Supplementary Information

Near-Surface Microrheology Reveals Dynamics and Viscoelasticity of Soft Matters

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S1. Linear relationship between output and input for logarithmic amplifier.

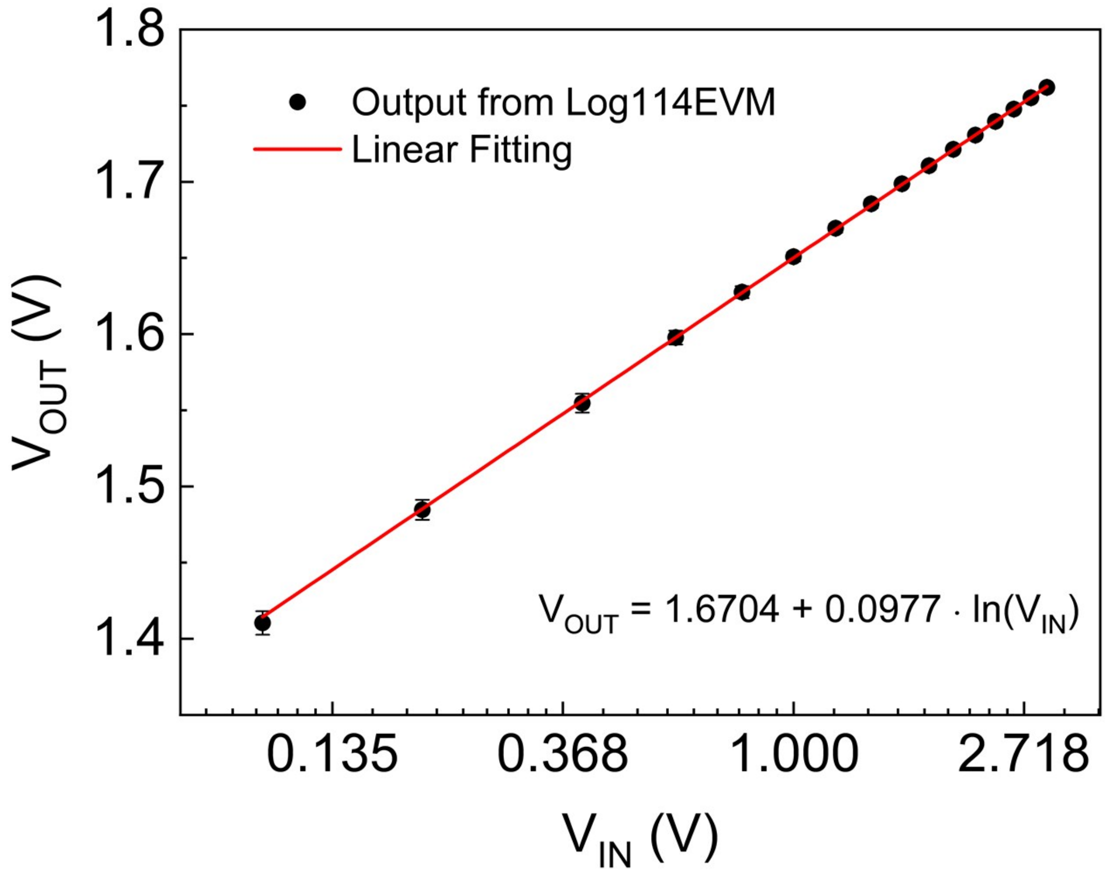

Fig. S1. Linear relationship between output (V_{OUT}) and input (V_{IN}) for logarithmic amplifier. The impedance used in the LOG114 module is about 0.5 $M\Omega$, the input voltage is generated by a function generator in a square-wave function.

