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DUCTILE SUPERCONDUCTING WIRE THROUGH NOVEL METALLURGICAL TECHNIQUES

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1. INTRODUCTION

The work reported here has been carried out under a new project, in its first full year, which addresses the synthesis of superconductors through controlled precipitation of A15 phases from supersaturated solution in the solid state. There are three potential advantages to this approach to making a superconductor: (1) The wire or tape may be formed prior to precipitation of the A15 phase, allowing manufacture through relatively simple rolling or drawing of a material which is, at this point of the process, a normal metal with reasonable ductility. (2) Since the solid-state precipitation of the A15 phase involves a significant transformation strain the reaction will occur preferentially at elastic defects such as grain boundaries and dislocations. If the precipitation can be made to occur preferentially along dislocation lines then the superconductor should retain some useful ductility in the aged condition. (3) Fine precipitates formed in the solid state tend, for thermodynamic reasons, to be rich in solute content relative to the equilibrium concentration. Precipitation of fine particles along defects in solids hence gives the possibility of forming A15 compounds of more nearly stoichiometric composition than can be obtained from bulk precipitation processes under more nearly equilibrium conditions. The principal barrier problem to the synthesis of a superconductor through solid state precipitation is the difficulty of forming a continuous network of fine precipitate particles, a problem made more serious by the limited available data on the details

of the precipitation of A15 phases.

2. TECHNICAL APPROACH

The initial system for research was chosen to be the vanadium-gallium system, largely because of the simplicity of the relevant portion of its phase diagram (FIgure 1). At temperatures above ∿1300°C the stability field for Ga in solid solution in vanadium envelopes the top of the field of the superconducting (A15) V_3Ga phase. By annealing at ∿1500°C one may thus create a homogeneous solid solution of Ga in V. The precipitation of the V_3Ga phase may then be suppressed by quenching to room temperature, yielding a supersaturated metallic phase which should be formable into a tape or wire by thermomechanical processing. Assuming that the forming process is carried out so that solid state precipitation does not occur to a significant extend the processed product will be a supersaturated solution of Ga in V with a very high defect density as a consequence of the mechanical work. If the product is then aged at relatively low temperature (500-800°C) the V_3Ga phase should precipitate in a process strongly catalyzed by defects,which raises the possibility of creating a semi-continuous network of fine precipitate particles in a refined microstructure which preserves at least some low-temperature ductility.

3. INITIAL RESULTS

Research to date has focused primarily on the problem of melting, homogenizing and thermomechanically processing supersaturated solutions of Ga in V to achieve thin foils having a high defect density. The initial melt is made by enclosing measured quantities of vanadium (commercial purity) and gallium in a vanadium envelope and melting in an arc furnace. The resulting ingot is homogenized at T>1500°C, then quenched to room temperature. Microstructural studies indicate that the precipitation

of V_3Ga is essentially suppressed if reasonable cooling rates are used.

The V, Ga ingot is reduced into a foil of 1-5 mil thickness in the processing sequence diagrammed in Figure 2. The ingot is first encased in a stainless steel envelope with a Ta inner lining (to prevent oxidation and contamination of the foil by iron) and rolled to ∿30 mil thickness at 800°C. This controlled rolling process simultaneously accomplishes initial reduction of the ingot to a foil and refines the microstructure of the foil to impart substantial ductility at room temperature. The stainless steel envelope is then removed and the final reduction, to ∿3 mil thickness, is accomplished by cold rolling at room temperature.

High voltage TEM studies show that the final foil is severely dislocated and free of any evident V_3Ga precipitates. The absence of significant precipitation during thermomechanical processing is further indicated by the low critical temperature of the product foil (T_c<5.5°K).

Controlled aging treatments and superconductivity measurements have only recently been begun, and it would, therefore, be premature to report data. Initial results do, however, show a substantial increase in T_c on aging at 500-800°C. The greater part of this increase is achieved during the early stages of the aging process. High voltage TEM studies show that the initial increase in T_c occurs when the volume fraction of the A15 phase is very small, suggesting that the precipitate does tend to form in a semi-continuous network along defects.

Current research involves aging treatments, critical temperature and mechanical property measurements, and high resolution microstructural studies to determine the characteristics of the precipitation reaction accomplished during aging and its influence on superconductivity and on low temperature properties.

