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Microgravity studies of solidification patterns in model transparent alloys onboard the International Space Station

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We review recent in situ solidification experiments using nonfaceted model transparent alloys in science-in-microgravity facilities onboard the International Space Station (ISS), namely the Transparent Alloys (TA) apparatus and the Directional Solidification Insert of the DEvice for the study of Critical Liquids and Crystallization (DECLIC-DSI). These directional-solidification devices use innovative optical videomicroscopy imaging techniques to observe the spatiotemporal dynamics of solidification patterns in real time in large samples. In contrast to laboratory conditions on ground, microgravity guarantees the absence or a reduction of convective motion in the liquid, thus ensuring a purely diffusion-controlled growth of the crystalline solid(s). This makes it possible to perform a direct theoretical analysis of the formation process of solidification microstructures with comparisons to quantitative numerical simulations. Important questions that concern multiphase growth patterns in eutectic and peritectic alloys on the one hand and single-phased, cellular and dendritic structures on the other hand have been addressed, and unprecedented results have been obtained. Complex self-organizing phenomena during steady-state and transient coupled growth in eutectics and peritectics, interfacial-anisotropy effects in cellular arrays, and promising insights into the columnar-to-equiaxed transition are highlighted.

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INTRODUCTION

Solidification microstructures in alloys largely determine the properties of materials, and their characterization is of utmost interest in industrial research. It is common practice to identify those microstructures ex situ under the microscope and to measure their morphological features with full knowledge of the chemical nature of individual compounds and the physical properties of the mixture. Most often, however, information is lacking on the actual solidification path during the cooling process, and a clear interpretation of how the distribution of the microstructures in the bulk solid occurred cannot be achieved. The central question—how, upon cooling, a heterogeneous crystalline solid forms from a homogeneous liquid mixture—is actually strikingly complex when considered on a fundamental level[1,2]. Frozen-in or as-cast microstructures form out of equilibrium. They arise from self-organizing processes during growth at the advancing interface between the solid and the liquid. Some characteristic lengths and their approximate scaling with microscopic properties and control parameters can be derived theoretically. A scaling analysis is however insufficient: spatiotemporal phenomena during solidification depend on boundary conditions, initial conditions, and the whole history of the process[3]. Theoretical challenges are primarily associated with steady-state shapes and patterns, their morphological stability against symmetry breaking, and the formation of long-lived stacking defects within basically periodic arrangements. In addition, this dynamics can be influenced by instrumental characteristics and by the crystalline structure of the growing solid—being a single- or a polycrystal or made of crystals of different phases—via the so-called interfacial anisotropy. Such challenging issues call for fundamental research based on in situ experimental diagnostics, using systematic protocols guided by the general concepts of the nonlinear physics applied to solidification phenomena[4].

In this review, we will report on recent observations made during microgravity solidification experiments using model transparent alloys. Focus is placed on unprecedented results obtained with two devices installed onboard the International Space Station (ISS), namely, the Transparent Alloys (TA) apparatus of the European Space Agency (ESA)[5] and the Directional Solidification Insert of the DEvice for the study of Critical Liquids and Crystallization (DECLIC-DSI) developed by the French National Center for Space Studies (CNES)[6] in close collaboration with NASA. Two distinctive features and strengths of this scientific research are worth underlining. First, considering the long characteristic times of the targeted phenomena, the ISS is the only facility that provides a stable reduced-gravity environment for experimental campaigns that typically require several weeks. Access is thus given to dynamic phenomena that are difficult to reproduce in a laboratory due, in particular, to the interaction of the solidification with convective motion in the liquid. High-quality experiments in essentially diffusion-controlled crystal growth conditions are key to a direct comparison with numerical simulations and an unequivocal identification of the relevant physical and geometrical parameters. Second, transparent alloys *that freeze like metals*[7] have been used for many decades as model systems for in situ experimental studies of solidification patterns[8–12]. The shape of the solid growing from the liquid mixture can then be followed in

