Invited: SMPB-I-01

Percolation in colloidal model systems

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Connectivity percolation is the transition in which isolated clusters of solid particles in a fluid (or of voids in a solid) become connected in some sense to form a system-spanning network. This network has a significant effect on the mechanical and transport properties of the material on a macroscopic scale. If, for example, an electrically insulating polymer is mixed with conductive fibres such as carbon nanotubes, the conductivity of the composite increases by ten or more orders of magnitude near the percolation transition of the filler material.

We discuss percolation in suspensions of fibres and of platelets and present results from computer simulations as well as connectedness percolation theory. For fibres, our study covers the entire range of aspect ratios from spheres to extremely slender rods. Theory and simulations agree very well for aspect ratios down to values as low as 10. The percolation threshold for both hard and ideal rod-like particles of aspect ratios below 1000 deviates significantly from the inverse aspect ratio scaling prediction, thought to be valid in the limit of infinitely slender rods and often used as a rule of thumb for fibres in composite materials. Hence, most fibres that are currently used as fillers in composite materials cannot be regarded as practically infinitely slender from the point of view of percolation theory.

We also show the effects of polydispersity on the percolation transition. We discuss length and diameter polydispersity as well as dispersity in the connectedness criterion. The main result is that the percolation threshold shows universal behaviour, i.e. it depends only on certain cumulants of the size distribution.

For platelets we show that the percolation threshold is independent of aspect ratio – a fact that can be exploited in composites made from graphene suspended in a polymeric matrix to produce high-k materials.

References:

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