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Technical Support Package

Large-Strain Transparent Magnetoactive Polymer Nanocomposites

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Technical Support Package

for

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NASA Tech Briefs

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Large-Strain Transparent Magnetoactive Polymer Nanocomposites

Brief Abstract

Actuators and smart materials are materials which respond to external stimuli such as magnetic field. Inducing mechanical deformation using an external field is demonstrated by magneto-static means. Polymer nanocomposite super-paramagnetic magnetic actuators were prepared by addition of organically modified superparamagnetic nanoparticles to the polymer matrix. The nanocomposite films exhibited superparamagnetic behavior which increased with increasing nanoparticle loading. All magnetic polymer nanocomposite films exhibited large deformations under a magneto-static field with a low loading level of 0.1wt% in a thermoplastic polyurethane elastomer (TPU) matrix. The maximum actuation deformation of the nanocomposite films increased exponentially with increasing nanoparticle concentration. The cyclic deformation actuation of a high loading magnetic nanocomposite film was examined in a low magnetic field and exhibited excellent reproducibility and controllability. Low loading TPU nanocomposite films (0.1 – 2 wt%) were transparent to semi-transparent in the visible wavelength range owing to good dispersion of the magnetic nanoparticles.

Magneto-actuation phenomena was also demonstrated in a high modulus, high temperature polyimide resin with less mechanical deformation.

Description of the Problem

Actuation and morphing of light-weight structural materials have great impact in outperforming current aerospace components to the new generation of aerospace vehicles. Adaptive structures (soft and hard materials) have applications ranging from unmanned aerial vehicles (UAVs), micro air vehicles (MAVs), deployable antennas, satellite structures, remote light-weight unlocking mechanisms, deployable structures on Moon and Mars, morphing and adaptive wing skin. Mechanical manipulation of the structures in extreme outer space environment by wireless remote method is of great significance to space missions. Unlocking compact volume to a large structure is essential for transportation of structures to the orbit or outer space. Adaptive materials will enhance air vehicle maneuverability such as bio-inspired moving wings, where airplane wings could change depending on the altitude and mission. Shape change could result in reduced fuel consumption by change of structural components during takeoff, cruising, and landing.

Current structural components are static and serve only one function. Different methods of actuation consist of electromechanical actuation, thermal energy, and electrochemical media have been reported. The electro-resistive heating requires electrodes and wiring to the structural components, and the thermal shape memory polymers necessitate applying stress at a temperature above switching temperature to fix the polymer shape after recovery. A novel approach is the remote actuation of a magnetic polymer nanocomposite by a magneto-static or electromagnetic field. This will enable mechanical manipulations of the structural components in a remote and wireless manner which is of high value in extreme environment.

Unique or Novel Features of the Innovation

Actuators are materials that exhibit mechanical deformation in response to external stimuli such as electric field, magnetic field, light, and thermal energy. Magneto-active materials are materials that exhibit magnetic properties coupled with mechanical deformation in a static or electromagnetic field. This invention describes novel superparamagnetic polymer nanocomposites actuator films prepared by addition of superparamagnetic nanoparticle into the polymer films both thermoplastic elastomer (TPU) and high stiffness polyimide resin. The TPU magnetic nanocomposites are called soft magneto-active materials and polyimide magnetic nanocomposites are called hard magneto-active nanocomposites. The developed polymer films exhibited superparamagnetic characteristics.

The novel feature of this invention is that the polymer nanocomposites exhibit large deformation > 10mm in the static magnetic field even with low loading level of 0.1wt% for the thermoplastic polyurethane elastomer. The magneto-actuation deformation is increased with increasing magnetic nanoparticle content exponentially.

Novel TPU magneto-active polymer nanocomposites reported in this invention are both transparent and magnetically active with low loading levels of superparamagnetic nanoparticles < 2wt%.

The novel TPU magneto-active polymer nanocomposites have been prepared by solvent casting; however as a thermoplastic elastomer, they can be melt processed by injection molding, extrusion,…, which is significantly important for high throughput industrial processes.

Novel hard magneto-active superparamagnetic nanoparticles polyimide resin has been prepared. Larger concentration of the magnetic nanoparticles is necessary to obtain actuation in the polyimide magnetic nanoparticle nanocomposites.

The mechanical deformation of the superparamagnetic polyimide resin nanocomposites is lower than the superparamagnetic TPU nanocomposites.