ACKNOWLEDGEMENT

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FIGURE CAPTIONS

Figure 1. The phase diagram of V-Ga system

Figure 2. Rolling process of the V-rich solid solution

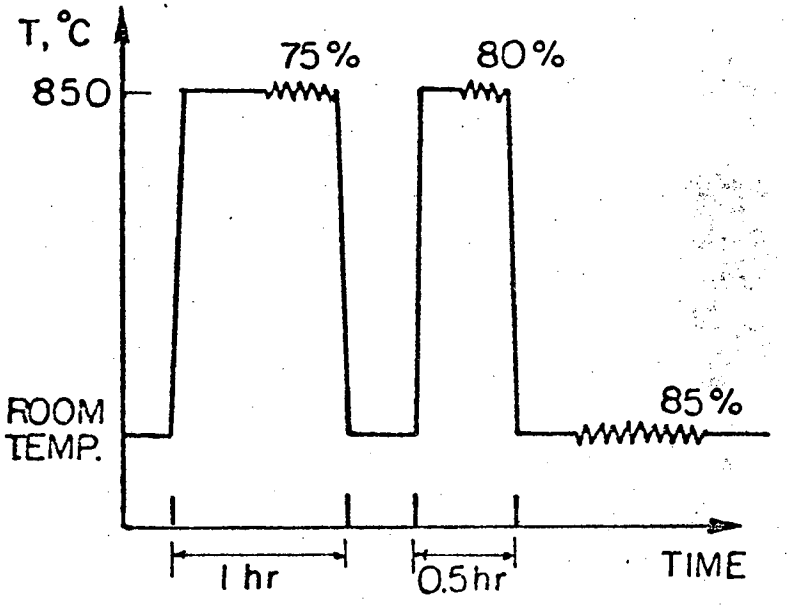
T, °C
850
75%
80%
ROOM
TEMP.
85%
1 hr
0.5hr
TIME

FIG. 1

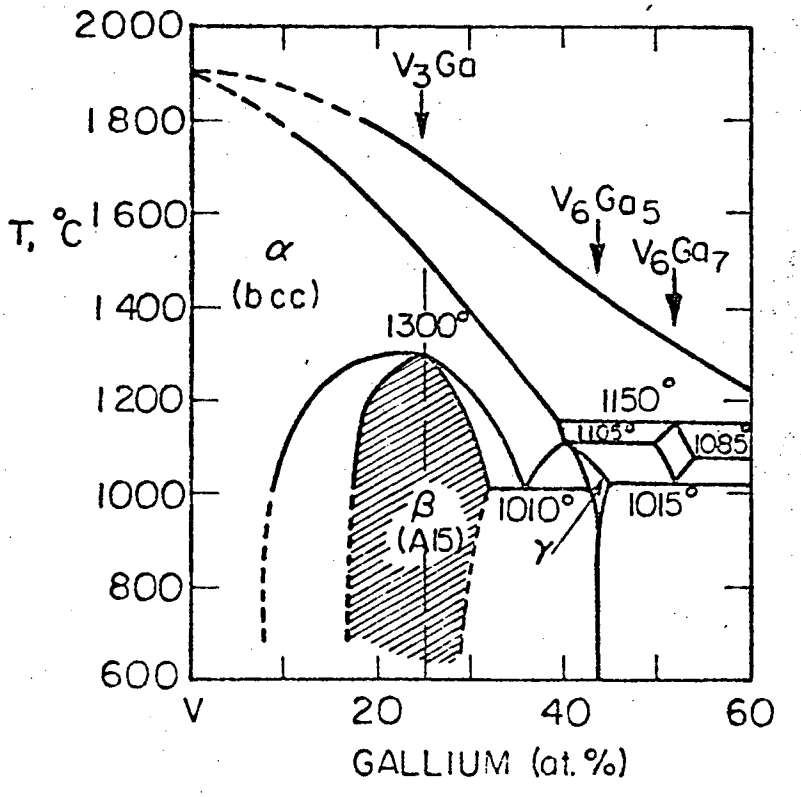
2000
1800
1600
1400
1200
1000
800
600
T, °C
V
20
40
60
GALLIUM (at.%)
V3Ga
V6Ga5
V6Ga7
α
(bcc)
1300°
1150°
1105°
1085°
β
(A15)
1010°
1015°
γ

FIG. 2

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