S2. Correction of output for lock-in amplifier in AC coupled mode

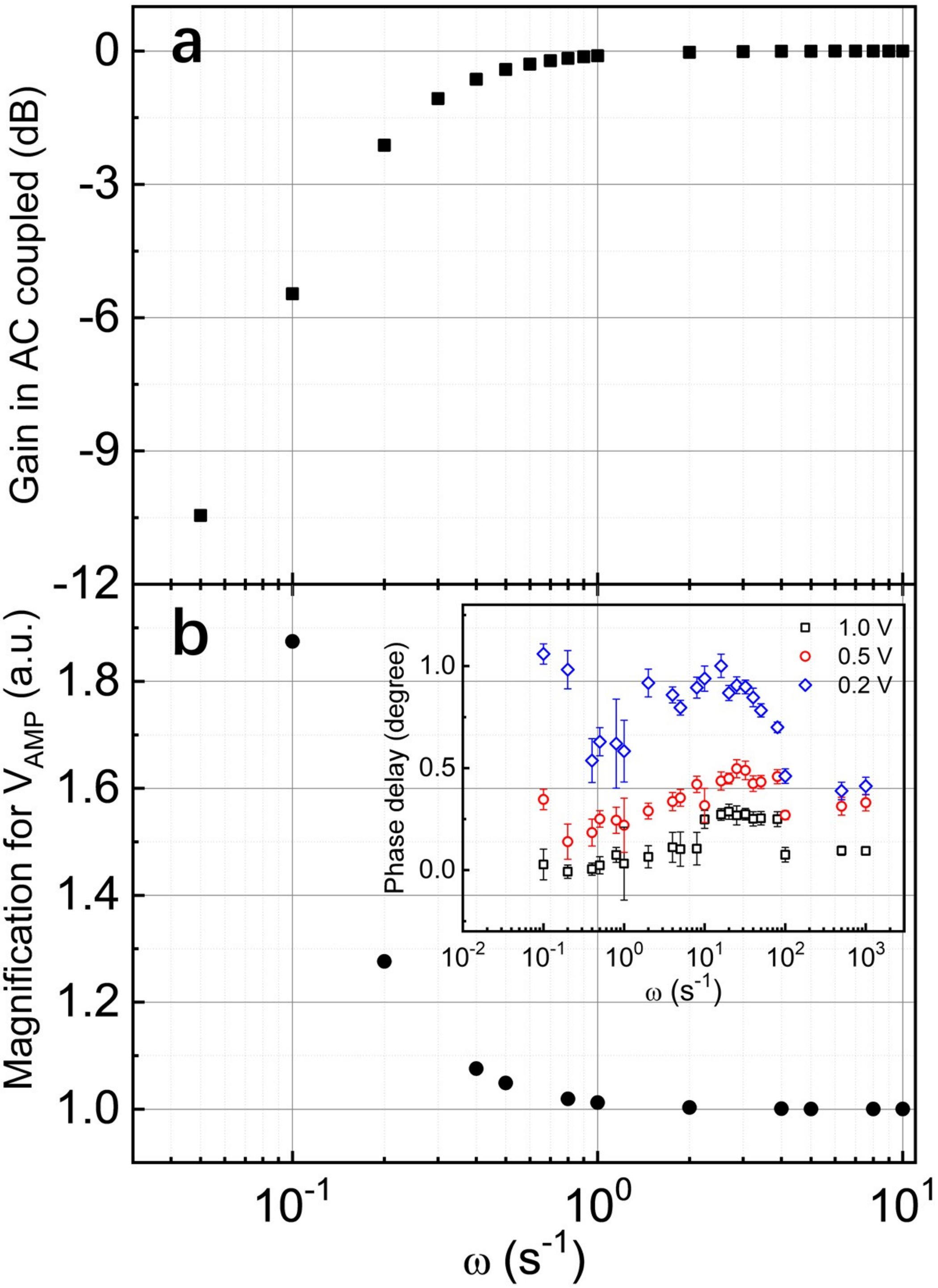

Fig. S2. Correction for amplitude and phase lag for the lock-in amplifier. (a) Attenuation of V_{AMP} at low frequencies ($f_{(gain=-3dB)} \leq 0.16\ Hz$) is confirmed

when the input of lock-in amplifier is set as AC coupled. (b) Magnification for the amplitude V_{AMP} at low frequencies. Inset figure shows the phase deviations for different input voltages.

