Conclusion

The behavior of liquid-filled projectiles over long flight paths is well determined by the use of solar aspect sensing and FM/FM telemetry. Transient eigenfrequencies have been experimentally demonstrated to exist for appropriate cavity geometry and fill. A slow angular momentum interchange between the liquid and casing increases the probability of projectile undamping by allowing the casing nutational frequency to hover in the vicinity of the primary eigenfrequency mode.

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Electrical Resistivity of Gallium-Bismuth Solidified in Free Fall

LEWIS L. LACY*
NASA Marshall Space Flight Center, Huntsville, Ala.
AND
GUENTHER H. OTTO†
The University of Alabama in Huntsville, Huntsville, Ala.

Introduction

IMMISCIBLE materials in their liquid state may be defined as two or more component alloys which are mutually insoluble at a given temperature and pressure. A study of existing phase diagrams[1] reveals that there are about 500 binary liquid immiscible systems occurring between two metals or metals mixed with metallic oxides, indicating that the phenomenon of immiscibility is rather common. Despite their immiscibility, two liquid metals may be mixed to form a dispersion. In this case, one of the fluids generally breaks up into small droplets which are dispersed into the second fluid that forms the host or matrix phase. However, since the two liquid metals usually have different densities, gravity-induced segregation will occur, and the two components will finally separate by coalescence. If the dispersion is performed in a zero-g environment, density segregation does not occur, and a uniform and stable dispersion can be obtained as demonstrated recently with an experiment on Skylab.[2] Appropriately chosen material combinations can then be solidified in a low-gravity field to yield unique composite alloys, as demonstrated by experiments performed on Apollo 14,[3] Skylab,[4] and the Marshall Space Flight Center (MSFC) drop tower.[5,6]

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Index categories: Materials, Properties of; Structural Composite Materials (Including Coatings); Liquid and Solid Thermophysical Properties.

* Senior Solid State Physicist, Space Sciences Laboratory.

† Assistant Research Professor, Department of Physics.

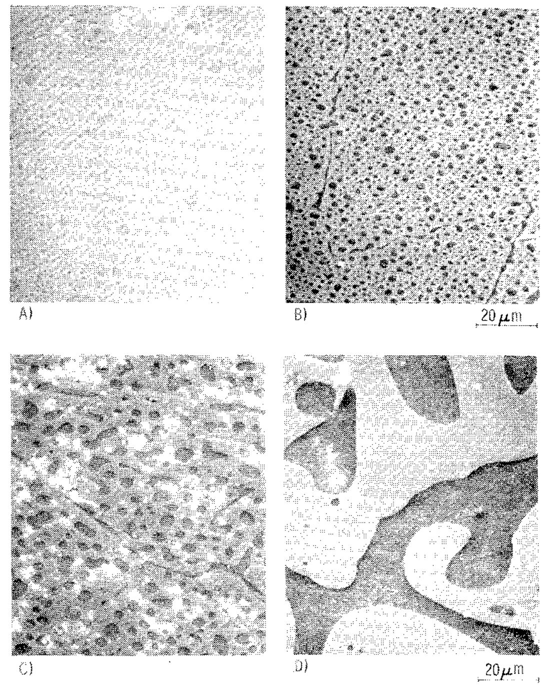

Fig. 1 Photomicrographs of the Ga-Bi immiscible alloys. Pictures A, B, and C are for free-fall solidified samples, and picture D is for a one-*g* sample prepared under otherwise identical conditions. The light colored areas represent the bismuth matrix whereas the dark areas are gallium particles.

We will report the unusual temperature dependence of the electrical resistivity found on gallium-bismuth immiscible alloys which were solidified during free fall conditions in a drop tower. The interesting superconducting properties of zero-gravity processed Ga-Bi can be found in Ref. 6.

Experimental Results

A simple method for obtaining a liquid dispersion of two metals without having to mechanically mix is to make use of the miscibility gap, occurring in numerous metallic constitution diagrams. Samples of Ga-Bi were processed during 4 sec of free fall in the MSFC drop tower.[7] In this time span, a single-phase metallic liquid was cooled through the liquid miscibility gap to form two liquid phases which were subsequently solidified. A ground control sample was processed under otherwise identical conditions except that the sample was not dropped. The Ga-Bi samples were processed in tantalum containers using metals with at least 99.999% purity and a concentration of 50 a/o of each element. Details of the processing procedure are given in Ref. 5.

Photomicrographs of the samples can be seen in Fig. 1, where the light-colored areas represent the Bi matrix and the darker, circular areas are the Ga. As expected, the low-g processing led to a finer and more uniform dispersion of Ga particles in a Bi matrix. The different dispersions obtained for samples A, B, and C are associated with different solidification times in zero-g. The preliminary results of these experiments indicate that the longer solidification times lead to finer dispersions.

