3. The Dynamics of First-order Phase Transition: A Stochastic Approach with the Domain-size Distribution Function for the Late Stage

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changes drastically. In other words, we could say that at the
temperature where the relaxation time becomes $\tau \sim 10^{-10}$ s, which is
caused not only by temperature but also by enzymes, the double helix
would be melted out. Thus it has been found that the dynamical
structure of the primary hydration shell plays an important role in the
melting phenomena of the DNA double helix.

3. The Dynamics of First-order Phase Transition: A Stochastic Approach
with the Domain-size Distribution Function for the Late Stage
（一次相転移の動力学後期過程の
ドメイン・サイズ分布関数による記述）

Kazuyo Kaneko（金子一代）

Abstract

Many systems in nature make phase transitions of the first order.
Such a system, if quenched from a single-phase thermal equilibrium state
into a single-phase nonequilibrium state, evolves into another equilibrium
thermodynamic state which consists of two coexisting phases. These phase
separation processes are characterized by nucleation, spinodal
decomposition, and late stage growth and coarsening.

In this thesis, we first review existing studies of the phase
separation, and then attempt to treat the phase separation as a stochastic
process. In both cases of the early stage and the late stage of phase
transitions, all studies dealt with either semi-macroscopic dynamical
variables, i.e. the order parameters or the time-dependent probability
distribution functional. In their results, we place particular importance on
their conclusions on the time dependence of the domain growth.

In the treatment of the early stage, an important aspect is how the
nonlinearity is taken into account in the semi-phenomenological equations...
of motion for the order parameters. Hillert (1961), Cahn (1961) and Cook (1970) analyzed the early stage of spinodal decomposition by a linearized theory, so that they could not of course describe the last stage behavior of phase separations. Then, Langer et al. (1975) handled both effects of thermal fluctuations and the nonlinearity by deriving an equation for the probability distribution functional of the order parameters. On the other hand, Saito (1976) emphasized the necessity of considering the coherency spread over a system as well as the nonlinearity in order to analyze the evolution of a quenched system from a nonequilibrium state to an equilibrium state.

In the treatment of the late stage, the characteristic aspect is how the nonlocality is considered. When two or more kinds of domains coexist, there are two ways of approach: the derivation of equations of motion for the interface and the investigation of the time dependence of domain growth. Kawasaki et al. (1982, 1983) assumed that the interface thickness is thinner than the domain size, and transformed a nonlinear diffusion equation for the order parameter, i.e. the time-dependent Ginzburg-Landau equation, into an equation of motion for the interface. Concerning the domain size approach, Binder (1977) and Furukawa (1981, 1984) assumed that the domain size distribution function or the observable, i.e. the scattering function, should be scaled in unit of averaged domain size, and obtained the domain growth rate. In all the theories mentioned above, the power law behavior for the domain growth, $t^a$, is predicted, and discussions for the exponent $a$ are made. Shugard and Reiss (1976) proposed a stochastic model concerning the domain size distribution function and calculated the number of droplets with radii over the critical size at a time $t$.

In this thesis, we make an attempt to use a stochastic model in order to obtain the time dependence of the domain growth. The domain size is regarded as a coordinate in one-dimensional discrete "size space", and the process that a representative droplet grows or shrinks by the addition or loss of single element is thought of as a random walk on a lattice. The
domain size distribution function satisfies a differential equation or an
integral equation. In both formulas, the time-dependent moving rate on the
lattice determines two basic properties in the variation of domain size
distribution function: the magnitude of a small change in domain size and the
distribution of time interval necessary for the change. On the assumption of
an adequate functional form on the moving rate, the power law behavior for
the domain growth, \( \propto \), is obtained. The domain size distribution function
concerns originally with a one-dimensional characteristic length. In order to
know the distribution of area or volume, the explicit shape of a domain must
be considered. Therefore, we treat only one-dimensional case. The
asymptotic logarithmic growth law, already predicted by one-dimensional
equation of motion for the interface, is also confirmed by experiment. From
these observed data, we try to infer the time dependence of the domain size
distribution function.