Investigation of the Crystal Growth of Dielectric Materials by the Bridgman Technique Using Vibration Control

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Objectives of Investigation

The principal goal of this ground-based program, which started in February 1998, is to investigate the influence of low frequency vibrations on the fluid flow and quality of dielectric oxide crystals grown by the vertical Bridgman method. This experimental program, a collaborative effort between Stanford University and the General Physics Institute of the Russian Academy of Sciences in Moscow, includes a strong emphasis on both physical modeling and the growth of some technologically important materials. It is in close collaboration with the theoretical and numerical investigations of A. Fedoseyev and I. Alexander in another NASA-sponsored program. This latter program involves a study of vibro-convective buoyancy driven flows in cylindrical configurations with the expectation of being able to use vibrational flows to control buoyancy driven fluid transport to off-set the effect of "g-jitter" during microgravity Bridgman crystal growth. These two programs taken together will lead to a new parametric control variable which can be used to either suppress or control convection and thereby heat and mass transport during Bridgman crystal growth. It is expected to be effective in either a terrestrial or space environment.

The experimental program is designed to verify and refine the results of the predictions made in the theoretical program, lead to the design of vibration controlled growth systems which can adapted to NASA flight ready crystal growth furnaces, and provide recommendations for the use of this vibrational technology in space growth experiments.

The specific objectives of the program are as follows:

1) Investigate how applied low frequency vibrations affect fluid flow during Bridgman crystal growth and develop relationships between vibro-convective-mediated flows and crystal quality. This part of the program will involve extensive experimental physical modeling using noncrystallizing water-glycerine mixtures and low temperature, transparent model growth systems;

2) Establish the most appropriate mode(s) for introducing low frequency vibrations into crystal growth systems, and optimize parameters for producing desirable fluid flow regimes (heat and mass transport conditions) in crystal growth systems with different physical and material properties. Solve the specific technical problems associated with the introduction of vibrations into real growth systems. Design and construct apparatus for fluid flow and crystal growth experiments;

3) Correlate vibration induced flows with: a) interface shape and position; b) striations; c) microsegregation; d) dopant distribution; and, e) crystal perfection, etc.;

4) Demonstrate the effectiveness of vibroconvection control during the growth of nominally pure and doped technologically important dielectric oxide single crystals;

5) Verify and refine the theoretical predictions derived from mathematical modeling research;

6) Develop quantitative laws for predicting the most appropriate growth conditions for a specific material and system geometry; and,

7) Provide recommendations for the use of vibrational technology in space and terrestrial growth experiments.

Benefits to Microgravity Research

It is well known that natural buoyant convection in terrestrial crystal growth systems has a profound (often negative) influence on crystal quality (defects and homogeneity) and growth rates. Recent numerical modeling work has confirmed that vibrations can be used to suppress buoyancy driven flows. It has been indicated that such suppression might be very effective at reduced gravity levels of 10^{-4} g or less. This has raised the possibility that, under microgravity conditions, controlled vibrations might be used to mask the undesirable "g-jitter" induced convective effects. Such g-jitter convection can be caused by quasi-steady residual acceleration (due to gravity gradients and atmospheric drag effects) and to transient and oscillatory acceleration disturbances. One approach to vibration isolation might be the use of low frequency vibrations to either suppress flow or to provide stable flow regimes tailored to a particular set of crystal growth experiments which essentially overwhelm the unstable flows.

Significant Results

Since the program began a few months ago, the construction of a video accessible, computer controlled transparent Bridgman furnace has been designed and built by the Russian group, and special ampoules designed for the vibrational studies. The U.S. program has focused its initial efforts on the effect of induced vibrations on fluid flow in a simulated Bridgman growth system. The particular case being studied involves two orthogonal vibrations normal to the crucible axis (equal amplitude, phase difference 90°) which has been shown to produce high rates of fluid flow in a terrestrial environment. Data previously collected on the relationship of fluid flow to the Reynolds number, Froude number, dimensionless amplitude of vibration and crucible aspect ratio has been recently analyzed. This analysis shows that two of the independent parameters are gravity dependent. We are continuing to study this latter method to understand the effect of reduced gravity on the fluid flow rates.