On microstructural length scales in metallic materials

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In multiscale modelling of metallic materials, the micro-macro transition is frequently used sequentially and need not be related to a specific dimension range. However, the mechanical properties transferred from the micro to macro level may depend on microstructural length scales. The main challenge is to introduce into the material model such intrinsic length scales that possess a physical meaning and are suitable for predictive modelling of size effects. This lecture concerns the inelastic behaviour of metallic materials at the micron or submicron scale, with a focus on the modelling of microstructure formation and evolution during the deformation process. Three different approaches are presented along with the examples of size-dependent microstructures. In the first approach, illustrated by martensitic microstructures in shape memory alloys undergoing phase transformation, microstructural length scales are determined by the incremental energy minimization that includes the interfacial energy investigated at different levels of multiscale modelling. In the second approach, in phenomenological modelling of the microstructure evolution and strain hardening of metals during severe plastic deformation, dimensions of ordinary dislocation cells and cell blocks have a significant influence on the flow stress. In the third approach, illustrated by the characteristic wavelength of dislocation patterns in plastically deforming metal crystals, the intrinsic length scale in gradient plasticity is derived from phenomenological laws of plasticity of metals. The quantitative agreement between the predicted and observed indentation size effect has been found satisfactory.