Supporting Information

Figure SI-1, representative oscillatory rheology measurements performed on a 2 wt% MAX1 hydrogel (pH 7.4, 20 °C, 400 mM NaCl): (a) dynamic time sweep (0.2 % strain, 6 rad/s), (b) dynamic frequency sweep (0.2 % strain, 0.1-100 rad/s), (c) dynamic strain sweep (0.1-1000 % strain, 6 rad/s)
Figure SI-2, representative oscillatory rheology measurements performed on a 0.5 wt% MAX8 hydrogel (pH 7.4, 37 °C): (a) dynamic time sweep (0.2 % strain, 6 rad/s), (b) dynamic frequency sweep (0.2 % strain, 0.1-100 rad/s), (c) dynamic strain sweep (0.1-1000 % strain, 6 rad/s)
Figure SI-3, Gel restoration kinetics: storage modulus, $G'$ and loss modulus, $G''$, restored as a function of time after shearing three 2wt% MAX1 gels formed on the rheometer (pH 7.4, 50 mM BTP, 400 mM NaCl at 20 °C) at a constant shear rate of 1000/s for 5, 40 and 120 seconds, respectively.
Figure SI-4. Gel restoration kinetics: storage modulus, $G'$ and loss modulus, $G''$, restored as a function of time after shearing three 2 wt% MAX1 gels (pH 7.4, 50 mM BTP, 400 mM NaCl at 20 °C) formed on the rheometer at a constant shear rate of 10/s, 100/s, 1000/s for 40 seconds, respectively.
**Figure SI-5**, Gel restoration kinetics: storage modulus, $G'$ and loss modulus, $G''$, restored as a function of time after a 2 wt% MAX1 gel (pH 7.4, 50 mM BTP, 400 mM NaCl at 20 °C) was subject to shear induced by syringe injection.
Figure SI-6, Gel restoration kinetics: storage modulus, G’ and loss modulus, G’’, restored as a function of time after shearing three 2 wt% MAX8 gels formed on the rheometer (pH 7.4, 25 mM HEPES, 37 °C) at a constant shear rate of 1000/s for 5, 40 and 120 seconds, respectively.
Figure SI-7, Gel restoration kinetics: storage modulus, $G'$, and loss modulus, $G''$, restored as a function of time after shearing three 0.5 wt% MAX8 gels (pH 7.4, 25 mM HEPES, 37 °C) formed on the rheometer at a constant shear rate of 10/s, 100/s, 1000/s for 40 seconds, respectively.
Figure SI-8. Gel restoration kinetics: storage modulus, $G'$ and loss modulus, $G''$, restored as a function of time after a 0.5 wt% MAX8 gel (pH 7.4, 25 mM HEPES, 37 °C) was subject to shear induced by syringe injection.
**Figure SI-9.** Gel restoration kinetics: storage modulus, $G'$, and loss modulus, $G''$, restored as a function of time after shearing two MAX1 gels (1 and 2 wt% at pH 7.4, 20 °C with 400 mM NaCl) at 1000/s for 40 seconds.
**Figure SI-10**, Gel restoration kinetics: storage modulus, $G'$ and loss modulus, $G''$ restored as a function of time after shearing two 2 wt% MAX1 gels (pH 7.4, 20 °C with 150 mM and 400 mM NaCl) at 1000/s for 40 seconds.
Figure SI-11, Radial 2D scattering patterns obtained from rheo-SANS measurements (0.003Å⁻¹ <q<0.01Å⁻¹) of (a-d) 1 wt% and (e-h) 2 wt% MAX1 (pH 7.4, 400 mM NaCl at 20 °C) gels under shear rate of 0/s, 10/s, 100/s and 1000/s. The flow direction points to the horizontal right.

Figure SI-12, Radial 2D scattering patterns obtained from rheo-SANS measurements (0.003Å⁻¹ <q<0.01Å⁻¹) of 0.5 wt% MAX8 (pH 7.4, 37 °C) gels under shear rate of 0/s and 1000/s. The flow direction points to the horizontal right.
Figure SI-13, (a) one-dimensional rheo-SANS intensity curves: $I$ vs. $q$ for 1 wt% MAX1 hydrogels (pH 7.4, 400 mM NaCl at 20 °C) under various shear rates; (b) the scattering curves at 0/s and 1000/s were fit with the summed model respectively.
**Figure SI-14**, (a) one-dimensional rheo-SANS intensity curves: $I$ vs. $q$ for 2 wt% MAX1 hydrogels (pH 7.4, 400 mM NaCl at 20 °C) under various shear rates; (b) the scattering curves at 0/s and 1000/s were fit with the summed model respectively.
**Figure SI-15**, one dimensional rheo-SANS intensity curves and fits with the summed model: $I$ vs. $q$ for 0.5 wt% MAX8 hydrogels (pH 7.4 at 37 °C) under various shear rates.