The signal input of lock-in Amplifier can be either AC or DC coupled. The AC coupling high pass filter passes signals above 0.16 Hz and attenuates signals at lower frequencies. Therefore, a correction for the output amplitude of the lock-in amplifier in AC coupled mode at low frequencies should be considered. A function generator (33220A Arbitrary Waveform Generator, 20 MHz, Keysight Technologies) is employed to generate a voltage signal at specific frequencies as well as a SYNC reference voltage to the Lock-in amplifier. The voltage gain in AC coupled mode is showed in Fig. S2 (a), where signals at frequencies lower than 0.16 Hz are attenuated by more than -3 dB. Characteristic magnification at specific frequencies is showed in Fig. S2 (b). The output of amplitude V_{AMP} from the lock-in Amplifier is multiplied by these values of magnification when recorded by a homemade Labview program. This correction can be ignored when the frequency is higher than 2 Hz as the deviation is smaller than 0.1%. Inset in Fig. S2 (b) shows a negligible phase deviation smaller than 0.5 degree at input voltages lower than 1 V, while the correction at input voltages higher than 1 V should be made especially at low frequencies as the phase deviation is about 1 degree.

S3. Method to measure the retardation effect of magnetic field

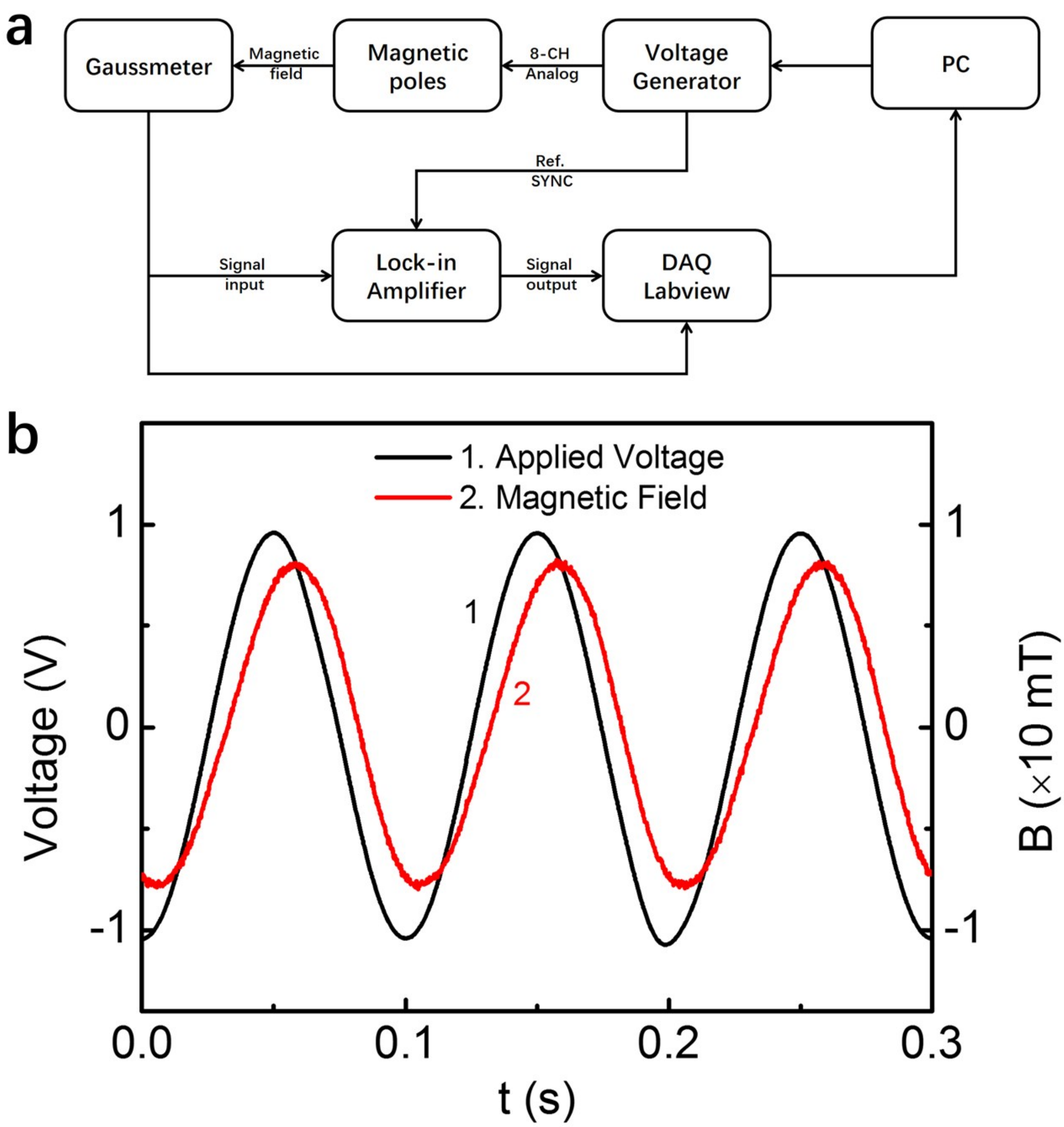

Fig. S3. (a) Schematic to measure amplitude decay and phase delay of the magnetic field. (b) Time dependence of the applied voltage and the corresponding magnetic field (B). An AC voltage signal at frequency of 10 Hz is applied on the two sets of magnetic poles, where a Gaussmeter probe is placed in between with a distance of 0.5 mm from each set.

