RADIATION DAMAGE AND ION BEHAVIOUR IN ION IMPLANTED VANADIUM AND NICKEL SINGLE CRYSTALS

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ABSTRACT

Distributions and annealing behaviour of heavy ion induced radiation damage in single crystal nickel and vanadium are compared. Sharp annealing stages are reported for Ni while for V the production of a polycrystalline layer, ascribed to the action of precipitates, prevented the annealing of damage after high dose implantations. The use of $^4$He$^+$ ion channelling revealed disorder at depths much greater than the ions projected range, an observation that was supported by electron microscopy measurements. Implanted ion diffusion in vanadium was found to be dependent on the ion species used and the annealing behaviour of precipitates. Preliminary quantitative measurements indicate that diffusion coefficients are low.

INTRODUCTION

The investigation of radiation damage in transition metals by heavy ion bombardment is rapidly becoming a useful means of simulating long term damage in reactor environments. Further, there appears to be a growing interest in alloying and isotope enrichment using high dose implantation. In this present study, radiation damage and ion diffusion have been studied in the reactor base metals nickel and vanadium.

For fcc structured nickel, a number of electron microscopy investigations\(^{(1-3)}\) dealing with radiation damage have been reported. At low ion doses in this metal, only vacancy clusters have been detected while for higher doses interstitial clusters are...
dominant. In general, the majority of damage has been detected within the ion projected range, although in other fcc metals some interstitial clusters at depth greater than the ion ranges, have been observed and explained by focussed collision sequences\(^4\). For bcc vanadium, however, only few results are presently available\(^5\). In previous publications\(^6,7\) dealing with single crystal vanadium, we have reported enhanced damage depths with increasing ion energy and dose, a small dependence of the magnitude of damage on these parameters, the generation of a polycrystalline layer in the ion range for high dose implants and values of substitutional components dependent on the implanted ions ionic radii.

Results reported in this present work have been obtained using the backscattering technique from single crystal nickel implanted with bismuth, and single crystal vanadium implanted with gallium, bismuth and selenium. Some preliminary electron microscopy measurements have been taken for gallium ion induced damage in vanadium. The backscattering technique has also been employed to monitor the distribution of the implanted ions and its subsequent variations during heat treatment.

**EXPERIMENTAL**

Our backscattering system and the surface preparation of vanadium single crystals have been described in detail elsewhere \(^7\). Like vanadium, nickel single crystals produced by electron beam zone refining have been purchased from Metals Research Corporation. Nickel samples were cut perpendicular to the \(\langle 110 \rangle\) direction with a continuous wire saw and subsequently lapped with 15 \(\mu\), 7 \(\mu\), 1 \(\mu\) and 0.25 \(\mu\) diamond pastes. Samples were then etched for 5 second periods in a solution consisting of 30 cc HNO\(_3\), 10 cc H\(_2\)SO\(_4\), 10 cc H\(_3\)PO\(_3\) and 50 cc glacial CH\(_3\)COOH held between 85 - 95\(^\circ\)C. Vanadium samples for our electron microscopy studies were prepared by mechanically thinning from the not implanted side to 0.1 mm by careful polishing on SiC paper followed by a vibratory polish with \(\gamma\)-Al\(_2\)O\(_3\) of 0.05 \(\mu\) diameter. Final thinning was done electrolytically with a mixture of 80 \% acetic acid and 20 \% perchloric acid. With this technique depth determination was estimated to be about \(\pm 200 \AA\).

Implantations were performed at room temperature with a scanned ion beam from a heavy ion accelerator. Metal samples were bombarded over an energy range from 20 - 360 keV and a dose range of \(10^{15} - 10^{17}\) ions/cm\(^2\). Irradiated specimens were annealed in a stainless steel tube under a vacuum of \(\leq 6 \times 10^{-7}\) torr, isochronally, to temperatures of 1000\(^\circ\)C and isothermally for times lasting to 18.5 hours.