Phase-field approach of multiple twinning and variant-variant transformations in martensite and multiphase phase field theory for temperature- and stress-induced PTs

***New advanced phase field model of transformations between martensitic variants and multiple twinning within martensitic variants is developed for large strains and lattice rotations. It resolves numerous existing problems. The model, which involves just one order parameter for the description of each variant-variant transformation and multiple twinings within each martensitic variant, provides a well-controlled description of variant-variant transformations and multiple twinning, including expressions for interface tension which are consistent with the sharp interface limit. The finite element approach is developed and applied to the solution of a number of examples of twinning and combined austenite-martensite and martensite-martensite phase transformations (PTs) and nanostructure evolution.

In multiphase phase field theory, a critical outstanding problem on developing of phase field approach for temperature- and stress-induced phase transformations between arbitrary n phases is solved. Thermodynamic Ginzburg-Landau potential for temperature and stress-induced phase transformations (PTs) between n- phases is developed. It describes each of the PTs with a single order parameter without explicit constraint equation, which allows one to use analytical solution to calibrate each interface energy, width, and mobility; reproduces the desired PT criteria via instability conditions; introduces interface stresses, and allows controlling presence of the third phase at the interface between two other phases. A finite-element approach is developed and utilized to solve problem on microstructure formation for multivariant martensitic PTs. Results are in quantitative agreement with experiment. The developed approach is applicable to various PTs between multiple, solid, and liquid phases and grain evolution and can be extended for diffusive, electric, and magnetic PTs.