Third and Final Shuttle Mission of the Isothermal Dendritic Growth Experiment Conducted--Highest Supercooling Ever Recorded Achieved

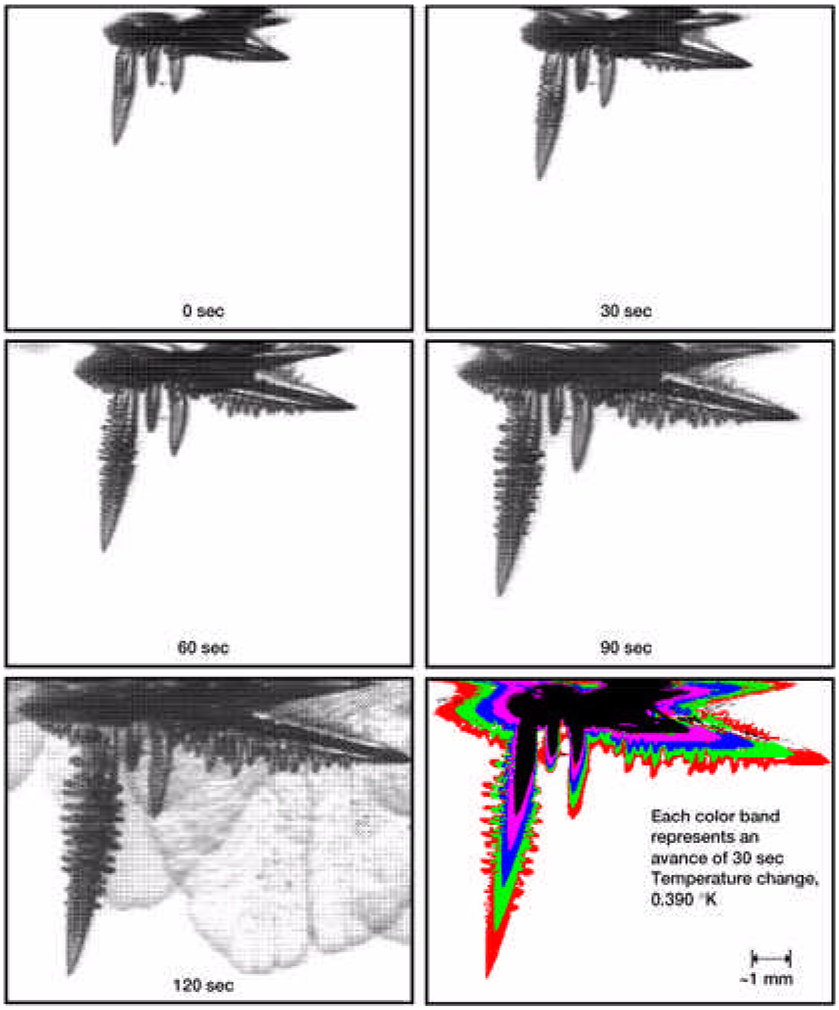
Dendrites describe the treelike crystal morphology commonly assumed in metals and alloys that freeze from supercooled or supersaturated melts. There remains a high level of engineering interest in dendritic solidification because the size, shape, and orientation of the dendrites determine the final microstructure of a material. It is the microstructure that then determines the physical properties of cast or welded products.

Although it is well known that dendritic growth is controlled by the transport of latent heat from the moving solid-liquid interface, an accurate and predictive model has not yet been developed. The effects of gravity-induced convection on the transfer of heat from the interface have prevented adequate testing, under terrestrial conditions, of solidification models.

The Isothermal Dendritic Growth Experiment (IDGE) constituted a series of three microgravity experiments flown aboard the Space Shuttle Columbia. The apparatus was used to grow and record dendrite solidification in the absence of gravity-induced convective heat transfer, thereby producing a wealth of benchmark-quality data for testing solidification models and theories. The principal investigator is Prof. Martin E. Glicksman of Rensselaer Polytechnic Institute in Troy, New York. The project is managed by the Microgravity Sciences Division at the NASA Lewis Research Center and is supported by a contractor team of engineers and technicians employed by Aerospace Design & Fabrication (ADF), Inc., under subcontract to the NYMA, Inc.

The first two flights of IDGE (STS-62 and STS-75) aboard the Second and Third United States Microgravity Payload (USMP-2 and -3) used ultrapure succinonitrile (SCN) as the test material. SCN is an organic crystal that mimics the solidification of body-centered-cubic metals, such as ferrous metals. The third and final IDGE flight (USMP-4), which was launched on STS-87 in November 1997, employed a different test material. This flight used pivalic acid (PVA)--a face-centered-cubic organic crystal that solidifies like many nonferrous metals. PVA, like SCN, has convenient properties, such as its transparent nature and its low melting point, that make it ideal for conducting benchmark experiments. Because a different sample was used, the universality of solidification theories could be tested.

The third and final flight of IDGE was a resounding success. Dendritic growths were obtained across the full range of supercooling required. In fact, during the mission, a growth was achieved at the high end of the supercooling range, 1.25 K--something never before accomplished even under terrestrial conditions. The data and subsequent analysis from the final flight experiment are currently at a preliminary stage. Thus far, the results indicate that dendritic growth in PVA is (as in SCN) diffusion-limited, with little, if any, kinetic response. This observation conflicts with the conclusion reached by other investigators that there are large interfacial kinetic effects in PVA.



Time-elapsed photographic sequence of a PVA dendrite grown during the STS-87 mission.

In addition to the investigation of dendritic solidification kinetics and morphology, the IDGE has been part of the development of remote, university-based teleoperations. These teleoperation tests point the way to the future of microgravity science operations on the International Space Station (ISS). NASA Headquarters and the Telescience Support Center at Lewis set a goal for developing the experience and expertise to set up remote, non-NASA locations from which to control space station experiments. Recent IDGE space shuttle flights provide proof-of-concept and tests of remote space flight teleoperations.

The IDGE flight series is now complete. The principal investigator and his team are currently completing analyses and moving toward final data archiving. The IDGE published results and archived data sets are being used actively by other scientists and engineers. In fact, they have been referenced in the classroom by a graduate-level instructor at Case Western Reserve University. In addition, the techniques and IDGE hardware systems that were developed are being employed for future dendritic growth flight experiments.

Find out more about this research. http://www.rpi.edu/locker/56/000756/

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