PHASE TRANSITION BOUNDARY DYNAMICS IN THE PRESENCE OF CRYSTALS NUCLEATION

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The theory of motion of the solid/liquid interface in a supercooled melt is developed. Crystal nucleation and growth processes are responsible for the release of latent crystallization heat, which reduces the undercooling of the melt and narrows the thickness of the two-phase layer.

The crystal nucleation and growth in a metastable system (supersaturated solution or supercooled liquid) is well known to completely determine the dynamic behavior and properties of the phase transition layer. Such evolutionary processes can occur in a range of fields of modern science, from condensed matter physics to physical chemistry, biophysics, and the life sciences [1]. The main objective of this research is to formulate a theoretical method for solving the problem of the moving boundary of combined directional and bulk crystallization in a non-stationary regime.

The theory of motion of the solid-liquid interface in the presence of nucleation and particle growth processes in a supercooled layer is developed. Together with the developing crystals, that partly compensate for undercooling, this layer is propagating into the pure melt at a velocity that depends on the crystal growth rate and the nucleation rate. The result of this study is the dynamic law of interface motion Z(t)=a*t^(1/2) + b*y*t^{7/2} (a,b are constants, y is a function determined in [2]). This law differs significantly from the case without nucleation and crystal growth, which determines the interface as Z_0(t)=a*t^(1/2). A negative coefficient y [2] reduces the undercooled layer starting from a certain point in time. This is due to the effect of latent heat release, which reduces the supercooling of the melt and narrows its spatial size (the thickness of the two-phase layer).

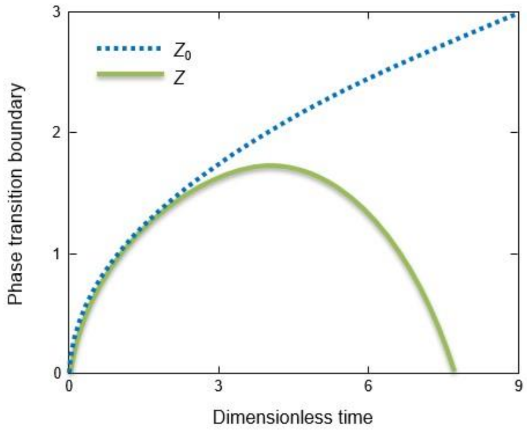

Fig. 1. The phase transition boundary as a function of dimensionless time

The analytical solution is shown in Fig. 1. The dynamics of the interface differs significantly from the particle-free case in the two-phase layer. This purely frontal case, shown by the dashed curve is described by the law of the square root of time, i.e. Z_0(t) $\sim$ $t^{(}$1/2). The nucleation and evolution of solids in the two-phase layer dramatically changes this dynamic law. Beginning at a certain point in time, the law of interface motion becomes a decreasing function of time. This is due to the fact that growing crystals release the latent heat of the phase transition, which partially reduces the undercooling in the two-phase layer and, consequently, its thickness.

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