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"Transparent Metal Model Study of the Use of a Cellular Growth Front to Form Aligned Monotectic Composite Materials "

Final Report

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Transparent Metal Model Study of the use of a Cellular Growth Front to Form Aligned Monotectic Composite Materials

Final Report on NAG 8 - 069

by

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PURPOSE AND BACKGROUND:

The purpose of this work was to resolve a scientific controversy in the understanding of how second phase particles become aligned during unidirectional growth of a monotectic alloy. A second aspect of the study was to make the first systematic observations of the solidification behavior of a monotectic alloy during cellular growth in situ. This was done by using transparent materials which model metallic growth. This has been completed.

Recent observations during the study of the hyper-monotectic solidification of Al-In-Sn, indicated that second phase alignment might have been caused by a mechanism reported first by Parr and Johnston where cellular interface morphology controlled the alignment at higher growth velocities, rather than the alignment mechanism suggested by Grugel and Hellawell which allowed alignment only at slow growth rates. This study utilized transparent models in which the formation of the aligned structure could be observed as it occurs for a variety of growth conditions.

APPROACH:

The succinonitrile-glycerol, SNG, system was chosen for the the study. This system freezes as a 'regular' monotectic during unidirectional solidification when contained between glass microscope slides. Cellular growth was obtained by a combination of the following: using hypermonotectic composition alloys made from slightly impure components, using growth rates, R, greater than those required for planar freezing, and using a temperature gradient, G, too low to sustain a planar front. The present study entails the direct observation and analysis of the growth front as a function of R, G, and the composition. Photomicrographs are used to document the solidification morphology. Fourier Transform Infrared Spectroscopy of specimens provides composition information of the directionally solidified sample and the quenched solid-liquid interface.

ACCOMPLISHMENTS:

1) This research (to our knowledge) provides the first systematic transparent model study of cellular solidifica-

tion in monotectic alloys.

2) An interface stability diagram was developed for the planar to cellular transition of the SNG system, Fig. 1. This data was reasonably close to that predicted form the simple Tiller, Jackson, Rutter and Chalmers constitutional undercooling theory (Acta Met. 1953, vol 1, p428) shown as a solid line in Fig. 1.

3) A method has been developed utilizing Fourier Transform Infrared Spectroscopy (in collaboration with Gretchen L. Perry, NASA/MSFC ES75) which allows quantitative compositional analysis of directionally solidified SNG along the growth axis and of the quenched melt ahead of the solidification interface. This method allows the application of the data to test and develop fundamental theories for monotectic solidification.

4) To determine the influence of cellular growth front on alignment for directionally solidified monotectic alloy we observed the planar and cellular growth morphology in situ for SNG with between 8 and 17 % glycerol (the on-monotectic to moderate hypermonotectic compositions) and for a range of over two orders of magnitude in G/R. From these observations we make the following conclusions:

a) The Rayleigh breakdown mechanism (Schaefer, C., Johnston, M. H., and Parr, R. A., Acta Met. 31, pp.1221, 1983) is not important for the SNG system. Although enriched solute in the cell boundaries promotes alignment hydrodynamic breakdown of $liquid_2$ droplets was not observed. Further, we did not find a correlation between cell cusp depth and the breakdown of $liquid_2$ rods into spheres predicted from the Rayleigh breakdown model.

b) We did observe that the alignment can occur only at the cell boundaries concurrently with aligned or usualy unaligned intracellular monotectic microstructure. The spacing between aligned particles (not those within the cells) is then of the order of the cell spacing. Thus, for the SNG system the cellular growth front promotes alignment at G/R values to low for the monotectic microstructure to remain aligned. We did not, however, observe a regime where the $liquid_2$ spacing was equal to the cell spacing as expected from the Parr et al theory (Parr, R. A. and Johnston, M. H., Metall. Trans. 9A, pp. 1825, 1978). It is reasonable that for systems where the cell spacing is closer in value to the aligned $liquid_2$ spacing, $liquid_2$ incorporation may become exclusively limited to the cell cusps as Parr et al suggest for Al-Bi.

5) A detailed report on the project is available as a NASA Technical Memorandum.

6) A condensed version of the TM is being submitted to Met. Trans. A for publication in February.

7) The work has been presented at the TMS-AIME con-

ference session on Solidification on Jan. 25, 1988 in Phoenix, Az.

