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DESCRIPTIONS OF EXPERIMENTS SELECTED FOR THE SPACE TRANSPORTATION SYSTEM (STS) MATERIALS PROCESSING IN SPACE PROGRAM

Edited by Robert J. Naumann
Space Sciences Laboratory

May 1978

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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16. ABSTRACT

This report presents the experiment description summaries for the first group of materials processing experiments planned for a Shuttle mission. The summaries give the objectives, the approach, the rationale for the use of space, and the anticipated results for each experiment. These experiments form the nucleus of the Materials Processing in Space program in the Shuttle era and provide the science requirements for the definition of the space processing facilities being developed for the Spacelab Module and Pallet.

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FOREWORD

The first group of investigators to conduct materials processing experiments on a Shuttle mission has been selected from proposals submitted in response to the Announcement of Opportunity AO-77-3. This selection was made by the Associate Administrator of the Office of Applications (now the Office of Space and Terrestrial Applications), National Aeronautics and Space Administration, based on recommendations from a specially appointed peer review committee and from the Applications Steering Group. This document is a collection of experiment summary sheets prepared by the Principal Investigators giving the objectives, the approach, the rationale for use of space, and the anticipated experiment results.

The first seven experiments discussed take advantage of the greatly reduced convective flow which provides quiescent growth or solidification conditions with precise control of temperature, growth rate, and composition. The next three are glass experiments that take advantage of the containerless aspects of space processing as well as the absence of Stokes bubble rise to investigate phenomena that cannot be unambiguously studied on Earth. The remaining experiments depend primarily on the absence of sedimentation to keep a material of different density in suspension during a process.

These experiments form the nucleus of the Materials Processing in Space program in the Shuttle era and provide the science requirements for the definition of the space processing facilities being developed for the Spacelab Module and Pallet. Precursor experiments for some of these investigators may be performed as part of the Space Processing Application Rocket (SPAR) program or the Materials Experiment Assembly (MEA) package carrying modified SPAR hardware during the Orbiter Flight Test (OFT) program.

It is anticipated that similar Announcements of Opportunity will be issued in the future and that 10 to 15 new investigators will be selected each year.

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Experiment No. M7706

GROWTH OF SOLID SOLUTION SINGLE CRYSTALS

Mirt C. Davidson
NASA/Marshall Space Flight Center

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Co-Investigators: A. F. Witt, MIT
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The objective of this experimental program is to determine suitable growth conditions for the production of high-quality solid solution crystals such as $Hg_{1-x}Cd_xTe$. This material is particularly useful as infrared detectors in the 8 to 14 micron band and is in great demand for both military and civilian applications. Many of these applications require larger crystals with much better homogeneity than are currently available. Particular emphasis in this study will be directed toward producing material with extremely high frequency response for wide bandwidth application. This requires very pure intrinsic material with carrier concentrations in the low 10^{14} cm^{-3} range.

An extensive ground-based program is under way to determine the effects of purity of starting materials, optimum growth conditions, and container material as well as the suitability of various growth techniques. Growth from the melt, from Te solvent zone, and solid state anneal are being considered. Samples of the material grown are characterized by several techniques, including resistivity, Hall mobilities, and infrared spectrometry.

The initial set of experiments will be carried out in the multiple zone furnace on STS-18. These experiments will be directed toward establishing the growth characteristics of HgCdTe in both growth from the melt and in growth from a traveling Te solvent zone. These data will be used to design the optimum growth techniques for later experiments utilizing growth systems of advanced design.

Growth of HgCdTe is extremely difficult for a number of reasons; i.e., the high preferential segregation of CdTe with respect to HgTe, microscale fluctuations in growth rate which result in severe compositional variations and contribute to interfacial breakdown, and the high vapor pressure of Hg which interferes with the liquid-solid interface in Te solvent zone growth.

