Stress Overshoots in Soft Glassy Materials

Supplementary information

EXPERIMENTAL DETAILS

This section provides some details about the experiments used for the comparison with our fluidity model in the main text. Microgels were prepared from Carbopol ETD 2050 powder dispersed in water at weight concentrations C ranging between 0.5% and 3% wt. Carbopol ETD 2050 is made of homopolymers and copolymers of acrylic acid that are highly crosslinked with a polyalkenyl polyether. When neutralized using NaOH, the polymer particles swell and jam to form a dense, amorphous assembly of soft particles with typical size 6 μm [1]. The reader is referred to Ref. [2] for the full preparation protocol.

The experiments shown in Figs. 1(a) and 3 in the main text were performed at room temperature in a parallel-plate geometry of radius 21 mm and gap 1 mm covered with sandpaper of roughness 46 μm. A stress-controlled rheometer (Anton Paar, MCR 301) imposes a constant shear rate $\dot{\gamma}$ to the sample thanks to a feedback loop on the shear stress σ. Figure S1 shows the flow curves of the various samples together with the Herschel-Bulkley behaviors used for rescaling the data in the main text and summarized in Table S1. Additional stress responses showing some overshoots analyzed in Fig. 3 in the main text are shown in Fig. S2 for 2% and 3% wt. Carbopol microgels. More data can be found in Ref. [2] where the influence of boundary conditions was also explored.

The experiments shown in Fig. 4 in the main text were performed at room temperature in a concentric-cylinder geometry of gap 1.1 mm covered with sandpaper of roughness 60 μm. The radius of the inner cylinder attached to the rotating shaft of the rheometer is 23.5 mm and the immersed height is 28 mm. Both cylinders are covered with sandpaper of roughness 60 μm. The velocity profiles presented in the lower inset in Fig. 4 were obtained through ultrasonic speckle velocimetry coupled to rheometry as introduced in Ref. [3]. To provide acoustic contrast to the microgel and allow for local velocity measurements, hollow glass microspheres (Potters, Sphericel, mean diameter 6 μm density 1.1) were suspended within the initial Carbopol dispersion at a volume fraction of 0.5%.

Symbol	C (% wt)	G_0 (Pa)	$\sigma_{\rm y}$ (Pa)	n	A (Pa.s^n)
▽	0.5	72 ±8	13 ±1	0.50 ±0.03	7.9 ±0.5
△	1	142 ±15	41 ±4	0.56 ±0.02	13 ±2
•	2	285 ±20	111 ±9	0.60 ±0.01	18 ±2
□	3	408 ±30	167 ±20	0.54 ±0.02	31 ±3

TABLE S1: Experimental parameters for the Carbopol microgels used in the present study: weight concentration C, elastic modulus G_0, yield stress $\sigma_{\rm y}$, shear-thinning exponent n and the consistency index A are inferred from Herschel-Bulkley fits of the steady-state flow curves, σ vs $\dot{\gamma}$, shown in Fig. S1. The uncertainties reflect the typical variations of the various parameters due to sample volume variability from one loading to another and to possible solvent evaporation over long durations of a few hours, as well as the sensitivity of the HB parameters when fitting the flow curves over different ranges of shear rates.

[1] B. Géraud, L. Jorgensen, C. Ybert, H. Delanoë-Ayari, and C. Barentin, Eur. Phys. J. E **40**, 5 (2017).
[2] T. Divoux, C. Barentin, and S. Manneville, Soft Matter **7**, 9335 (2011).
[3] S. Manneville, L. Bécu, and A. Colin, Eur. Phys. J. AP **28**, 361 (2004).