The temperature dependence of the electrical resistivity $\rho(T)$ was measured on three dropped samples (A, B, and C) and on one ground control sample (D) by the conventional four-contact technique. A constant current of 10 mA was passed through a thin slice of the material by means of fine-spring-

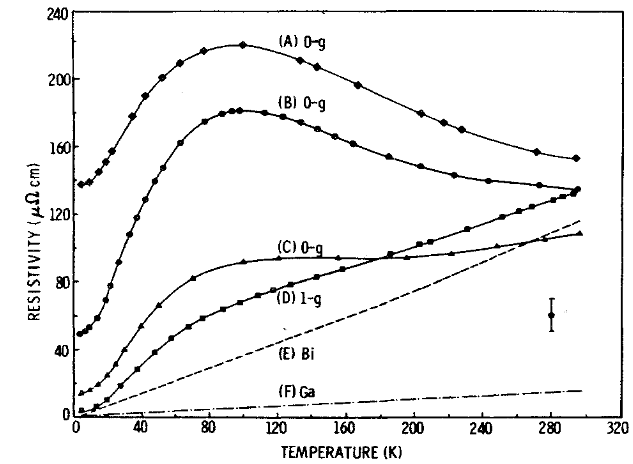

Fig. 2 The temperature dependence of the electrical resistivity of the zero-*g* and one-*g* solidified samples. Curves E and F are for the pure elements Bi and Ga, respectively.

loaded-copper wires contacted to the sample bases by silver conductive paint. The voltage drop was measured on two separate potential leads and could be recorded as a function of temperature. The sample temperature was measured with a calibrated platinum resistance thermometer to 20 K and below this temperature with a calibrated Ge resistance thermometer.

The results of the resistivity measurements $\rho(T)$ are given in Fig. 2. Each letter refers to the same samples as identified in Fig. 1. The results clearly show that the resistivity of the zero-*g* samples A, B, and C is quite different from the ground control sample D. For comparison, the resistivities for pure Bi (curve E) and pure Ga (curve F) have also been included. The room temperature (295 K) value for all samples is approximately the same as for the pure Bi. An absolute determination of ρ for all samples is limited by the small sample geometry to within 8%, indicated by the room temperature error bar. However, the relative values of ρ for a given curve are accurate to within 1%. What is of interest here is that the changes in resistivity as a function of temperature for the three samples are quite different.

The slope $(d\rho/dT)$ for the curves D, E, and F are all positive which is typical of normal conductors. Note that the coarse dispersion of the ground control sample D has given a material with the same electrical characteristics as for pure Bi. However, when the dimensions or diameter of the dispersed Ga particles in sample C become small (3–10 μm), the electrical characteristics of the Bi matrix have changed (i.e., $d\rho/dT \approx 0$). For even smaller dispersions ($d \gtrsim 1$ μm) as seen in the zero-*g* samples *A* and *B*, the conductivity of the matrix has completely changed such that $d\rho/dT < 0$, and a broad maximum occurs at 100 K. The high temperature resistivity of samples A and B behaves similar to an intrinsic semiconductor. As can be seen in the photomicrographs, there is a correlation between the size of the Ga particles and the resistivity curves of Fig. 2.

In the low temperature region between 25 and 4.2 K, all samples show typical metallic behavior. In accordance with Matthiessen's rule,[8] the temperature-dependent resistivity may be expressed as the sum of a temperature-independent term, ρ_o, and a temperature-dependent (intrinsic) term $\rho_i(T)$. Thus, the resistivity may be expressed as

$$\rho(T) = \rho_o + \rho_i(T) \tag{1}$$

where the intrinsic term is usually found to be

$$\rho_i(T) = CT^n \tag{2}$$

The value of ρ_o can be associated with electron scattering from impurities, defects, or interfaces and is indeed very high for sample A, having the finest dispersion. From Fig. 2, it can be seen that ρ_o increases as the particle size becomes smaller, indicating that ρ_o is correlated with the interface area of the Ga particles. The temperature-dependent term for all samples could be expressed by Eq. (2) with n varying between 2 for pure Bi and 4 for pure Ga. What is indeed surprising about this material is that for the same chemical composition, both ρ_o and ρ_i depend upon the degree or fineness of the dispersion.

Similar resistivity peaks have been reported by Thompson[9] for Bi samples doped with Pb, Sn, and Ge. It should be noted, however, that our results are not expected to be influenced by impurity effects, since very pure materials were used and since the resistivity peak does not occur for the ground control sample.

In summary, our results show that the electrical properties of the Bi matrix are drastically changed by zero-*g* processing, and that the electrical properties can be correlated with the degree of dispersion obtained as shown in the photomicrographs. The finer the dispersion, the more pronounced is the change in the properties of the composite. Even with the short duration of zero-*g* obtained in a drop tower,‡ useful solidification experiments can be performed with immiscible alloys. Additional investigations with Ga-Bi for longer solidification times are presently being carried out to obtain even finer dispersions.

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‡ The actual acceleration levels in the MSFC drop tower are approximately 10^{-3} g and are here referred to as "zero-g" or "low-g."

Solution of an Eigenvalue Problem in Solid Mechanics Employing Parameter Differentiation

T. Y. NA* AND G. M. KURAJIAN†
The University of Michigan, Dearborn, Mich.

Introduction

IN a previous paper by the authors,[1] an initial value method for solving the eigenvalue problem resulting from the analysis of the finite deflections of a nonlinearly elastic bar,[2] clamped at one end and axially loaded at the other (Fig. 1) was treated.

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Index category: Structural Static Analysis.

* Professor of Mechanical Engineering. Associate Member AIAA.
† Professor of Mechanical Engineering.