It was demonstrated on Skylab by Gatos and Witt that the microfluctuations in growth rate are related to convective effects and do not occur in low gravity. Also, they found that a diffusion boundary layer was established after an initial transit region in which a steady-state compositional uniformity is maintained. The implication is that in a weightless environment, compositional uniformity can be accomplished on a micro- and macroscale. The macroscale uniformity will result in a large segment of the material grown having a prescribed band gap allowing optimization for a particular wavelength. The microscale variation in growth rate experienced on Earth represents a particularly critical problem. In systems such as HgCdTe, the conditions necessary to avoid interface breakdown include a very high thermal gradient together with a very low growth rate. In the presence of a fluctuating growth rate, these conditions are not achievable, resulting in a breakdown of the single crystalline structure.

The first experiments are limited by the gradient that can be imposed by the furnace facility but will provide information on how rapidly the diffusion-controlled boundary layer is established, establish whether there are microfluctuations in the growth rate, allow the determination of the radial compositional variations resulting from departure from a planar solidification front, and establish the growth rate at which interfacial breakdown occurs. This information will be utilized in designing an experiment to be carried out in the float zone or other suitable facility allowing limited production of high-quality HgCdTe for evaluation in devices.

Experiment No. M77087

SEMICONDUCTOR MATERIALS GROWTH IN LOW-G ENVIRONMENT

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NASA/Langley Research Center

Principal Investigator: R. K. Crouch, NASA/Langley Research Center

Co-Investigator: W. J. Debnam, Jr., NASA/Langley Research Center

The principal purpose of this experiment is to utilize the microgravity environment of space to investigate the growth of solid solution semiconductors. The specific objectives are to minimize or eliminate the segregation of constituents and to minimize the influence of thermal convection on the solidification process in the growth of single crystalline $Pb_xSn_{1-x}Te$. This particular material, like $Hg_xCd_{1-x}Te$, is a solid solution crystal, and the relative amounts of Pb and Sn can be continuously varied to give different band-gap energies. There is considerable demand for this material for use as infrared detectors out to 14 microns. Present production techniques can produce only small crystals whose electrical properties cannot be precisely controlled. There is a demand for larger, highly homogeneous crystals for use as detector arrays for infrared imaging devices.

Three different growth processes will be considered: (1) a vapor phase sublimation for seeded growth, (2) a modified Bridgman growth in which polycrystalline aggregate is necked down to encourage growth of a single crystal, and (3) a modified Bridgman melt-back and regrowth. These experiments will be carried out in the furnace module on STS-18.

It is difficult to grow crystals such as PbSnTe with a controlled composition because of the large difference between the solidus and liquidus lines on the phase diagram. Since PbTe solidifies first, macro- and microsegregation results. In zero-gravity conditions, macrosegregation is avoided because of the absence of sedimentation. In the absence of gravity-driven convection, a diffusion layer should build up in front of the solidification interface in which steady-state compositional uniformity is maintained. The absence of convective transport will allow much sharper gradients in the melt which are needed to prevent interfacial breakdown due to constitutional supercooling. In the absence of gravity, much longer zones can be maintained which allow a more nearly planar interface. In the vapor phase sublimation, the absence of gravity-driven convection provides a diffusion-controlled growth environment in which a uniform steady-state composition will be established and maintained. It is hoped that this will provide the proper stoichiometry for the desired composition.

It is anticipated that processing in a microgravity environment will result in improved techniques for growing solid solution crystals. These experiments will establish the growth techniques that will be used to produce limited quantities of PbSnTe for evaluation in devices.

Experiment No. M77082

VAPOR GROWTH OF ALLOY-TYPE SEMICONDUCTOR CRYSTALS

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E. A. Irene, IBM
C. C. Wang, RCA

The results of the investigators' previous space experiments (Skylab and ASTP) demonstrated the positive effects of microgravity on crystal morphology and led to the observation of unexpected transport phenomena. This experiment is concerned with the continued investigation of basic vapor transport and crystal growth properties of electronic materials. Solid solutions of these materials offer a wider range of electronic properties and can be designed for specific applications. The purpose of this investigation is to grow single crystals of alloy semiconductors by chemical vapor transport techniques in a microgravity environment.

