X-ray photon correlation spectroscopy studies of slow dynamics in soft glassy materials

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Disordered soft solids, such as foams, gels, concentrated emulsions, and dense colloidal suspensions, exhibit apparently universal features that are characteristic of out-of-equilibrium systems. In particular these materials often display non-diffusive slow dynamics and a protracted evolution of their dynamical properties that bears strong resemblance to the phenomenon of aging seen in molecular glasses and glassy polymers, but also have features peculiar to soft systems. In an effort to understand the essential dynamical behavior of soft disordered materials at the nanoscale, we have conducted x-ray photon correlation spectroscopy (XPCS) studies on a variety of soft solids and complex fluids. The combination of large wave vectors and long time scales accessible with XPCS makes the technique uniquely well suited for elucidating the nanoscale motions in such glassy materials. In this talk, I will provide an overview of XPCS studies for a group of characteristic soft solids and complex fluids, including synthetic clay gels [1], concentrated nanoemulsions [2], nanoparticle networks [3,4], and polymer melts doped with nanoparticles [5]. For all the disordered soft solids, we observed the same generic slow dynamics characterized by an intermediate scattering function that follows a "compressed" exponential form, $g_1(Q,t) \sim \exp[-(t/\tau)^{\wedge}\beta]$, with $\beta \approx 1.5$ and $\tau \sim Q^{-1}$, as shown in Figure 1. Such behavior contrasts with glassy diffusion, for which correlation functions are stretched ($\beta < 1$) and $\tau \sim Q^{-2}$. Thus, we conclude that the dynamical evolution of the disordered soft solids, while displaying signatures of aging, cannot be directly related to traditional aging phenomena in glasses. Rather, these dynamical features can be explained in terms of strain from random, highly localized stress relaxation events [6]. Interestingly, we have found that such non-diffusive dynamics may also occur transiently in complex fluid systems, such as polymer melts [5] and concentrated polymer solutions.

References

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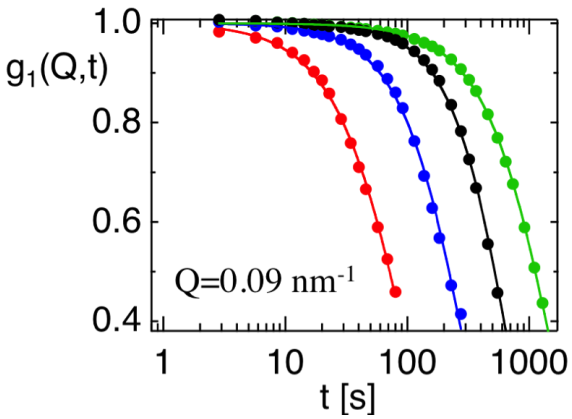

Figure 1: $g_1(Q,t)$ for nanocolloid depletion gels at times t_S=800, 2500, 6100, and 13000 s after shear fluidization. Solid curves are fits to a stretched exponential form with $\beta \approx 3/2$.