Failure precursors in the dynamics of a colloidal gel under creep

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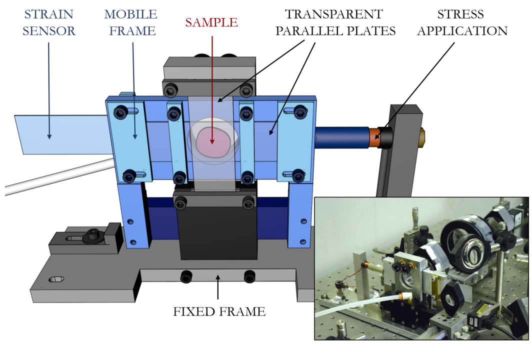

FIG. 1.

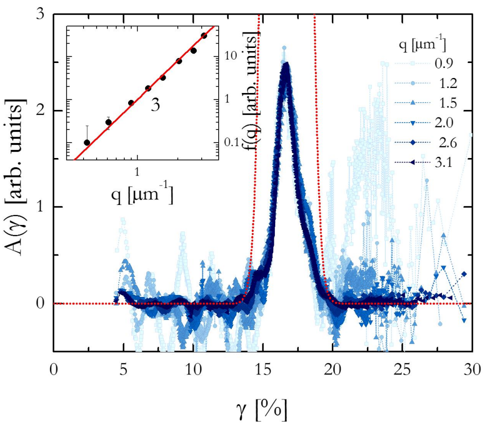

FIG. 2.

We study the microscopic dynamics of a model fractal colloidal gel under load by coupling a small angle light scattering apparatus to a custom stress-controlled shear cell [1], shown in Fig. 1. We find that the creep consists of three regimes. After an instantaneous elastic jump, a power law (primary) creep, well described by linear viscoelasticity, is found to last several hours. In this regime, non-affine microscopic dynamics are observed, but these non-affine dynamics are fully reversible. Upon deviation from linear viscoelasticity, a sharp acceleration of the non-affine dynamics is observed, localized in time. In this regime, the non-affine dynamics are irreversible: they lead to permanent changes in the gel that weaken the network. Remarkably, these faster rearrangements precede the macroscopic failure of the gel by thousands of seconds: they thus are 'dynamic precursors' of failure. Data collected at several scattering vectors q can be collapsed onto a master curve, proportional to the amount A of microscopic rearrangements per unit volume and unit strain deformation (fig. 2). Remarkably, the dynamics in these regime exhibit an unusual q^{-3} scaling of the relaxation time (inset of fig. 2). A exhibits a non-monotonic behavior: after a burst of plastic rearrangements lasting thousands of seconds, the gel dynamics slow down again, until the material suddenly fails.

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[1] S. Aime *et al.*, *A stress-controlled shear cell for small-angle light scattering and microscopy*, Rev. Sci. Instrum. **87**, 123907 (2016)