Rheological behaviors of fumed silica filled polydimethylsiloxane suspensions

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Introduction

Most usage of elastomers would be impossible without the reinforcing character of certain fillers, such as carbon blacks and structured silica. However, the mechanisms for reinforcement still remain controversial. As we all known, rheological measurement is a key to explore the reinforcing mechanisms of nanoparticle due to the dramatically changes of the viscosity and viscoelastic behaviors of these materials.

Herein, the rheology of fumed silica dispersed in PDMS is thoroughly investigated. In particular, the influence of molecular weight of polydimethylsiloxane (PDMS) and the concentration, surface character of fumed silica is explored. The mechanism of reinforcement of fillers has been discussed. To explore the effect of the hydrodynamic effect introduced by filler particles to mechanism of reinforcement, we use Guth-Gold formulae to fit.

Experimental

Fumed silica preheated at 110 ° C for at least 12 h was mechanically mixed with PDMS by using a planetary mixer with a rotor speed of 50 rpm at 30 ° C. PDMS was softened for 10 min in the planetary mixer and fumed silica was then added. The compounds was mixed for 30 min and then was degassed under vacuum to eliminate any influence of air bubbles inside the suspensions. The dispersions were extruded in a plastic cylinder (300 ml) and were stored at room temperature for at least 24 h before test.

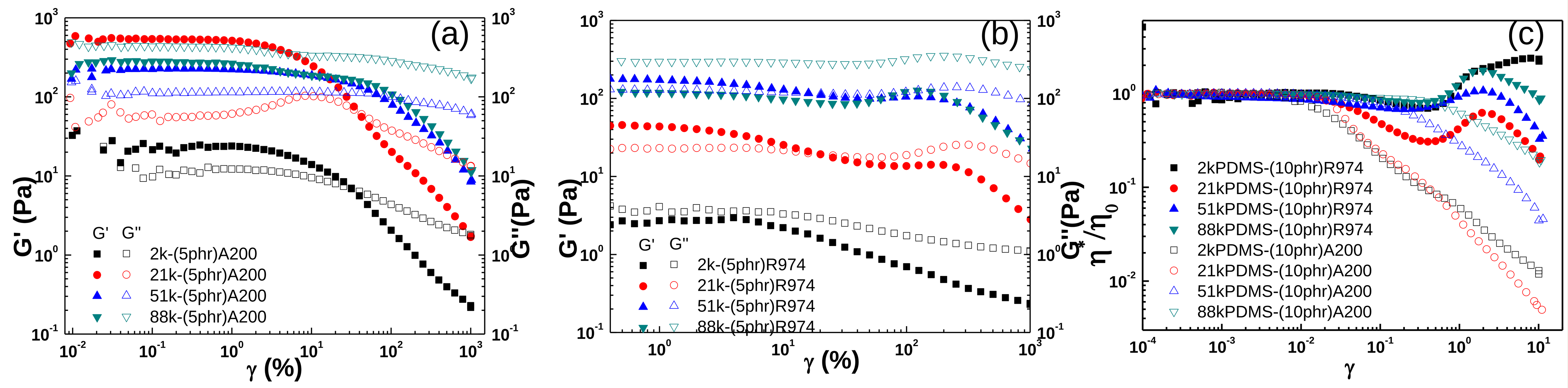

Fig. 1. (a) Storage modulus of the PDMS/R974 suspensions with various molecular weight of PDMS.(b) Storage modulus of the PDMS/A200 suspensions with various molecular weight of PDMS.(c) Normalized complex viscosity (η^*/η_0^* at ω=1 Hz) as a function of strain (γ) for PDMS varying the molecular weight.

