SPECIAL STRUCTURES AFTER SOLIDIFICATION PROCESSES

YEAR 2

Lecturer: prof. Waldemar Wołczyński

1/ Fundamentals of solidification

Description of typical structures appeared in the massive ingot.
Structure formation under positive and negative thermal gradients.
Space-time-structure map for the massive steel/cast iron roll as it results from the temperature field analysis. Columnar ➔ equiaxed structure transition (CET) due to the thermal gradient field calculated numerically for the solidification of massive ingot.
Scheil's theory for the non-diffusive non-equilibrium solidification/micro-segregation.
Equilibrium solidification as it results from the mass balance (so-called Lever Rule).
New theory for solidification based on two phenomena: solute partitioning and solute redistribution after back-diffusion. Perfect mathematical reduction of the new theory to the Scheil's model and to the equilibrium solidification.
Development of the Scheil's theory for the multi-peritectic systems and multi-peritectic / eutectic systems.
Principle of unidirectional solidification – the Bridgman's system

2/ Theory of diffusion soldering/brazing

Description of phenomena which occur during soldering/brazing like: dissolution, solidification, solid/solid transformation. Diffusion zones within the substrate. Application of the Umeda-Okane-Kurz criterion to justify the occurrence of technology under meta-stable conditions. Application of the new theory for solidification based on partitioning and solute redistribution after back-diffusion and accompanied by the undercooled peritectic reactions. Development of the new theory for the multi-peritectic systems and multi-peritectic/eutectic systems. Calculations of the phase diagrams for the meta-stable equilibrium (Thermocalc Softaware): a/ for dissolution, b/ for solidification accompanied by the peritectic reactions resulting in the intermetallic phases/compounds formation. Experimental justification for the non-influence of time and non-influence of real temperature on the average solute concentration within the interconnection. Determination of the solidification path, solid/liquid interface path and solute redistribution path for the diffusion soldering/brazing. Simulation of the diffusion joint formation (reproduction of a ratio of the sub-layers thicknesses and the solute concentration profiles across the given joint sub-layers). Mass balance within the diffusion interconnection.

3/ Model for the solute micro-field ahead of the solid/liquid interface of a growing lamellar eutectic

Improvement of the Jackson-Hunt's theory for the lamellar eutectic growth. Replacement of the ideally coupled growth by the coupled growth with differentiated undercooling of both eutectic phases. New solution to differential diffusion equation. New boundary condition for the solution to diffusion equation. Localization of mechanical equilibrium, thermodynamic equilibrium and protrusion of the leading eutectic phase over the wetting eutectic phase. Application of the calculation of the entropy production due to the new description of the solid/liquid interface. Total mass balance and local mass balance. The relationship between growth rate and protrusion.

4/ Theory for the lamella ➔rod transformation in some eutectic alloys
Critical discussion of the Jackson-Hunt's theory for the prediction of the lamellar or rod-like structure formation within the eutectic alloys. Model for the irregular eutectic structure formation based on both a/ criterion of the entropy production minimum and b/ concept of the marginal stability. Transformation irregular➔regular eutectic structure shown on the paraboloid of entropy production on which trajectory of local minima of entropy production for stationary states and trajectory of marginal stability are drawn schematically. Oscillation of the structure parameters. Growth laws for the lamellar structure formation and for the rod-like structure formation of regular eutectics developed due to the application of the criterion of the minimum entropy production. Experimental determination the threshold rate and operating range of growth rates for the lamella ➔ rod transformation of the Al-Si eutectic. Simulation of the lamella ➔ rod transformation by the selection of lower minimum of entropy production (minimum at which rod-like structure formation occurs or minimum of entropy production at which lamellar structure formation is observed).