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RF Project 764977/717636
Quarterly R & D Status Report

STRENGTH AND STRUCTURE OF $GA_{1-x}IN_x$ AS ALLOYS

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Department of Ceramic Engineering
and
John P. Hirth
Department of Metallurgical Engineering

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Building 410
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Contract No. F49620-85-C-0129

January 1986

The Ohio State University
Research Foundation
1314 Kinnear Road
Columbus, Ohio 43212

Strength and Structure of $Ga_{1-x}In_xAs$ Alloys

Quarterly R & D Status Report

January 15, 1986

APRA Order 5526

Program Code 5Y10

Contractor: Air Force Office of Scientific Research

Contract Dates: September 1, 1985 - August 31, 1986

Contract Amount: $142,286

Contract Number: F49620-85-C-0129

Co-Principal Investigators:
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(614) 422-2960 and (614) 422-0176

Program Manager:
Captain Kevin Malloy
(202) 767-4984

Substantial solid solution strengthening of GaAs by In acting as $InAs_4$ units has recently been predicted. This strengthening could account for the reduction of dislocation density in GaAs single crystals grown from the melt. Our objective is to investigate the mechanism by which strengthening is produced by In additions to GaAs. In the first stages of this study, experimental measurements of hardness as a function of temperature and In content are reported.

This work has been presented at the 1985 Materials Research Society's Fall Meeting, December 2-7, 1985 and submitted for publication in the Proceedings of the MRS. This submission has been sent under separate cover.

(1) Progress

Vickers hardness measurements on (100) GaAs wafers and (100) $Ga_{0.9975}In_{0.0025}As$ wafers, supplied by Westinghouse R & D Center, were made over the temperature range of room temperature to 900 C. Indium contents were confirmed in our laboratory by atomic absorption spectroscopy.

Indium additions to GaAs resulted in significantly higher hardnesses than that of the undoped material above 300 C consistent with the solid-solution strengthening model. The hardness drops sharply with temperature and flattens at T > 500 C. The latter temperature independent hardness region is indicative of a plateau stress region. By virtue of its higher hardness, the alloy containing In could be inferred to have a higher plateau stress level. The tests are to be extended to higher temperature to examine trends as the crystal growth temperature is approached.

Marked relaxation is seen in high temperature indentations and no cracks were seen at indentation corners above 400 C. This observation suggests that the ductile-to-brittle transition occurs between 300 and 400

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C. Above 700 C, significant vaporization and surface damage is observed. If tests are to be extended to high temperatures, specimens must be encapsulated with a thin protective film. The use of boric oxide as a protective coating was not successful, as chipping of the coating occurred around indentations which made measurements difficult. Higher In content wafers ($Ga_{0.989}In_{0.011}As$) have recently been obtained, one of which had a silox coating. Si_3N_4 encapsulation is also under consideration.

While hardness data thus far show a significant strengthening effect, it does not fully reflect the above expectation based on solid solution strengthening. It is possible that the Peierls stress dominates at lower temperatures and the influence of solution strengthening is small. At higher temperatures, it is expected that solution strengthening will dominate and hence, it is necessary to go to higher temperature testing.

(2) Major experimental equipment constructed.

For hardness measurements, a high temperature hardness tester was designed and fabricated. The loading is applied by dead weights with a counterbalance arrangement to vary the load from 10 to 300 g. The indenter can be raised and lowered at a constant rate of about 3mm/min by a screw mechanism. The furnace used is a low heat-capacity Pt-20%Rh resistance wire-wound unit capable of fast heating and cooling rates and a maximum temperature of 1500 C. Ultra high-purity argon, flowing into the enclosure, is used to cool the upper part of the indenter shaft. All indentation diagonal measurements are made at room temperature.

(3) Change in key personnel

None.

(4) Substantive information derived from meetings

From the 1985 Materials Research Society Fall Meeting, sessions on Defects in III-V Compound Semiconductors, Ohmic Contacts on III-V Compound Semiconductors and Rapid Thermal Annealing of GaAs were attended. It was determined that no single encapsulent material has been found to be completely satisfactory for GaAs. SiO_2, Si_3N_4, phosophosilicate glass and borosilicate glass have been used; AlN is somewhat attractive because of its similar coefficient of thermal expansion to GaAs. R.S. William et al. (UCLA) suggested that $PtGa_2$ would be a thermodynamically stable encapsulent up to 1000 C.

Work is currently ongoing at the University of California, Berkeley under the direction of Eugene Haller on compression testing of GaAs, Ga-In-As and Ga-Si-As. Experimental results in a December 1985 thesis showed similar trends to our own experimental data.

(5) Problems of concern

Encapsulation of GaAs for higher temperature hardness tests poses a minor problem at this stage. These problems will be alleviated in our compression testing, where near perfect encapsulation is not required. However, for a coupon used for hardness testing, surface and near surface chemistry must remain stable.

(6) Fiscal status

(a) Amount currently provided for contract: $110,000

(b) Expenditures and commitments to 12/31/85: $51,530.33
December financial statement is attached.

(c) Amount needed to complete work: $90,755.67

(d) Estimated date of completion: 8/31/86

RET10 RETF10C PROJECT FINANCIAL SUMMARY SYS DATE 1/15/86 TIME 12:37:05
OPTION: 01 KEY: 717636 PROJ 717636 MPN 764977 MONTHLY DATA AS OF: 12/31/85
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WKSTN 4 RPN 060006 DO WOODY PA VENTRESCA IDC G 44 45.00

DESCRIPTION	BUDGET	EXP MONTH	EXP TO DTE	COMMITMENTS	UNEN BAL
SPONSOR					
S & W -REL	10190.00	1150.00	2300.00	6325.00	1565.00
S & W -RTY	43250.00	2160.00	7576.62	12960.00	22713.38
FRINGE-REL	1896.00	201.07	402.14	885.50	608.36
FRINGE-RTY	9403.00	322.24	1105.12	1776.82	6521.06
*TOT PERS	64739.00	3833.31	11383.88	21947.32	31407.80
REPORTS		86.68	97.43		97.43-
PURCHD SRV	1000.00	133.60	133.60		866.40
SUBCONTR	2000.00				2000.00
MAT & SUPP	7000.00	145.08	1107.82		5892.18
OTHER D/C	123.00	64.50	64.50		58.50
TRAVEL-DOM	1000.00	803.61	803.61		196.39
*TOT DIR	75862.00	5066.78	13590.84	21947.32	40323.84
IND COSTS	34138.00	2280.05	6115.88	9876.29	18145.83
**TOT SPON	110000.00	7346.83	19706.72	31823.61	58469.67

CSG% .00% OSU% .00% CSG$ OSU$ TOT$ 19706.72