Surface Polymerization of Iron Particles for Magnetorheological Elastomers (MREs) and Their Potential Application as Sensors

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Magnetorheological Elastomers (MREs) are intelligent materials which are fabricated from magnetic particles and a crosslinked polymer matrix. MRE have viscoelastic, magnetorestrictive, and magnetoresistive properties which can be used for vibration damper and sensing devices. This is possible because of the alignment of the magnetic particles in the polymer matrix. Chainlike magnetic particles are formed by the induced magnetic field. These chains are locked in place during chemical cross linking of the elastomer. In addition, changes in the magnetostrictive and magnetoresistive properties are controlled by varying the magnetic field. Chain-like magnetic particles provide rapid time response of milliseconds.

The magnetostrictive effect of MRE is caused by changing the distance between magnetic particles in the elastomer matrix under the influence of an external magnetic field. The magnetostrictive effect includes stiffness change and dimensional change in MRE. Under the influence of a magnetic field the MRE becomes stiffer due to decreased distance between the magnetic particles. This phenomenon is suitable for the vibration damper application. The MRE magnetostrictive effect is the most important feature for the vibration control application. Another phenomenon, the magnetoresistive effect, is important for sensor applications. The magnetoresistive effect is due to the change in electric impedance of the material. The impedance consists of a real and imaginary part. The real impedance represents the material resistance and the imaginary part represents the capacitance. The applied external magnetic field onto MRE only causes the magnetostrictive effect. The addition of an external force onto magnetized MRE will cause the deformation of the chain-like structure of magnetic particles. The electric properties of MRE will be changed by deformation of the chain-like structure.

Oxidation takes place when the MRE is in contact with air and a magnetic particle. This effect can be reduced by surface treatment of the carbonyl iron surface. “Bridging” between iron particles due to surface coating is an additional concern. Two approaches to deal with this “bridging” issue include: 1) using a hard polymer coating in which the particles do not agglomerate or 2) using a soft polymer coating with diluents in which the coated particles are maintained in liquid until they are added to the elastomer. The polymer matrix provides thermal oxidative and chemical resistance. Silicone and polyurethane are good candidates as polymer matrices which have good oxidation resistance and mechanical properties.

Many of living polymerizations have been studied including ionic polymerization, emulsion polymerization, nitroxide radical polymerization (NMP), ring opening polymerization (ROP), atom transfer radical polymerization (ATRP), and reversible addition fragmentation chain transfer (RAFT). The application of ATRP for surface polymerization of iron particles has been investigated by Fuchs et. al. The iron particles has been coated using poly(butyl acrylate). Surface modified iron particles were used in magnetorheological fluid (MRF) application. As a result, MRF with surface coated particles has shown better performance in compared with regular MRF. The grafting technique of thermo responsive poly(*N*-isopropylacrylamide) poly(NIPAAm) onto silica nanoparticles using ATRP has been investigated by Wu et. al.

In this present work, MREs were synthesized from polyurethane (PU) elastomer and silicone RTV (Room Vulcanizing Temperature) eslatomer with iron particles as magnetic particles. The iron particles concentration was varied from 10 wt.%, 30 wt.%, 50 wt.%, and 70 wt.%. The ATRP technique was used for surface polymerization of iron particles with fluorinated styrene as monomers. As a comparison, the radical polymerization was also used for surface polymerization of iron particles. The mechanical properties and electrical properties of MREs, thermal properties of surface coating polymer, and the alignment of iron particles within MRE have been characterized.

The mechanical properties and electrical properties of MREs have been characterized using force – displacement test device (instron) and electrochemical impedance spectroscopy (EIS) respectively, thermal properties of surface coating polymer were characterized using differential scanning calorimetry (DSC), and the alignment of iron particles within MRE have been characterized using scanning electron microscopy (SEM). MREs (70 wt.%) with surface coated iron particles have higher oxidation stability based on the force – displacement test results. The EIS and force – displacement test results have showed that the impedance and real resistance value at low frequency (1 Hz) of MRE was inversely proportional to the displacement or strain, and supplied current (magnetic fields). As results, MREs have potential to be used as a smart material for vibration isolator, force – displacement sensor and magnetic field sensor, and combination of damping and sensor material.