Fabrication and Electrorheological Response of Pickering Emulsion Polymerized Core-Shell Structured Particles

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ABSTRACT

The fabrication of conducting polymer nanocomposites via the Pickering emulsion polymerization process has attracted a lot of attentions recently. One of their excellent applications is an electrorheological (ER) fluid, which is a special type of smart suspension with controllable fluidity under an electric field. In this presentation, we introduce several ER responsive core–shell structured particles synthesized by the Pickering emulsion method and their ER characteristics but mainly focusing on polymeric particle emulsifier.

INTRODUCTION

Electrorheological (ER) fluids as smart complex fluids are generally composed of conducting and/or dielectric particles dispersed in an insulating liquid medium, whose properties change reversibly and drastically from a fluid-like to solid-like state by the application of an electric field.[1] As electro-responsive particles, several core-shell structured smart composite particles were fabricated by Pickering emulsion polymerization[2] and then applied for ER fluids.

Pickering emulsion polymerization has been known to be a feasible way of preparing inorganic/polymer composite nanoparticles without an organic surfactant or stabilizer to prevent the droplets from coalescence and agglomeration.

Various inorganic particles such as clay, magnetite, graphene oxide, and silica nanoparticles[3,4] which are partially wettable by two phases of water and oil have been adopted as novel solid stabilizers in Pickering emulsions to fabricate hybrid particles. These composite particles have been adopted for not only ER fluids but also magnetorheological (MR) fluids under an applied magnetic field. In addition, polymeric nanoparticles were also introduced as potential stabilizer particles to replace inorganic materials, as they do not require surface modification, because of their surface similarity with the final product polymer.

EXPERIMENTAL

In this work, we synthesized not only different types of polyaniline/inorganic composite particles with a core-shell form via a Pickering emulsion process in organic medium phase by adopting clay, laponite and silica as stabilizers, but also other types of polymer composites with graphene oxide and polymeric particles such as poly(divinylbenzene-alt-maleic anhydride) (PDVMA).[5] The surface morphology of synthesized particles was investigated by SEM and TEM analysis. Other characterizations using XRD and TGA were also performed to confirm their production. These core-shell structured composite particles were applied as smart materials for ER fluids by dispersing fabricated particles in silicone oil and their ER performances were investigated by a rotational rheometer test in the presence of applied electric fields. Their smart characteristics of rheological properties including flow curve with shear stress, yield stress, dynamic modulus and dielectric spectra were observed to show typical ER behaviours.

As for core-shell structured PANI/PDVMA particles, they were fabricated through Pickering emulsion polymerization, using PDVMA particles as a solid surfactant. The synthesized PANI/PDVMA particles were adopted as an ER material suspended in silicone oil (particle concentration: 10 vol %).[5]

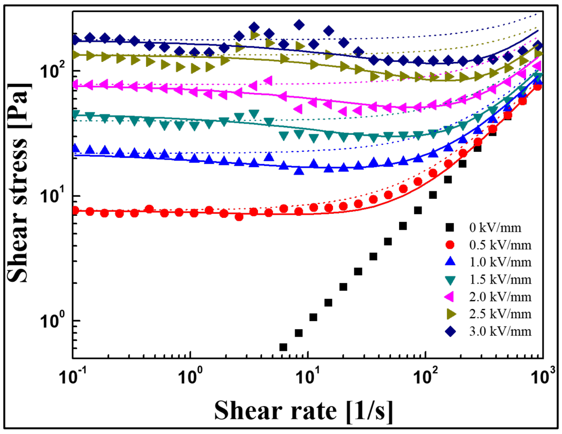

Figure 1. Shear stress vs. shear rate of PANI/PDVMA particle-based ER fluid. The lines in are fitted from CCJ (solid) and Bingham (dotted) models [adopted from Ref. 5].

RESULTS AND DISCUSSION

Figure 1 represents the shear stress of the PANI/PDVMA particle-based ER fluid at various electrical field strengths. The ER fluid exhibited a Newtonian fluid-like behaviour in the absence of an input electrical field. However, when the electric field strength was applied, ER fluid shows a significant increase in shear stress. The shear stresses increased with increasing electric field strengths. The solid lines following the trend of the flow curves precisely were generated from a flow curve equation known as Cho-Choi-Jhon (CCJ) model, which has been widely adopted to investigate the shear stress behaviours by fitting the curves with six parameters for both ER and MR fluids.[6]

$$\tau = \frac{\tau_0}{1+(t_1\dot{\gamma})^{\alpha}} + \eta_{\infty}\left(1+\frac{1}{(t_2\dot{\gamma})^{\beta}}\right)\dot{\gamma} \qquad (1)$$

where τ_o represents a yield stress; t_1 and t_2 are time constants; α and β are associated to the transition of the shear stress in a low and a high shear rate region, respectively; and η_{∞} represent the viscosity at infinite shear rate. In addition, viscoelastic and dielectric properties were examined along with their material characteristics.

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