The starting materials, transport agent, and end product are contained in evacuated closed ampoules of fused silica. The ampoule will be subjected to a temperature gradient, resulting in material transport via the gas phase from the source to the condensation region where the reverse reaction predominates, leading to crystal growth. Initial experiments will be carried out on the early Space Shuttle test flights using modified SPAR furnaces. The later experiments will utilize the furnace modules on STS-18, which will allow larger samples and will provide more precise control.

The inherent partial pressure gradients of the system and the presence of gravitational forces on Earth cause convective interference with the transport and condensation processes. The negative effects of this interference on crystal perfection are known. In the absence of gravity-driven convection, crystals of better quality can be obtained, as was demonstrated on previous experiments. It was thought that this superior quality resulted from the more uniform growth environment associated with diffusion-controlled conditions; however, the observed transport rate was much faster than predicted by diffusion theory, perhaps because the assumed chemical reactions involved are incomplete. Therefore, more work both on the ground and in space is required to understand crystal growth by chemical vapor transport in low gravity.

The prospect of growing reasonably larger crystals with very low defects is interesting for a variety of technologies ranging from high-temperature semiconductors to room-temperature nuclear radiation detectors. It is anticipated that these experiments will contribute to the understanding and the development of a chemical vapor transport model for microgravity conditions. This would establish boundary conditions for space processing of multicomponent systems by this process.

Experiment No. M77055

HgI_2 CRYSTAL GROWTH FOR NUCLEAR DETECTORS

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Co-Investigators: Lodewijk van den Berg, EG&G, Inc.
Michael M. Schieber, Consultant to EG&G, Inc., and Professor, The Hebrew University, Israel

The purpose of this investigation is to grow mercuric iodide crystals in a low-gravity environment to obtain higher perfection by taking advantage of diffusion-controlled growth conditions and by avoiding the problem of strain dislocations produced by the crystal's weight. This crystal has considerable practical importance as a sensitive gamma-ray detector and energy spectrometer that can operate at ambient temperature, as compared to presently available detectors that must be cooled to near liquid nitrogen temperatures. However, the performance of such crystals only rarely approaches the expected performance, presumably because of defects that limit the distance the carriers can drift before being trapped.

These crystals will be grown by vaporization and recondensation at approximately 120°C in a specially designed furnace aboard Spacelab 3. Provisions will be made to reverse the growth procedure if polycrystalline growth begins, which is a common problem in growing this crystal on the ground. Extensive experiments will be conducted prior to flight to optimize the growth process, to establish the best performance that can be obtained in the terrestrial laboratory, and to provide a basis for comparison with the low-gravity results.

There is good reason to believe that the growth of this crystal can be improved in a low-gravity environment. The absence of gravity-driven convection reduces fluctuations in the vapor density and temperature in the vicinity of the seed crystal. This better-controlled environment is conducive to uniform growth with far fewer defects, as demonstrated by Wiedemeier on Skylab. Secondly, this particular crystal is a layer type with weak bonding between slip planes, and it is believed that the high dislocation densities and strain fields observed in the terrestrially grown crystal originate from the weight of the crystal as it is supported at the growth temperature.

It is anticipated that the mercuric iodide crystals grown in space will have much lower defect densities and will exhibit much better performance than the best mercuric iodide grown perviously. This will establish the inherent performance of this crystal and may lead to a limited production of these crystals in space for experimental nuclear radiation detectors.

Experiment No. M77058

SOLUTION GROWTH OF CRYSTALS IN ZERO GRAVITY

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Co-Investigator: Roger Kroes, NASA/Marshall Space Flight Center

A series of experiments will be performed in which crystals will be grown by the low-temperature solution growth technique in a microgravity environment of the orbital Spacelab. The objectives are: (1) to produce structurally more homogeneous crystals free from inclusions of solution by eliminating convection transients, (2) to obtain data on mass and heat transport in a diffusion-controlled growth system, and (3) to confirm the advantages of a microgravity environment for solution crystal growth.

