Kinetics of Nucleation and Glass Formation

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Results are summarized on the more general, non-steady-state description of the kinetics of nucleation. It is shown, how in a number of recent developments the initial theoretical concepts, derived by Zel'dovich have been enlarged. These developments include a number of investigations of the effect of active foreign substrates (crystallization cores), of surfactants, of athermal nuclei etc. on the transient kinetics of nucleation. The influence of non-steady-state nucleation on the kinetics of the overall crystallization process is investigated and Ostwald's Rule of Stages is explained in terms of the same transient theory of nucleation.

It is shown, how the main kinetic parameter of the process of nucleation - the non-steady-state time-lag can be calculated in different cases of phase formation and how it is influenced by the nature of the newly formed phase (liquid or crystalline), and by the self diffusion coefficient (or the viscosity) of the initial phase. In glass forming melts characterized in the viscinity of the temperature of vitrification T_g by enormous viscosity, non-steady-state time-lags of the order of many hours can be expected.

Experimental results are given on the kinetics of nucleation in a number of simple glass forming substances ($NaPO_3$, Li_2OtSiO_2, metallic glasses etc.) demonstrating the non-steady-state character of this process in glass forming melts. It is shown, that the formation of glass-ceramic materials can be described as a case of heterogeneous non-steady-state nucleation and methods are given to calculate the activity of crystallization cores in the induced nucleation of glass forming melts.

The kinetic stability of an undercooled melt is derived by calculating the cooling rate, at which no detectable crystallization can be observed. In this way, by combining the Avrami-Kolmogorov equation in its more general, non-steady-state formulation with the cooling rate, generalized criteria for glass formation are formulated. These generalized criteria show, that the influence of non-steady-state effects on glass formation is most significant, when heterogeneous nucleation, or crystallization catalysis, due to surfactants are to be expected.

More detailed information in the basic developments given in the present lecture, may be found in the review articles cited below.

1. I.Gutzov, Contemp.Physics, 21, 121, 243, (1980).
2. I.Gutzov, D.Kashchiev, I.Avramov, J.Non-Cryst.Solids, 73, 477, (1985).
3. I.Gutzov, I.Penkov, Proceedings III Otto-Scholt-Symposium, Jena 1987, Wiss.Zs.Friedrich-Schiller-Univ., Jena, (Naturewiss. R.) 907, (1987)