Why solidification loves to occur in a metastable manner

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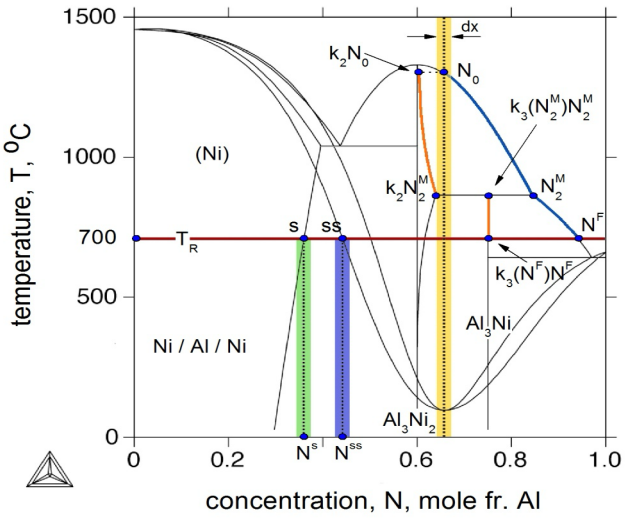
Abstract

Statement of the Problem: Some solidification processes very often occur in a metastable manner. Therefore, a metastable solidification is explained and justified thermodynamically. Thus, it is shown how the phase diagram for stable equilibrium can be transformed into a phase diagram for metastable equilibrium. The criterion for the mentioned transition, as formulated by Umeda, Okane and Kurz, is successfully applied. The mass balance fulfillment is discussed for the processes under investigation. The use of the Gibbs's Phase Rule allows to justify and show the satisfaction of the condition for the Zero Degrees of Freedom at every stage of the solid phases formation. A "mantis" phenomenon has been revealed and defined as the process also occurring according to the Gibbs's Phase Rule with the fulfillment of the condition for the Zero Degrees of Freedom. The Ni-Al, and Fe-Zn phase diagrams for the metastable equilibrium are calculated by means of the *Thermocalc* professional program. The Aziz's model for the partitioning varying with the solidification rate is applied to understand how the common eutectic reaction can be transformed into an oscillatory mode of the eutectic structure formation. The current considerations are referred to the known technologies such as diffusion soldering, hot dip galvanizing leading to formation of the protective coating with the presence of flux and D-gun spraying of the Fe-Al particles onto a steel substrate. Finally, it is explained why solidification loves to occur in the metastable manner with the use of the phenomenon of partitioning instead of the stable formation of the intermetallic compounds or intermetallic phases, usually, being the result of a proper peritectic reaction.

Conclusion & Significance: Technologists, not always, are aware of the occurrence of solidification processes under metastable conditions. Material, being the product of metastable solidification, changes its metastable structure into stable one during exploitation. Thus, the thermodynamic description of three popular technologies are delivered. Formation of the intermetallic compounds and phases is interpreted according to the phase diagrams for metastable equilibrium. It is presented how to understand the transformation from stability into metastability.



Superposition of the Ni-Al phase diagram for metastable solidification over the Ni-Al phase diagram for metastable dissolution. Thermodynamic prediction of the zones which are to be revealed experimentally within the Ni-substrate: dx – dissolution; ss – supersaturation, s – saturation zone.

Recent publications

1. Wołczyński W (2007) Concentration micro-field for lamellar eutectic growth. Defect and Diffusion Forum 272:123-138.
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3. Wołczyński W (2018) Development of the Jackson and Hunt theory for rapid eutectic growth. Archives of Metallurgy and Materials 63(1):65-72.
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6. Wołczyński W (2020) Entropy production in the stationary eutectic growth. Archives of Metallurgy and Materials 65(1):403-416.
7. Wołczyński W (2020) Pattern selection in the eutectic growth – Thermodynamic interpretation. Archives of Metallurgy and Materials 65(2):653-666.
8. Kwapisiński P, Wołczyński W (2023) Growth Law for columnar structure in copper and copper alloys solidifying at a high Peclet Number. Archives of Metallurgy and Materials 68(2):579-584.

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Photograph

Biography

Professor W. Wolczynski has expertise in the thermodynamic modelling of solidification processes and interpretation of the phenomena accompanied with solidification. He is the author of the theory based on the mass balance for the solute redistribution and micro-segregation after back-diffusion. He delivered a new solution to the diffusion equation for solidification of lamellar eutectic structure. Recently, application of the criterion of minimum entropy production allowed him to formulate the so-called Growth Law for both, the lamellar and rod-like eutectic structure formation. He extended the Growth Law for the irregular eutectic structure appearance. The thermodynamic description of some technologies such as diffusion soldering, hot dip galvanizing with presence of flux and D-gun spraying of particles onto steel are of the Professor's authorship.

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