Triglycine sulfate (TGS) crystals will be grown in the multipurpose fluids facility on Spacelab 3 by slowly extracting heat at a programmed rate through a seed crystal of TGS suspended on an insulated sting in a saturated solution of TGS. Variations in the liquid density, solution concentration, and temperature around the growing crystal will be studied using a variety of techniques such as optical absorption at selected wavelength, schlieren, shadowgraph, and interferometric measurements. Growth in Earth gravity will be studied by the same optical techniques, and the resulting crystalline features will be compared and correlated with the growth conditions.

Schlieren and shadowgraph images of crystals growing from solutions in unit gravity show massive convective flow because of thermal and concentration gradients as the solute is incorporated into the crystal. Generally, this is controlled by gently stirring the solution to keep uniform growth conditions. However, this uniformity can only be approximated, and small-scale inhomogeneities always exist which adversely affect the growth of the crystal. In a microgravity environment, it should be possible to eliminate convective flows and establish a diffusion-controlled transport of the solute to the interface. By extracting heat from the crystal in a controlled manner it should be possible to maintain saturation at the growth interface. This should allow a slow but very uniform growth, resulting in a high degree of crystal perfection.

It is expected that the growth rate will be slower but more uniform in a microgravity environment because of the diffusion-limited process. This should lead to much greater crystal perfection. Also, the growth rates for different crystallographic axes should be determined unambiguously and can be compared with existing crystal growth theories. In addition, TGS has practical applications as infrared detectors whose performance might be improved by increased perfection.

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Experiment No. M77100

CRYSTAL GROWTH IN A SPACEFLIGHT ENVIRONMENT

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Co-Investigators: Martin H. Leipold, Jet Propulsion Laboratory
William R. Wilcox, Clarkson College of Technology

Program Manager: Charles H. Savage, Jet Propulsion Laboratory

The experiment will determine whether the near-weightless environment of a Space Shuttle/Spacelab mission is sufficient for the growth of defect-free crystals and the extent to which residual and transient accelerations, such as orbital correction maneuvers, should be suppressed or minimized. In addition, data will be obtained on growth rate and crystal quality as a function of the presence or absence of forced convection.

Crystals will be grown from transparent fluids at programmed cooling rates in controlled thermal geometries. A time-lapse movie camera will record a continuous cyclic sequence of schlieren, shadowgraph, and reflected-light images of the growing crystal and surrounding fluid. Analysis of these images will provide maps of the growth rate, fluid motion, and interface surface texture. These data will be compared with the distribution of defects and impurities in the recovered crystal and with the accelerational history of the space flight.

At 1-gravity conditions, crystal growth causes buoyant convection in the surrounding fluid. This convection is usually unstable and causes defects and impurity fluctuations in the crystal. Skylab experiments demonstrated that growth in a near-weightless environment results in more uniform crystals with fewer defects. However, it is not yet known whether the residual gravity or transient accelerations in a typical Space Shuttle mission are large enough to have an adverse effect on crystal growth experiments. Moreover, since convection is usually the principal mechanism of mass transfer at one gravity, crystals grown from flux or solution in space might have to be grown very slowly, unless forced laminar convection can be used without impairing crystal quality.

The experiment will provide data on the acceptable limits of residual and transient accelerations that can be tolerated on space flight missions involving crystal growth experiments. It will also provide information on optimum temperatures, fluid compositions, and growth rates for optimum crystal growth.