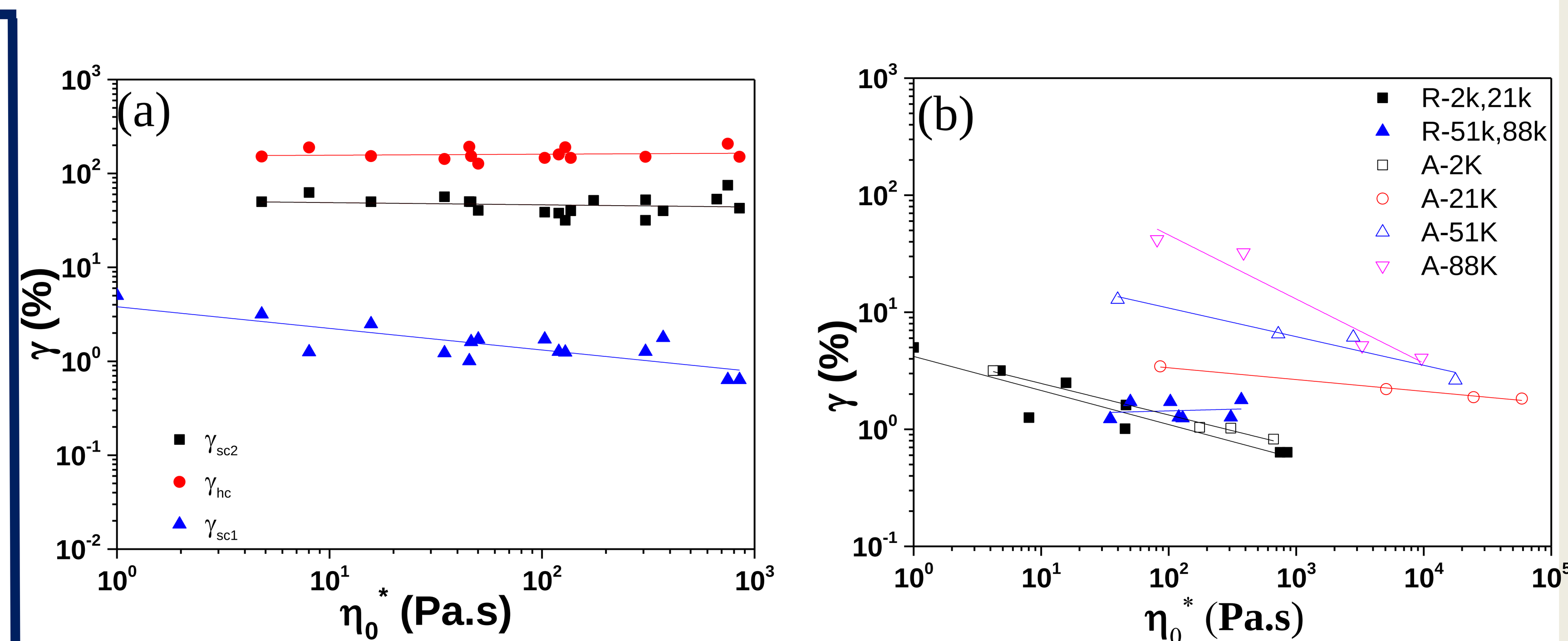

Fig. 2. (a) Critical strains at ω=1 Hz for the onsets of the first softening (γ_{sc1}), the hardening (γ_{hc}), the second softening (γ_{sc2}) against η_0* for the PDMS/R974 suspensions are investigated.(b) Critical strains at ω=1 Hz for the onsets of the first softening (γ_{sc1}) against η_0* for the PDMS/A200 suspensions are investigated.

