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Physics of electroactive nano-heterogeneous elastomers. Key role of the Architecture

Abstract

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The conversion of electrical energy towards mechanical energy or electrostriction consists to induce the deformation of a material placed in an electric field. Classically, piezoelectricity allows such conversion where the deformation is linear with the applied field, but only concerns crystalline materials, like ceramics or some crystalline phases of polymers. The drawback is that with such crystals, deformations are limited to fraction of %, as the only way to obtain large deformations leads to the use of rubber (amorphous polymers well above their glass transition temperature). New efficient materials, easy to produce and thus cheap, are of large interest.

Generally speaking, elastomers (polymers in their rubbery state) exhibit a non-linear deformation S versus electric fields following behavior law like $S=M.E^2$, where E is the applied electric field. Most often, the physical understanding of polymer electrostriction is based on electrostatic stresses (so-called Maxwell stresses) between electrodes, exhibiting also a quadratic dependence upon E, which leads to electrostriction coefficient M ~10^{-17} SI for typical polymers having dielectric constant of ε_r~10 and a young modulus Y~10MPa.

However, some polymers are known to be much more active, such as polyurethane (PU) and in recent experiments, people found electrostrictive coefficient as large as M_{exp}~10^{-15} which cannot be explained by the Maxwell stress analysis. The PU microstructure was probed and it was shown that intrinsic architecture is present in these polymers due to a phase separation during their processing. Based on this observation, a model based on the dielectric interaction of spherical particles with their surrounding was derived, in order to represent the effective interaction between the two phases. This model is able to predict electrostrictive coefficients much larger than that due to Maxwell stress. It can provide a possible explanation for large deformation under electric field, and moreover be a tool to optimize the microstructure of new promising materials for energy conversion.