Experiment No. M77075

ALIGNED MAGNETIC COMPOSITES

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Co-Investigator: W. R. Wilcox, Clarkson College of Technology

The MA-070 experiment conducted on the Apollo-Soyuz Test Project (ASTP) directionally solidified the MnBi/Bi eutectic, with a planar faceted/nonfaceted interface. The microstructure of the orbitally grown ferromagnetic MnBi phase was considerably finer than within identically processed terrestrial samples. In addition, the space-processed samples exhibited substantial improvements over the intrinsic coercive strength, magnetic induction, and the static and dynamic energy products of the terrestrially processed samples. There are varying hypotheses to explain these results, and this investigation is designed to determine whether the origins of these improvements are gravitationally dependent. This will be first studied utilizing designed experiments that vary solidification processing parameters such as growth rate (R), thermal gradient (G), and composition (X). These experiments will ascertain whether the enhanced magnetic properties are unique to samples grown in space, or whether they can be duplicated on the ground by an optimization of the processing parameters.

Initial experiments within the SPAR 76-22 experiment ground-based program have shown that process optimization can improve the room temperature coercive and magnetization properties significantly. However, the ASTP flight samples remain some 30 percent better than terrestrial samples with virtually identical microstructures, or microstructures that should be superior magnetically. The reasons for this are being pursued further, on the ground.

Initial flight experiments will consist of directionally solidifying eutectic composites of MnBi/Bi on SPAR and on an early Space Shuttle flight. The solidification processing parameters will be systematically varied, and in situ thermal measurements will be made. Comparative analyses will be made of the flight samples and identically processed terrestrial samples.

Also, cooperative growth of off-eutectic alloys will be attempted to increase the percentage of the ferromagnetic MnBi phase. A theoretical analysis of off-eutectic directional solidification will be conducted using boundary layer analysis techniques. This should provide better insight into the effect, or lack thereof, of gravitationally induced transverse convective flows at the solidification interface. The results of this theory will be tested on the ground and in flight if, as anticipated, a low-gravity advantage is predicted.

Although directional solidification of nonfaceted eutectics is strictly a diffusion-controlled process, the coupling of a faceted eutectic has other kinetic limitations as well. These may well be influenced by thermal and flow processes that are directly, or indirectly, dependent on gravity. These, in turn, influence the microstructure and the magnetic properties. The understanding of convective influence on faceted eutectic and off-eutectic solidification is a primary consideration of the ground-based and flight programs. The fact that there was an unexpected gravitational effect in the previous experiment is a compelling reason for a systematic investigation of this phenomenon.

The anticipated results of this experiment are a better understanding of cooperative growth of directionally solidified eutectics, off-eutectics, and peritectics, particularly with regard to the role played by convective effects. This may lead to improved magnetic materials that approach their theoretical coercive strength, imposed by crystal anisotropy, and remanent magnetization.

Experiment No. M77022

FINING OF GLASSES IN SPACE

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Co-Investigator: E. J. Hornyak, Owens-Illinois, Inc.

Gas bubble removal (fining) is an important part of the glass manufacturing process. In general, high-technology glasses must be produced virtually free from bubbles to be useful. However, fining of glasses in space may prove to be difficult since Stokes bubble rise will be virtually inoperative in the microgravity environment of the Space Shuttle. Thus, the plan is to investigate the feasibility of employing bubble dissolution as an effective bubble removal mechanism. This will entail finding the appropriate refining agent, refining agent concentration, and temperature to employ for a given fining situation.

Space Shuttle experiments will consist of two types: (1) single-bubble studies and (2) multi-bubble refining investigations. A single bubble may be introduced into a small, well-refined glass melt via a bubble injection technique. The position and size of the bubble will be monitored as a function of time via photographic methods. The chemical composition of the bubble may be determined by quenching the melt and analyzing the gas content of the bubble entrapped in the glass. Refining experiments will also be performed utilizing batch mixtures of raw materials. Preliminary ground-based studies will be employed to determine the best methods of sample fabrication, fining temperature, refining agent concentration, and other processing parameters. Bubble number and bubble radii will be monitored continuously.

Since in the 1-gravity environment of an Earth-based laboratory both convective flows in the melt and buoyant forces will contribute to bubble dynamics, only in the microgravity environment of space can one determine the role of gas diffusion effects at refining temperatures.

