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Upscaling the dynamics of dislocations

Plasticity, the permanent deformation that one observes in metals, is the net effect of the movement of a large number of microscopic defects in the atomic lattice. These defects, called dislocations, are curve-like topological mismatches, and migrate through the metal under the influence of internal and external forces. Macroscopic, permanent, deformation arises through the concerted movement of a large number of these dislocations. It is a major challenge to connect a microscopic description of dislocation movement on one hand with models of macroscopic plastic behaviour on the other hand. If this were possible, then much could be gained: metals could be designed at the workstation with tailor-made properties, design of hybrid materials would become much easier, and generally the holy grail of 'materials by design' would come a little closer. At this stage we are not able to do this; there is a major gap between the models at these different spatial and temporal scales. Part of the difficulty lies in the complex interactions between dislocations: they attract and repel each other, and form complex higher-level structures that appear to play an important role in determining the macroscopic behaviour. Interestingly, the situation for the dynamics of the dislocations is significantly more complex than that of the energetics.

I will outline some recent results in this field, describe some of our own recent results in two dimensions, and mention some open questions and one or two mysteries.