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Strain-Rate Frequency Superposition (SRFS) - A rheological probe of structural relaxation in soft materials

HANS M. WYSS, Harvard University

The rheological properties of soft materials such as concentrated suspensions, emulsions, or foams often exhibit surprisingly universal linear and nonlinear features. Here we show that their linear and nonlinear viscoelastic responses can be unified in a single picture by considering the effect of the strain-rate amplitude on the structural relaxation of the material. We present a new approach to oscillatory rheology, which keeps the strain rate amplitude fixed as the oscillation frequency is varied. This allows for a detailed study of the effects of strain rate on the structural relaxation of soft materials. Our data exhibits a characteristic scaling, which isolates the response due to structural relaxation, even when it occurs at frequencies too low to be accessible with standard techniques. Our approach is reminiscent of a technique called time-temperature superposition (TTS), where rheological curves measured at different temperatures are shifted onto a single master curve that reflects the viscoelastic behavior in a dramatically extended range of frequencies. By analogy, we call our approach strain-rate frequency superposition (SRFS). Our experimental results show that nonlinear viscoelastic measurements contain useful information on the slow relaxation dynamics of soft materials. The data indicates that the yielding behavior of soft materials directly probes the structural relaxation process itself, shifted towards higher frequencies by an applied strain rate. This suggests that SRFS will provide new insight into the physical mechanisms that govern the viscoelastic response of a wide range of soft materials.