It is anticipated that gas bubble removal from melts in a microgravity environment may be a difficult task. Since the production of many glasses and other materials requires a defect-free product, the inability to remove such defects could have dire consequences for space processing such materials. It is believed that early flight data will provide the information which will lead to the correct procedures for eliminating gas bubbles from liquids in a microgravity environment. In addition, the "simpler environment" of the space laboratory should provide information regarding bubble behavior which could be utilized in manufacturing procedures used on Earth.

Experiment No. M77010

PHYSICAL PHENOMENA IN CONTAINERLESS GLASS PROCESSING

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Co-Investigator: Robert Cole, Clarkson College

The purpose of this experiment is twofold: (1) to develop novel techniques for mixing and fining glasses in a weightless environment and (2) to determine the feasibility of producing spherical glass shells with highly uniform wall thickness in space for the inertial confinement fusion program.

The experiments using molten glasses and model fluids will be carried out in a special furnace which uses a three-axis acoustic positioning device to manipulate the samples and to prevent them from contacting the furnace walls. A spot-heater will be used to introduce a thermal gradient to investigate thermocapillary mixing and thermal migration of bubbles. The centering of a bubble in the sample will be investigated by various mechanisms such as successive rotation about the three axes. Containerless processing of glasses in a weightless environment is a promising technological endeavor because problems of chemical reaction and nucleation at the container wall can be avoided. Also, the lack of buoyant forces on a bubble inside a thin-walled glass shell may allow more precise control of the wall thicknesses than can be accomplished by processing in normal gravity. The absences of gravitational forces may, on the other hand, adversely affect both the homogenization and fining (removal of gas bubbles) from the melt; therefore, it is necessary to consider alternate methods for accomplishing these operations in zero gravity.

The types of glasses that may eventually be produced in space range from lanthanum and other rare Earth oxide glasses with unique optical properties to high efficiency laser host glasses for high-power lasers. Glass shell fuel containers with diameters in the range of 1 to 5 mm and uniform wall thickness will eventually be needed for the inertial confinement program to develop fusion as a virtually inexhaustible energy source. Present Earth-based technology has not succeeded in producing satisfactory shells in this

size range. It is anticipated that these experiments will provide fundamental information of potential value to glass processing in space and/or on Earth.

Experiment No. M77095

CONTAINERLESS PREPARATION OF ADVANCED OPTICAL GLASSES

Ralph Happe
Rockwell International

Principal Investigator: Ralph Happe, Rockwell International

Melting of oxide glasses in space (Earth orbit) has the advantage that no container or mold is required. The absence of a melting container promises to eliminate reactions with the crucible, which would be particularly advantageous for melting refractory oxide materials. The absence of a mold for cooling would eliminate most heterogeneous nucleation sites, greatly enhancing the possibilities for glass formation. New glasses with interesting new combinations of optical properties (i.e., index of refraction, dispersion, partial dispersion, and transmission) might then be produced.

The primary purpose of this investigation is to obtain experimental evidence of the scope of the anticipated new area of optical glasses that may be prepared with containerless melting and cooling in space. It is also planned that this investigation will give a more complete knowledge of the processing parameters critical to glass formation with containerless melting and cooling in space.

A number of oxide compositions with melting points below 1600°C will be melted in a containerless melting facility located in the Space Shuttle pallet area. In addition to sample composition, variables that may be studied in the space experiments include effects of starting material preparation on final glass quality, effects of melting temperature and time on glass quality, and, perhaps, effects of various cooling rates on glass formation. A program of ground-based research will precede the flight experiments. This program will experimentally determine appropriate compositions to be studied in space and will investigate methods of starting material preparation. To the extent feasible, processing parameters will be studied to serve as a basis of comparison with flight experiment results. A postflight evaluation will study the flight records and perform pertinent quality and property measurements on the returned flight samples. The flight results will be compared with the ground-based results.

It is anticipated that unique glasses will be formed by using containerless processing in space. Some of these glasses should have sufficiently valuable combinations of optical properties to be of commercial interest.

