaffected
 - PVDF crystallinity affected by blend composition
 - Nafion "intercalates" PVDF lamellae

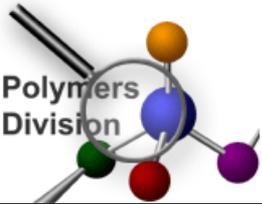


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Acknowledgments

Contributors:

Dr. Alamgir Karim
Dr. Christopher Soles
Dr. Brian Berry
Dr. Kevin Yager
Dr. Ron Jones
Dr. Victoria Garcia-Sakai



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