Modeling non-linear magneto-elastic effects in hydrogels filled with ferromagnetic nanoparticles

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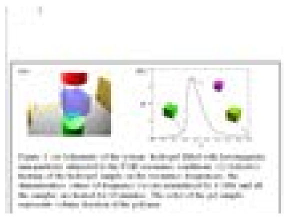
Via theoretical and computational modelling, we focus on the gel composites filled with ferromagnetic nanoparticles uniformly dispersed within the gel matrix. For the polymer matrix, we choose Poly(N-isopropyl acrylamide) gels, which have lower critical solution temperatures (LCST) and hence undergo shrinking upon heating. When these composites are subjected to an AC EM irradiation with a frequency close to that of the Ferro-Magnetic Resonance (FMR) frequency, the absorbance of these samples increases dramatically. We show that this magnetic heating is sufficient to drive the volume phase transitions and results in a giant mechanical response of the sample (see Figure 1) for a feasible range of experimental parameters. We develop a model for the system that accounts for the dynamical coupling between the elastodynamics of polymer gel and interactions between the EM waves and ferromagnetic nanoparticles embedded within the matrix. This coupling is non-linear: as the system is heated and the gel layer undergoes shrinking at the temperatures close to the volume phase transition, the particles concentration increases, which in turn results in the increase in the heating rates (positive feedback). The gel elastodynamics is modeled based on the three-dimensional gel Lattice Spring Model, while the heating rate is calculated based on the approach developed in ref. 6. We elucidated conditions at which even a low power EM signal comparable to that used in various communication protocols can lead to a significant mechanical response of the gel, hence the gel's motion can be effectively controlled by the remote low power EM signal. These results suggest a new design of active gel-based devices remotely controlled by the low power EM signals within the GHz frequency range.



Biography

Olga Kuksenok is currently an Associate Professor at the Materials Science and Engineering Department at Clemson University in Clemson, SC. She was formerly a Research Associate Professor at the Chemical Engineering Department at the University of Pittsburgh, Pittsburgh, PA. Dr. Kuksenok received her PhD in Physics and Mathematics from the Institute of Physics, National Academy of Sciences of Ukraine, Kiev, Ukraine, in 1997. Dr. Kuksenok has co-authored over 80 peer-reviewed publications and 6 book chapters.

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