Experiment No. M77012

SOLID ELECTROLYTES CONTAINING DISPERSED PARTICLES

J. Bruce Wagner
Arizona State University

Principal Investigator: J. Bruce Wagner, Arizona State University

In this investigation solid state electrolytes such as Cu and Ag halides with a uniformly dispersed second phase of fine Al_2O_3 and/or SiO_2 particles will be prepared in low gravity. It is known that the presence of a dispersion of this second-phase material considerably enhances the ionic conductivity of these electrolytes, but the exact mechanism is not understood. By varying the size and concentrations of the second-phase material, it may be possible to evaluate the relative importance of interfacial conduction, space charge effects, and possibly other ion conduction enhancement mechanisms if good control of the distribution of the dispersed particles can be maintained during solidification.

The first attempts at preparing these uniform dispersions will be made using existing Space Processing Applications Rocket (SPAR) hardware on early Space Shuttle test flights. The samples will be prepared by mixing the material in powder form and melting and solidifying the mixture in space. Care must be taken in controlling the solidification front velocity to prevent rejection of the second-phase material, and this investigation is being coordinated with another investigation using SPAR flights to establish a general theory of second-phase incorporation/rejection. Finally, experiments will be conducted in the solidification module carried on STS-18 which will provide optimized heating and solidification conditions for this experiment.

One of the difficulties involved in preparing such samples on Earth is that the dispersoids have a different density and tend to sediment when the matrix material is melted. In a low-gravity environment the buoyant forces responsible for this separation are absent and the initial homogeneity can be maintained through melting and solidification.

It is anticipated that the experiment will yield several samples with homogeneous distributions of the oxide particles that can be used to study ionic conductivity as a function of particle size and average spacing. These

studies will contribute to the understanding of ionic conduction enhancement in solid electrolytes, which could lead to improved performance of batteries.

Experiment No. M77030

LIQUID MISCIBILITY GAP MATERIALS

S. H. Gelles
S. H. Gelles Associates

Principal Investigator: S. H. Gelles, S. H. Gelles Associates

Co-Investigator: A. J. Markworth, Battelle Columbus Labs

The objective of this investigation is to study the evolution of microstructural features of alloys that contain a liquid phase miscibility gap. Of particular interest are the agglomeration and segregation that occur within the miscibility gap and the processes that occur at the monotectic and eutectic temperatures.

The effort will involve three alloy systems: Al-In, Pb-Zn, and Pb-Cu. Initial experiments using SPAR rockets will be used to verify homogenization techniques. These will be followed by experiments on the early Space Shuttle test flights using modified SPAR hardware and later on the STS-18 flight using the furnace module. The flight experiments will be supplemented by (1) laboratory tests in which the immiscible systems will be heated above the consolute temperature and cooled at various rates to determine the rate at which the phases separate and agglomerate and (2) by theoretical analysis of droplet nucleation and coalescence during cooling through the miscibility gap and the structural changes occurring during solidification.

Many alloy systems have miscibility gaps in which two liquid phases are immiscible below a particular temperature called the consolute temperature. Many of these alloys cannot be formed in bulk in Earth gravity because the density differences of the two liquid phases result in rapid separation when the melt is cooled through the miscibility gap. It is believed that removal of the buoyant forces by cooling such systems in a low-gravity environment will prevent this separation and allow the formation of these alloys.

The study of the behavior of immiscible alloys is an important theoretical problem in solidification physics that cannot be studied in an

Earth-gravity environment. Also, since there are some 500 systems that exhibit miscibility gaps, this investigation offers a rich opportunity to find new alloys with unusual properties.

