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Connectedness percolation of carbon nanotube dispersions: impact of interactions, polydispersity and external fields

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There is considerable industrial interest in novel flexible, transparent electrodes for electro-optical applications, in part because of dwindling natural reserves of indium, a component of transparent electrodes used, e.g., in LCD display technology. For this purpose, frantic research is currently being conducted worldwide into polymeric composites containing electrically conducting inorganic and metallic nanowires, carbon nanotubes, grafite flakes, graphene and so on. One of the objectives is to get as high as possible a conduction for as low as possible a nanoparticle loading but progress is slow. Unclear is why, e.g., carbon nanotubes dispersed in plastic matrix materials can have such widely diverging electrical percolation thresholds, even when their mean physical dimensions and other characteristics seem very similar. In an effort to shed light on this, we apply continuous space connectedness percolation theory to collections of anisometric particles with arbitrary polydispersity in length, width and levels of conduction between them. We find that the percolation threshold is extremely sensitive to even quite modest degrees of polydispersity and of alignment induced in the processing of the fluid composites before they set and become the final solid product. We find that the way polydispersity influences the percolation threshold depends on whether or not the length and width distributions are coupled or not. Finally, we provide an explanation why composites with graphene filler seems to have a larger percolation threshold than those with carbon nanotubes.