The inductance effect of the electromagnetic coils is examined using a Gaussmeter (F.W. BELL Gauss meter 5180 with a standard transverse probe STD18-0404, OECO Inc.) shown in Fig. S3 (a) under a 1V AC voltage at various frequencies from 0.1 to 40 Hz. An 8-channel analog output PCI board (PCI6722 analog output 8-CH board, National Instruments) is utilized to generate independent AC applied voltages to the 8 magnetic poles. A triggered SYNC voltage is input into the reference channel of the lock-in amplifier. The magnetic field is measured by the probe of the Gauss meter which is placed between the two sets of the magnetic poles with a distance of 0.5 mm. An analog output from the Gauss meter is transferred into the lock-in amplifier in an AC coupled mode. By comparison of the input signal from Gauss meter with the reference signal, a frequency-dependent amplitude decay of the magnetic field and a phase delay between the applied voltage and magnetic field are determined. Fig. S3 (b) shows a time dependence of the corresponding magnetic field under an applied voltage with frequency of 10 Hz, a notable phase delay about 20 degrees is observed.

S4. Schematic of using a Gaussmeter probe to detect magnetic field

Two magnetic poles are placed horizontally with a distance from 1.5 to 3.0 mm, and the applied DC current is kept as 1 A during the measurement. A transverse Gaussmeter probe with a thickness about 1.1 mm is employed to detect the magnetic field.

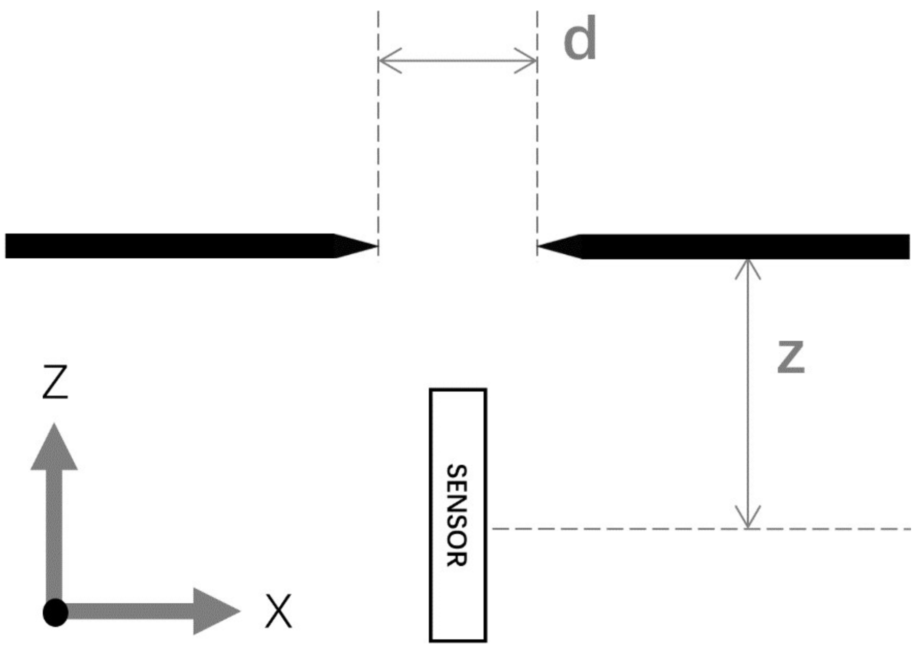

Fig. S4. Schematic of utilizing a Gaussmeter probe to access the distance dependence of the magnetic field from the magnetic poles (z) and the size of the gap (d) between them.

