Nano-Reinforced Composites: 
Performance and Percolation

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Abstract:
The unique properties of nanomaterials and their extremely large interfacial area, have promoted their incorporation in composite materials. A handful of nanocomposites with enhanced properties have been prepared employing a wide range of nanomaterials (used as nanofillers) differing in their morphology, composition and quality. However, a set of design rules for optimal enhancements is still missing. Does the dimensionality of the nanofiller affect its optimized performance? What is the effect of the matrix material?

I studied these fundamental questions in two antagonist matrices, namely, granular cement and continuous polymer, reinforced by a few types of nanofillers differing in their dimensionality. For both systems, I identified an optimal nanofiller concentration in which the maximal performances are obtained. I suggest that this behavior relates to nanofiller concentration thresholds (mechanical, electrical or rheological), analyzed by the percolation theory. For both polymer and cement systems, I found that indeed the performance of the composite is optimal near these threshold concentrations. Consequently, I introduce few design rules: robustness, reinforcement efficiency and a figure of merit that takes into account key composites parameters. These values provide rules for designing nanocomposites, and they are applicable for both granular and continuous systems.