# An effective elastic model for nanostructured composite materials

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## Abstract

The embedding of nanofillers into lightweight polymer composites leads to a significant enhancement of the macroscopic mechanical properties. The use of metal nanoparticles, nanoclay, graphene, carbon nanotubes as nano-reinforcement is increasingly growing also thanks to a concurrent development of efficient manufacturing techniques to synthetize nanomaterials and fabricate nanocomposites on large scales. However, the potential of nanofillers as reinforcement is generally not fully expressed due to the presence of defects and imperfections (i.e., nanofiller agglomeration, irregularity of the nanofiller dimensions and alignment, etc.) which still represents a challenge in nanocomposites manufacturing. In order to facilitate the development of nano-reinforced polymer composites, constitutive relationships must be developed to predict the bulk mechanical properties of the nanocomposites as functions of the microstructural and nanofiller morphological features [1,2]. Indeed, the most common micromechanical constitutive models for multi-phase materials tend to overestimate the effective elastic properties of such nanocomposites since they are modeled by introducing simplifications of the morphological features. A perfect dispersion and distribution of the nanofiller is generally assumed together with perfect regularity in geometry and dimensions of the nanofillers, as well as perfect adhesion at the nanofiller/matrix interfaces.

In this work, an effective elastic model based on the Eshelby and Mori-Tanaka theories, developed in [3] for carbon nanotube nanocomposites, is generalized to describe and predict the elastic response of any nanostructured polymer composites with different nanofillers geometry and orientation. By exploiting the statistics of collected experimental data on the morphological features and elastic moduli of several nanocomposites, nano/micro structural parameters are introduced into the Eshelby tensor to account for the effective elastic properties of nanocomposites.

Sensitivity analyses are carried out to estimate the effects of nanofiller shape, size, orientation and agglomeration within the polymer nanocomposites. Such morphological parameters enable to account for material imperfections and enhance the model predictions of the elastic moduli. A better match of the proposed model predictions with the experimental data is shown with respect to the predictions of the more classical Halpin-Tsai and Eshelby-Mori-Tanaka theories.

**References**

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