Superposition Rheology and Anisotropy in Rheological Properties of Sheared Colloidal Gels

Sunhyung Kimr,[1] Christian Clasen,[1] Jan Mewis,[1] KU Leuven,[1] and Jan Vermant[2,*]

[1] *University of Leuven, Department of Chemical Engineering, Celestijnenlaan 200F, B-3001 Leuven, Belgium*

[2] *ETH Zurich, Department of Materials, CH-8093 Zurich, Switzerland*

Gelling colloidal suspensions are characterized by a solid-to-liquid transition at a given shear stress level. Moreover, they often exhibit a complex time-dependent rheological behavior known as thixotropy. The viscosity changes find their origin in the microstructure, which depends on flow history. Yet, the structural response to flow of colloidal gels differs fundamentally from most complex fluids, where flow induces orientation and stretching. Upon yielding, low to intermediate volume fraction gels break down in a spatially anisotropic way. Bonds in the velocity-velocity gradient plane break down, whereas microstructural features in other planes are less affected. The subsequent flow-induced microstructural anisotropy is characterized by generic butterfly scattering patterns or can be inferred from microscopy images. However, as yet there was no evidence for the pertinence of this anisotropy for the rheological properties of these systems. In the present work, orthogonal superposition rheometry was used to first evaluate how the flow-induced microstructure affects the viscoelastic properties. It is shown to retain significant elasticity in the velocity-vorticity plane, even when the structure liquefies. Secondly, the shear-induced mechanical anisotropy was measured using two-dimensional small amplitude oscillatory shear, exploiting the fact that for suitable thixotropic samples the recovery after arresting the flow is relatively slow. It is hence possible to measure the anisotropy of the moduli upon cessation of flow. The mechanical anisotropy is shown to be spectacular, with the storage moduli in perpendicular directions differing by as much as two orders of magnitude.

* Corresponding author: jan.vermant@mat.ethz.ch