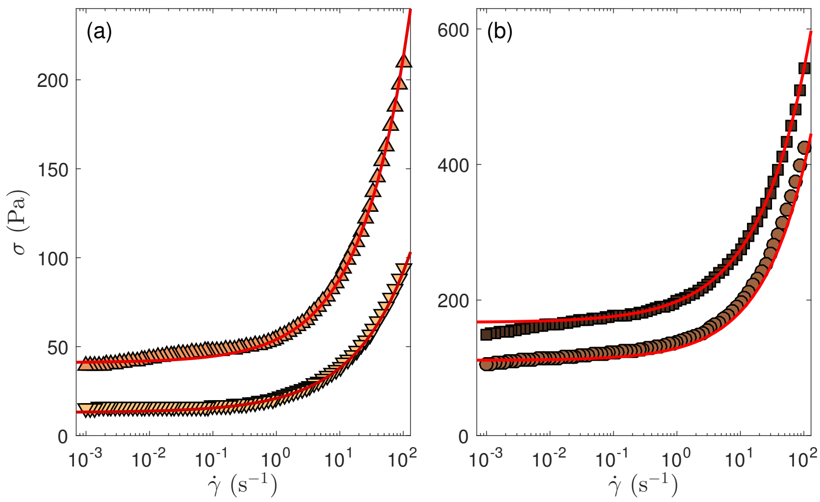

FIG. S1: Flow curves, shear stress σ vs shear rate $\dot{\gamma}$, of microgels made of Carbopol ETD 2050 with weight concentrations (a) $C = 0.5\%$ (▽) and 1% (▲), (b) 2% (●) and 3% wt (■). The red solid lines show the Herschel-Bulkley behaviors, $\sigma = \sigma_{\mathrm{y}} + A\dot{\gamma}^n$, used for rescaling the data in the main text. The values of the yield stress σ_{y}, the consistency index A, and the exponent n are gathered in Table S1. Experiments performed at room temperature in a parallel-plate geometry of gap 1 mm and covered with sandpaper of roughness 46 μm.

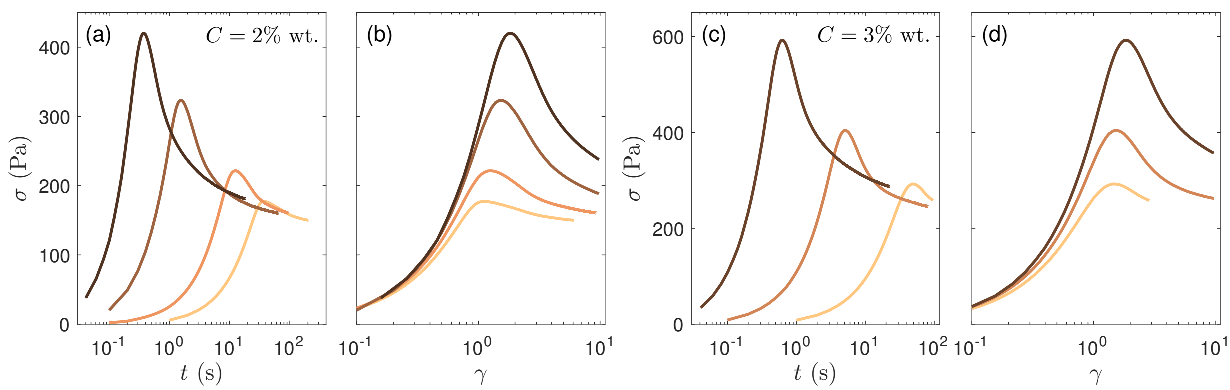

FIG. S2: Stress responses recorded (a,b) in a 2 % wt. Carbopol microgel under imposed shear rates $\dot{\gamma} = 5$, 1, 0.2, and 0.03 s^{-1} from left (darker color) to right (lighter color), plotted as a function of time t in (a) and as a function of the strain $\gamma = \dot{\gamma}t$ in (b), and (c,d) in a 3 % wt. Carbopol microgel under $\dot{\gamma} = 3$, 0.3, and 0.03 s^{-1} from left (darker color) to right (lighter color), plotted as a function of t in (c) and as a function of γ in (d). Experiments performed at room temperature in a parallel-plate geometry of gap 1 mm and covered with sandpaper of roughness 46 μm.