Thermal Effects of Phase Transformations in Materials

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Abstract

Phase transformations are among the most important factors that influence mechanical behavior of materials. In many situations phase transformations are accompanied by the release of latent heat, which comes as a result of change of the energy content in the system. The heat is drawn away from the sources by the heat conduction mechanism, which changes the rate and outcome of the transformation that was the source of the heat in the first place. The thermal effects may result in appearance of unusual states or phases, in particular in nanosystems. Temperature gradients that develop during phase transformations affect the state of stress in the material due to thermal expansion. These effects are robust and conceivably independent of the method employed for the analysis. In my presentation I will give a physicist's prospective of this problem, which attracts my attention for over 15 years.

Phase transformations may be conventionally broken into three stages that a material undergoes from the beginning to end: nucleation, growth, and coarsening, with all the stages of phase transformations subject to thermal effects. Examples are: modulation mechanism of the decomposition of unstable states, heat trapping and surface creation/dissipation effects of interfacial motion, thermal drag and thermal waves of antiphase-domain boundaries motion. The author attempts to build a comprehensive theory of various thermal effects using dynamical Ginzburg-Landau theory.

Evolution equation for the interfacial motion applicable in various situations will be derived on the common grounds. This equation identifies the local interfacial variables like velocity, curvature, jumps of temperature and temperature gradient across the interface, and relates them to the thermodynamic and kinetic properties of the medium like surface energy and thickness, latent heat, mobility and thermal diffusivity. To classify different thermal effects that manifest in various situations, we introduce a comprehensive diagram in the plane of material's parameters. Several experiments are suggested for the experimental verification of the thermal effects.