Results and Discussion

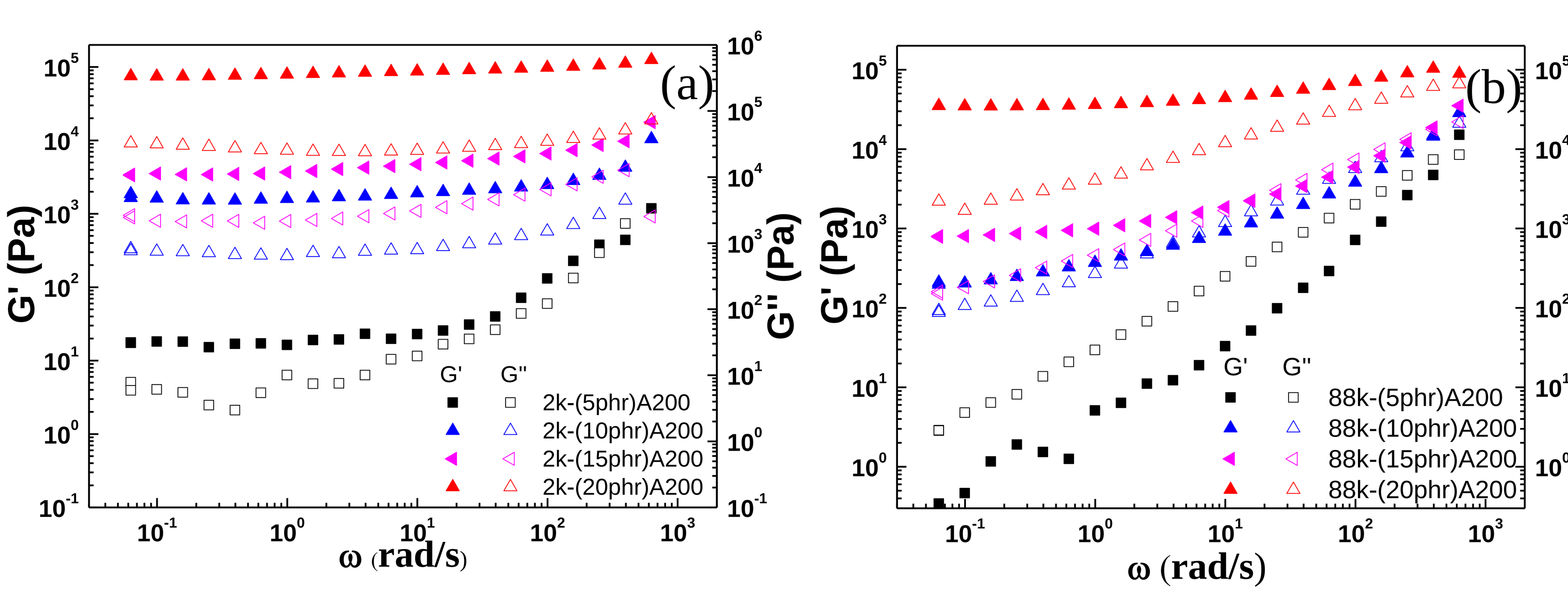

Fig. 3. (a) Storage modulus of the PDMS/A200 suspensions with various A200 loadings(Mw=2053) .(b) Storage modulus of the PDMS/A200 suspensions with various A200 loadings(Mw=88285)

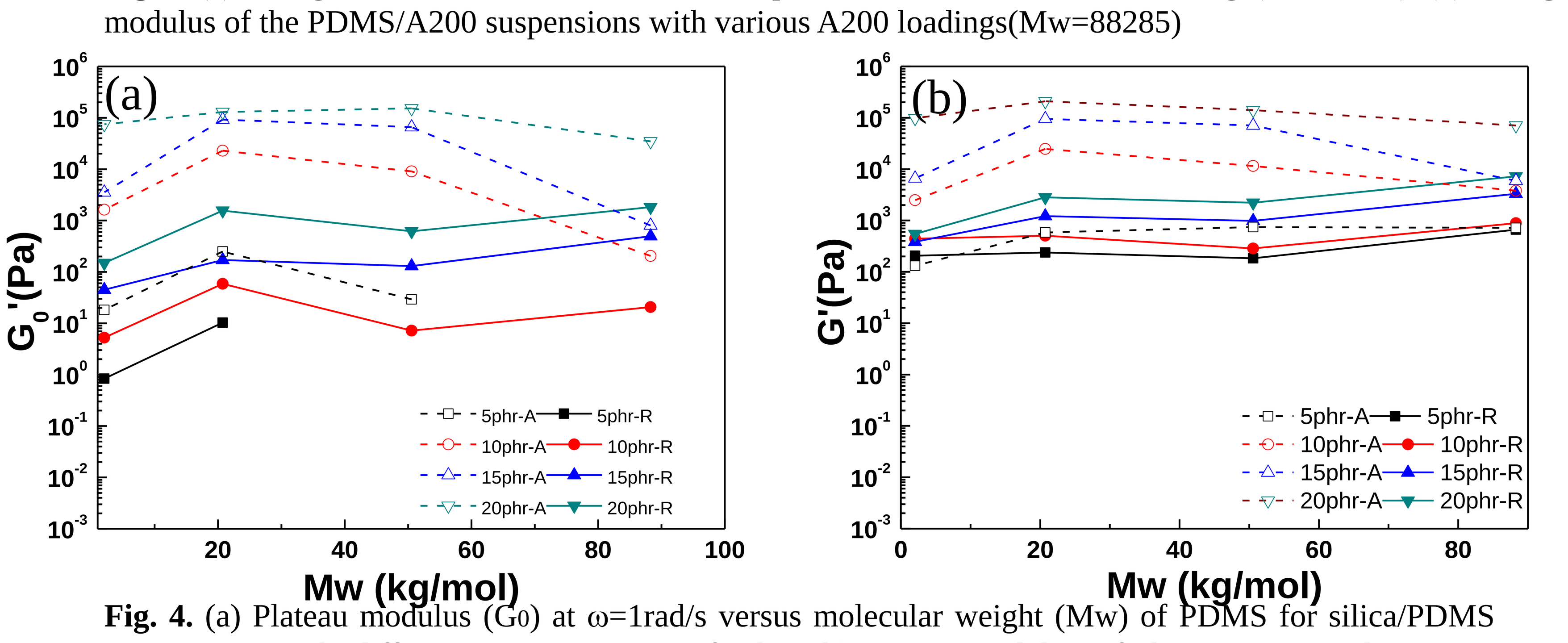

Fig. 4. (a) Plateau modulus (Go) at ω=1rad/s versus molecular weight (Mw) of PDMS for silica/PDMS suspensions with different concentrations of silica.(b)Storage modulus of the at ω=100rad/s versus molecular weight (Mw) of PDMS