S5. Time dependence of voltage and phase delay of the PNIPAM microgel suspension at various frequencies

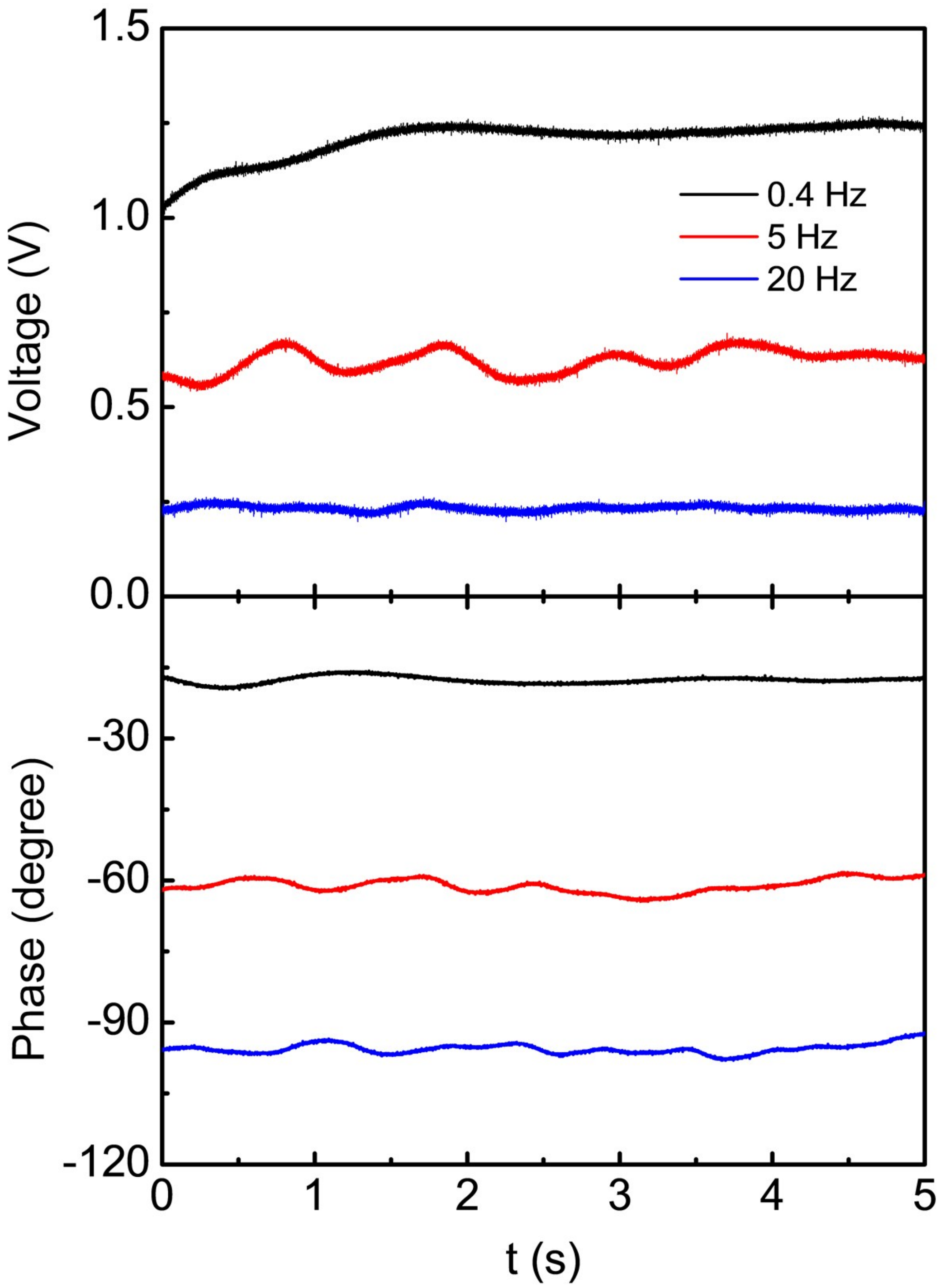

Fig. S5. Time dependence of voltages and phase delays of the PNIPAM microgel

suspension of $c = 0.0146\ g\ ml^{-1}$ at various frequencies at 31 ℃. The voltage is the V_{AMP}, the corresponding amplitudes of the oscillations are 187.8 nm, 88.2 nm and 33.1 nm at frequencies of 0.4, 5 and 20 Hz, respectively.

