Magnetic field sensitive elastic polymeric nanocomposites with tuneable mechanical parameters

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The identification and characterization of novel materials with enhanced magnetic properties is vital for the development of improved sensors and actuators. In several cases, the identification of new materials can open up innovative applications for magnetic sensors and actuators which were previously not possible[1]. The new generation of magnetic elastomers corresponds to a new type of composites consisting of magnetic nanoparticles dispersed in an elastic polymeric matrix[2]. In comparison with the existing magnetic materials (composed mainly by metals)[3], the polymer technology allows easily components fabrications with diverse forms and mechanical properties. Applications of these nanostructured materials may include force sensors, displacement/positioning devices, torque sensors and field sensors devices[4].
In the present work, magnetic nanocomposites were prepared by both: dispersion and melt-mixing methods[5]. The used elastic polymer matrix was an amorphous thermoplastic elastomer SEBS, characterised by cylindrical phase morphology of the polystyrene blocks in the ethylene-co butylene phase[6,7]. Two types of magnetic nanoparticles were used: 1) Ferromagnetic carbon coated cobalt nanoparticles with average size of 25 nm purchased to Nanoshel™ and 2) Superparamagnetic nanoparticles for avoiding strong particle-particle interactions that may result in particles agglomeration. The used superparamagnetic nanoparticles were: A stable dispersion of oleic acid coated magnetite nanoparticles dispersed in chloroform and toluene with average size of 10.5 nm (both purchased to Nanogap)[8], and graphite coated bimetallic FeCo and NiCo nanoparticles synthesised by a solid state chemical vapour deposition method. The nanocomposites were prepared by dispersion and melt-extrusion of magnetic nanoparticles with SEBS polymer using an UP400S ultrasonic processor and a twin-screw microextruder.
The prepared nanocomposites were characterized by transmission electron microscopy (TEM), thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC). Magnetic properties were evaluated by means of hysteresis loops and ZFC/FC measurements in a superconducting quantum interference device (SQUID). Results showed that with a small content of nanoparticles (<3wt%) a global magnetic response from the composite is achieved.
In order to establish the effect of the external magnetic field on the mechanical behaviour of the resulting composites, they were designed and built two mechanical test assemblies using an electromagnet and neodymium magnets: Shear test with the applied force (Fy) and the direction of the magnetic field (B) perpendicular between them; and a tensile essay (relaxation) with Fy and B parallel between them. A schema of the forces and the external field applied is showed in Fig. 1 for both cases.
It was found that the shear modulus and young modulus are increased by external magnetic field application. The differences in magneto-mechanical response among prepared composites are attributed to the type of used nanoparticles, their magnetic behaviour and magnetization, as well as the nanoparticles real concentration in polymer and the presence of residual solvent in the composites.
Our findings may assist, for example the development of new devices where the mechanical response can be actively controlled in real time by a magnetic field. These concepts would have general implication on the design of specific nanoparticles polymer composites and its processing for dedicated purposes.

References

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Figures

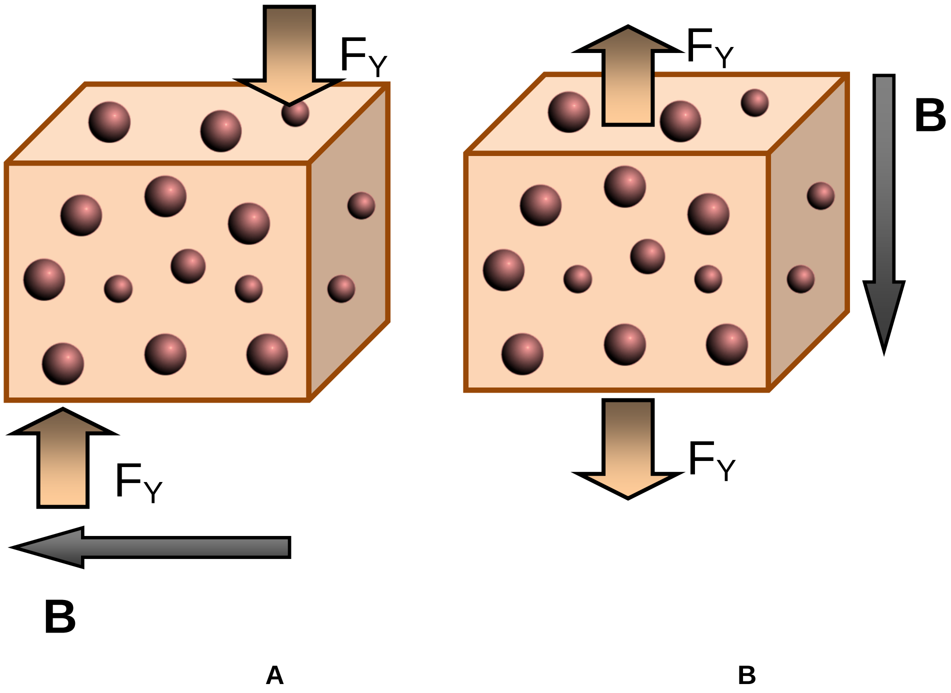

Figure 1. Magneto-mechanical test forces schema. a) Shear test and b)Tensile test (Relaxation).