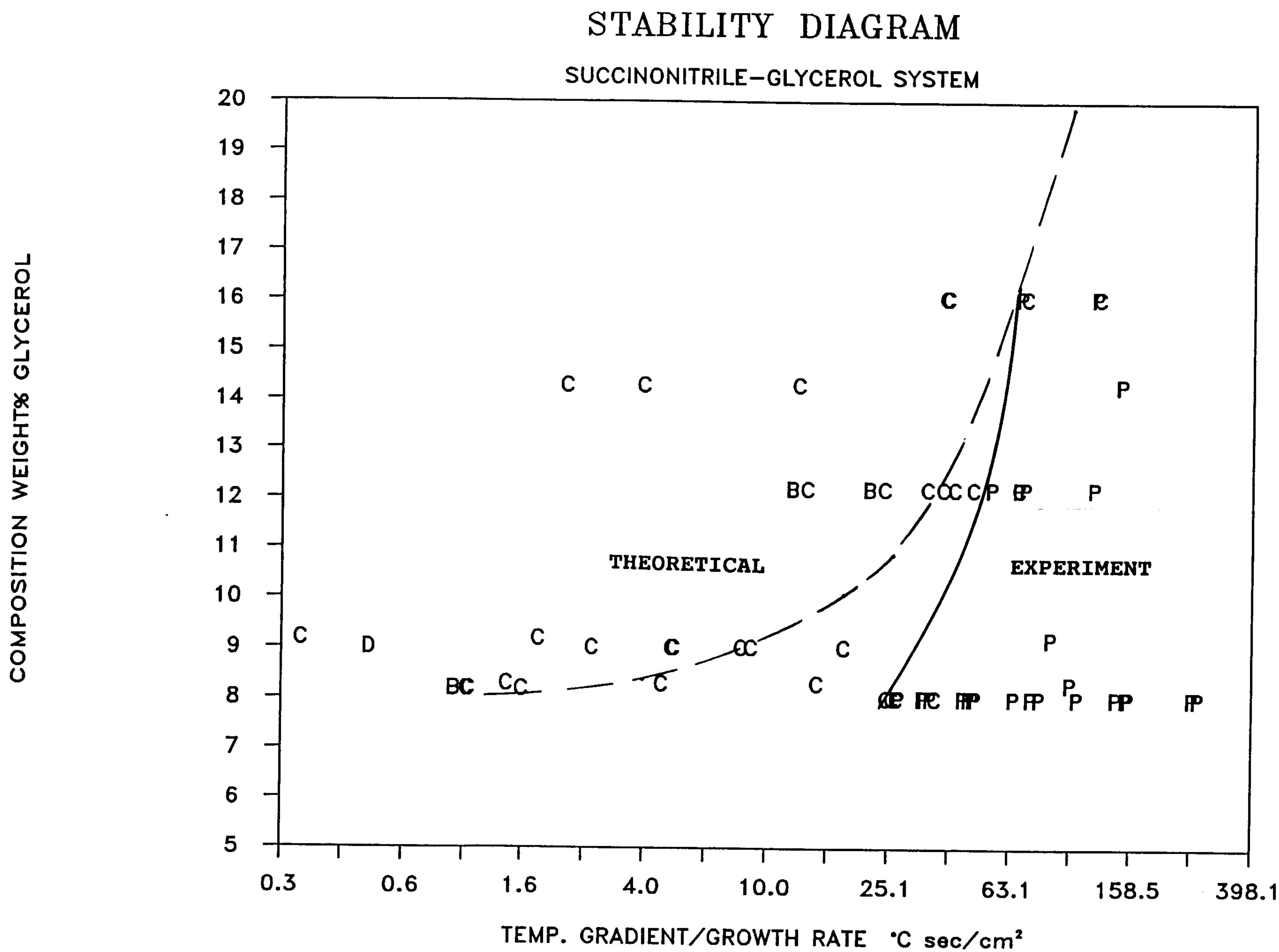
PLANNED FUTURE WORK:

This study provides a foundation for quantitative study using transparent systems of the important solidification mechanisms of monotectic alloys. A proposal is being prepared for funding by NASA Headquarters to extend the present study. Larger sample cell diameters will be used which will allow the study of gravity driven convection effects and "worm" morphologies that are suppressed in the thin cells used for the present study. The KC-135 aircraft will be used to provide a low-gravity environment for the experiments. Measurements of the diffusion coefficient for the melt constituents will also be attempted.

PUBLICATIONS:

Cellular Solidification in a Monotectic System, W. F. Kaukler and P. A. Curreri, NASA Technical Memorandum TM-100317, December 1987, Space Science Laboratory.

Figure 1. Interface Stability Diagram for Succinonitrile-Glycerol System. Data points; P = planar, C = cellular, BC = branched cells, D = dendritic. Solid line is the experimental and dashed line the theoretical boundary for the planar to cellular transition.


STABILITY DIAGRAM
SUCCINONITRILE–GLYCEROL SYSTEM
THEORETICAL
EXPERIMENT
COMPOSITION WEIGHT% GLYCEROL
TEMP. GRADIENT/GROWTH RATE °C sec/cm²
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
0.3
0.6
1.6
4.0
10.0
25.1
63.1
158.5
398.1