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Roósz,Kinga Tomolya,2014-05-09 Selected peer reviewed papers from the Sixth International Conference on Solidification and Gravity September 2 5 2013 Miskolc Lillaf red Hungary *Heat Transfer in Aerospace Applications* Bengt Sundén,Juan Fu,2016-10-19 Heat Transfer in Aerospace Applications is the first book to provide an overall description of various heat transfer issues of relevance for aerospace applications The book contains chapters relating to convection cooling heat pipes ablation heat transfer at high velocity low pressure and microgravity aircraft heat exchangers fuel cells and cryogenic cooling systems Chapters specific to low density heat transfer 4 and microgravity heat transfer 9 are newer subjects which have not been previously covered The book takes a basic engineering approach by including correlations and examples that an engineer needs during the initial phases of vehicle design or to quickly analyze and solve a specific problem Designed for mechanical chemical and aerospace engineers in research institutes companies and consulting firms this book is an invaluable resource for the latest on aerospace heat transfer engineering and research Provides an overall description of heat transfer issues of relevance for aerospace applications Discusses why thermal problems arise and introduces the various heat transfer modes Helps solve the problem of selecting and calculating the cooling system the heat exchanger and heat protection Features a collection of problems in which the methods presented in the book can be used to solve these problems 4th International Conference on Experimental Methods for Microgravity Materials Science Research Robert Aaron Schiffman,1992 This collection of papers presented at the 1992 TMS Annual Meeting in San Diego explores the unique experimental opportunities available in microgravity and high temperature environments *Solidification and Gravity V* A. Roósz,Valéria Mertinger,Péter Barkóczy,Csaba Hoó,2010-05-04 Selected peer reviewed papers from the FIFTH INTERNATIONAL CONFERENCE ON SOLIDIFICATION AND GRAVITY University of Miskolc Miskolc Lillaf red Hungary TMS 2016 Supplemental Proceedings The Minerals, Metals & Materials Society (TMS),2016-02-03 The TMS 2016 Annual Meeting Supplemental Proceedings is a collection of papers from the TMS 2016 Annual Meeting the unedited papers have not necessarily been reviewed by the symposium organizers and are presented as is The opinions and statements expressed within the papers are those of the individual authors only and no confirmations or endorsements are intended or implied **Microgravity Science and Applications Program Tasks, 1990 Revision** ,1991 Microgravity Science and Applications Program Tasks United States. Office of Space Science and Applications,1991 **International Aerospace Abstracts** ,1998 High Entropy Materials Yong Zhang,2023-01-18 High Entropy Materials Microstructures and Properties summarizes recent developments in multicomponent materials It discusses properties processing modeling and applications of high entropy materials including metallic alloys and oxides It also discusses solidification sputtering cryogenic treatments CALPHAD methodology biomedical implants Fe based superconductors Fe rich high entropy alloys and more **Aluminium Alloys** Subbarayan Sivasankaran,2017-12-21 The major issue of energy saving and conservation of the environment in the world is being emphasized to us to concentrate on lightweight materials in which aluminium alloys are contributing more in applications in the twenty first century Aluminium and its related materials possess lighter weight considerable strength more corrosion resistance and ductility Especially from the past one decade the use of aluminium alloys is increasing in construction field transportation industries packaging purposes automotive defence aircraft and electrical sectors Around 85% is being used in the form of wrought products which replace the use of cast iron Further the major features of aluminium alloy are recyclability and its abundant availability in the world In general aluminium and its related materials are being processed via casting drawing forging rolling extrusion welding powder metallurgy process etc To improve the physical and mechanical properties scientists are doing more research and adding some second phase particles in to it called composites in addition to heat treatment Therefore to explore more in this field the present book has been aimed and focused to bridge all scientists who are working in this field The main objective of the present book is to focus on aluminium its alloys and its composites which include but are not limited to the various processing routes and characterization techniques in both macro and nano levels **23rd Annual Conference on Composites, Advanced Ceramics, Materials, and Structures - B, Volume 20, Issue 4** Ersan Ustundag,Gary S. 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Laxmanan,E. W. Collings,1989 The exciting results obtained in Skylab experiments have encouraged researchers around the globe to study the behaviour of materials under microgravity conditions The book presents the latest results in this important new area of research

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