

**Homework 12**  
**Polymer Physics 2024**  
**Due Tuesday April 9 at noon**  
**(Please list the contributors to the HW at the top of the document)**

Yavitt BM, Salatto D, Huang Z, Koga YT, Endoh MK, Wiegart L, Poeller S, Petrash S, Kiga T *Revealing nanoscale dynamics during an epoxy curing reaction with x-ray photon correlation spectroscopy* J. Appl. Phys. **127** 114701 (2020) applied X-ray photon correlation spectroscopy (XPCS) to study “out of equilibrium dynamics” for filled epoxy resin as it cured. As Yavitt describes, epoxy resins are mostly studied at the early stages of curing where rheology techniques can be applied. It is difficult to study the dynamics after percolation of the chemical network. XPCS is a technique like dynamic light scattering (DLS) but at a larger  $q$ -range allowing measurements on the nanoscale. Yavitt studied micron scale particle motion. For a curing system, the dynamics change with time, so the window of time observation is limited. Yavitt describes a method to deal with this complication with interesting results. One year after Yavitt’s publication a group from AFRL in Dayton repeated Yavitt’s study using smaller nano-filler particles, Trigg EB, Wiegart L, Fluerasu A, Koerner H *Dynamics of Polymerization and Gelation in Epoxy Nanocomposites via X-ray Photon Correlation Spectroscopy* Macromolecules **54** 6575-6584 (2021). Also in 2021, a Japanese group published similar work, Hoshino T, Okamoto Y, Yamamoto A, Masunaga H *Heterogeneous dynamics in the curing process of epoxy resins* Nat. Sci. Reps. **11** 9767 (2021).

- a) What is the difference between equations 1 and 2 and what is the meaning of the 2D plots show in Figure 1?
- b) Equation 3 is like the correlation function from DLS but has three free parameters,  $C$ ,  $\beta$  and  $\gamma$ . Explain the meaning of these three terms and their behavior in Figures S3 and S4 from the supplemental information file. What are the expected values for a DLS measurement on a simple system.
- c) Figure 3 shows the behavior of  $I(q)$ . What dependence is expected for Brownian diffusive motion? What does the observed behavior indicate. Does this make sense for a reactive network? Why does the slope change with temperature (use Figure 4 in your explanation)? Compare Trigg’s Figure S5 (supplemental document) with Yavitt’s Figure 3. Explain the difference.
- d) Trigg’s 2021 paper uses his equation 3 to obtain the complex viscosity applying the methods of diffusive wave spectroscopy mentioned in class (DWS). Figure 4 of Trigg shows a comparison of bulk rheology measurements and the DWS type measurement using XPCS. Describe the DWS/XPCS method and specifically why it is useful for this system.
- e) Hoshino (2021) also used nanoparticles rather than microparticles (similar to what Trigg published). Explain what is new in the Hoshino paper that merited publication in Nature.