Review

Nanoparticles Functionalized by Conducting Polymers and Their Electrorheological and Magnetorheological Applications

Yu Zhen Dong 1,†, Kisuk Choi 2 †, Seung Hyuk Kwon 1, Jae-Do Nam 2 and Hyoung Jin Choi 1,*

1 Department of Polymer Science and Engineering, Inha University, Incheon 22212, Korea; 22152270@inha.edu (Y.Z.D.); focalis@naver.com (S.H.K.)
2 Department of Polymer Science and Engineering, Sungkyunkwan University, Suwon 16419, Korea; kisuk929@skku.edu (K.C.); jdnam@skku.edu (J.-D.N.)
* Correspondence: hjchoi@inha.ac.kr; Tel.: +82-32-860-7486
† These authors contributed equally to this work.

Received: 8 December 2019; Accepted: 6 January 2020; Published: 13 January 2020

Abstract: Conducting polymer-coated nanoparticles used in electrorheological (ER) and magnetorheological (MR) fluids are reviewed along with their fabrication methods, morphologies, thermal properties, sedimentation stabilities, dielectric properties, and ER and MR characteristics under applied electric or magnetic fields. After functionalization of the conducting polymers, the nanoparticles exhibited properties suitable for use as ER materials, and materials in which magnetic particles are used as a core could also be applied as MR materials. The conducting polymers covered in this study included polyaniline and its derivatives, poly(3,4-ethylenedioxythiophene), poly(3-octylthiophene), polypyrrole, and poly(diphenylamine). The modified nanoparticles included polystyrene, poly(methyl methacrylate), silica, titanium dioxide, maghemite, magnetite, and nanoclay. This article reviews many core-shell structured conducting polymer-coated nanoparticles used in ER and MR fluids and is expected to contribute to the understanding and development of ER and MR materials.

Keywords: nanoparticle; conducting polymer; electrorheological; magnetorheological

1. Introduction

Smart materials, also called intelligent materials, can sense external stimuli, such as light, temperature, pH, stress, strain, chemical, nuclear radiation, electric fields, and magnetic fields. In particular, these types of materials can usually select and control the degree of response according to the design requirement, and can quickly go back to their initial phase when the external stimulus is eliminated [1–3]. Among various smart materials, the electric field-responsive smart particle suspension, called an electrorheological (ER) fluid, can change state from liquid-like to solid-like immediately and reversibly with an applied electrical field [4–7]. The suspended electro-responsive particles in a non-conducting medium align along the applied electrical field direction, resulting in the build-up of chain-like forms that increase the shear viscosity dramatically with the appearance of a yield stress [8]. Therefore, their mechanical and rheological properties can be changed considerably with an electrical field strength within milliseconds and return to an original state when the applied field is turned off [9–11]. Similar to an ER fluid, a magnetorheological (MR) suspension usually consists of magnetic particles suspended in a carrier liquid that converts rapidly to a solid-like form under a magnetic field and returns to a liquid-like phase when the applied field is withdrawn [12,13]. These fascinating ER and MR fluids have attracted significant attention in many industrial applications, such as damper, tactile display, material polishing, robotics, clutches, and microfluidics [14–19].