Experiment No. M77045

PRODUCTION OF LARGE-PARTICLE-SIZE MONODISPERSE LATEXES IN MICROGRAVITY

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Lehigh University

Principal Investigator: John W. Vanderhoff, Lehigh University

Co-Investigators: Fortunato J. Micale, Lehigh University
Mohamed S. El-Aasser, Lehigh University
Dale M. Kornfeld, Marshall Space Flight Center

This program comprises the development of a process to produce monodisperse latex spheres in larger sizes than can be currently produced on the ground. Monodisperse latex particles have found a remarkable number of uses ranging from calibration standards for electron microscopy, light-scattering devices, and filters, to medical uses such as measuring pore sizes in membranes and sereological tests for a multitude of diseases. Monodisperse particles in the range from 2 to 20 microns are not available because they are too large to be grown in production quantities by emulsion polymerization and they are too small to be sized by microsieving. Particles in this range are in demand by the scientific community for calibration of devices, particularly those used for counting blood cells and for various membrane sizing applications.

The test flights of the Space Shuttle will be used to establish the reaction rates and will provide the necessary design parameters for the production runs to be carried out on Spacelab 3. A monomer is mixed with water and a seed latex in a reactor vessel, and heat is used to initiate the reaction. Careful control of the reaction must be maintained to prevent coagulation or initiation of new crops of particles. Larger particles must be produced by successive steps in which the product of the previous reaction serves as the seed for the next reaction.

The difficulty in preparing particles larger than 2 microns on the ground lies in the fact that the density of the particles changes during the process as the polymerization progresses. Since such particles are too large to be held in suspension by Brownian motion, they tend to "cream" during the early stages of growth and sediment during the later stages. This can be prevented by vigorous stirring or agitation, but this tends to coagulate the mixture. These problems should be eliminated in a low-gravity environment since the buoyant forces are absent and the larger particles should stay in suspension more or less indefinitely.

Production runs of 1-pound quantities each of four different sizes of monodisperse latex are planned for Spacelab 3. Current selling prices for monodisperse latex spheres are $30,000/pound, and a premium price could be expected for the larger sizes. In addition to the use of the larger size particles as calibration standards, they are also in demand for studying the diffusion of carcinogenic particles such as asbestos through the stomach and intestinal walls. Other such uses will become apparent when the particles become available to researchers.

Experiment No. M77113

AGGREGATION OF HUMAN RED BLOOD CELLS

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The objectives of this investigation are: (1) to study aggregation of red blood cells in order to define the maximum size and morphology of aggregates of red cells under conditions of weightlessness, (2) to define the effect of various agents (fibrinogen, cholesterol, drugs, etc.) on the size of these aggregates in order to develop a new diagnostic test, and (3) to study viscosity of blood under high and low shear rate.

Anticoagulated blood samples at normal or lowered percentage of red blood cells and known content of cells, proteins, and lipids will be injected into the space contained by two flat parallel plates made of optical-quality glass. Blood preparations from normal donors and patients suffering from various diseases (inter alia, myocardial infarct, hypertension, renal failure, diabetes, multiple myeloma and other forms of cancer) will be studied. Measured amounts of agents such as fibrinogen, cholesterol, triglycerides paraproteins, and snake venom preparations will be injected into the gap to observe two phenomena: (1) diffusion of the agent with corresponding increase/decrease of the size of aggregates, and (2) the effect of these agents as modified by the type of disease or type of ABO blood group.

The space environment offers the advantages of no fluid motion and weightlessness to determine the ultimate size of red cell aggregates. On Earth, gravity interferes with the measurement of aggregation because red blood cells, which are approximately 7 microns in diameter and have densities of approximately 1.09 g/cm^3, and their aggregates sediment rapidly.

It should be possible to establish the maximum size of red cell aggregates uninfluenced by flow or sedimentation due to gravity. This size should be intrinsically related to the concentration of ingredients in different blood samples and various patho-microcirculatory phenomena and thus have potential diagnostic application.

APPROVAL

DESCRIPTIONS OF EXPERIMENTS SELECTED FOR THE SPACE TRANSPORTATION SYSTEM (STS) MATERIALS PROCESSING IN SPACE PROGRAM

Edited by Robert J. Naumann

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

Charles A. Lundquist

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