S6. Heterogeneous gelation process of the hydrogel

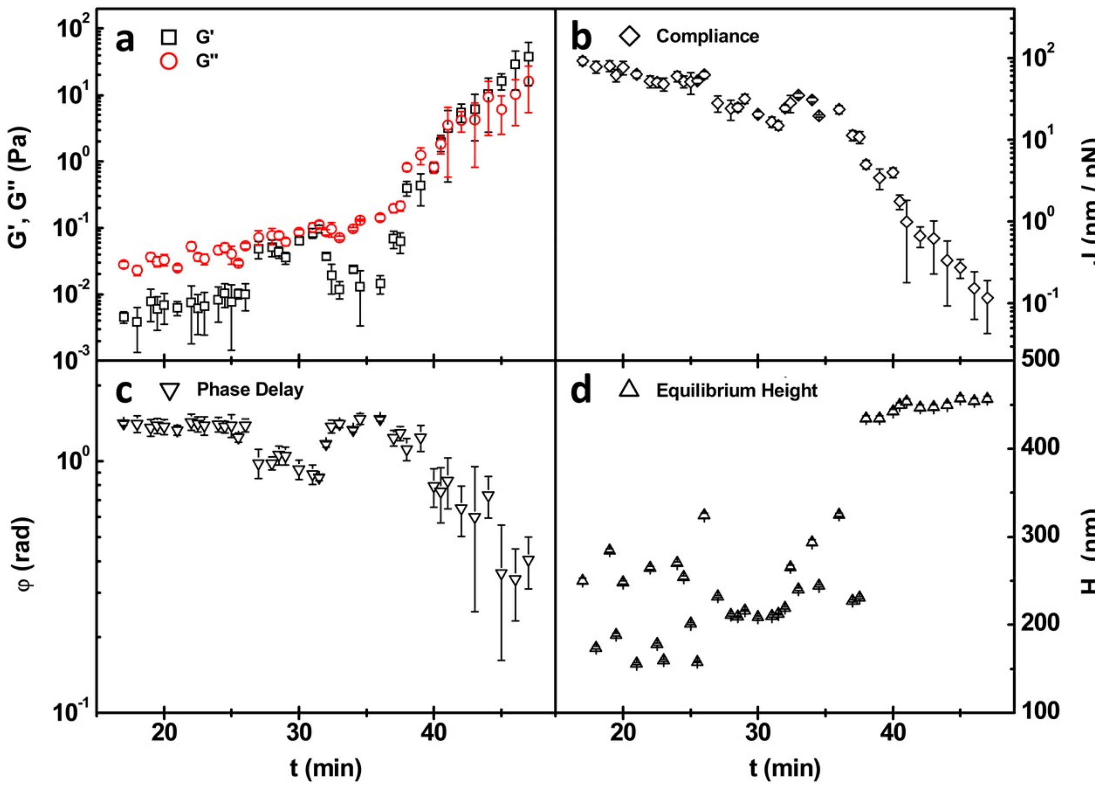

Fig. S6. Heterogeneous gelation of the hydrogel observed by the deviant behaviors of G' in the pre-gel regime ($c = 35\ mg\ ml^{-1}$, $\omega = 2.0\ s^{-1}$). (a) Time dependence of the viscoelastic modulus, (b) compliance J, (c) phase delay φ and (d) equilibrium height H_c of the probe particle. The corresponding deviations of G', J, φ and H_c are indicated by arrowheads, dashed lines are drawn for guidance.