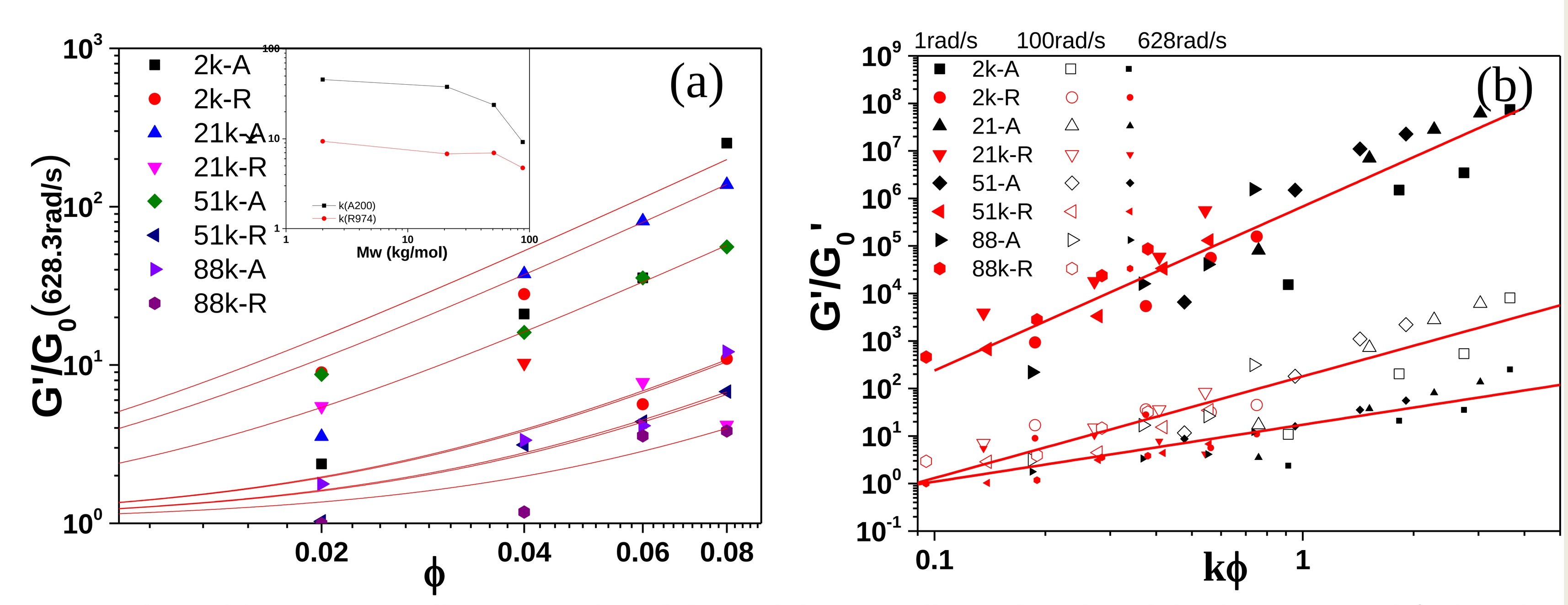

Fig. 5. (a) Experimentally measured modulus and theoretically predicted modulus by using modified Guth-Gold model. (b)the relation between G'/G0 and kϕ for the different molecular weight of PDMS

结论

- We found the suspensions which can form of an irreversible network only shows strain softening rheological behavior, while the suspensions which can form of a reversible network show stain softening, hardening, softening rheological behavior.
- The phase diagrams of PDMS with critical strains and η_0^* at frequency 1 Hz have been drawn. The hardening is initiated by a critical strain of 50 % and the critical strain of the second softening is 150 %. But the critical strain of the first softening depends on many aspects.
- The hydrodynamic influence plays a critical role in the mechanism of reinforcement at high ω, while the interaction between particles matter most at low ω.

References

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