Dislocations in Pt₈V ordered alloys

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Abstract. Platinum 11 at.% vanadium undergoes an ordering transformation to form a Pt₈V superlattice. Deformation of the alloy results in the formation of single dislocations or superdislocations, depending on the degree of order. The superdislocations take the form of triple dislocations with a separation of 20 nm in the fully ordered alloy.

1. Introduction

Platinum 11 at.% vanadium undergoes an ordering transformation to form a Pt₈V ordered structure upon heat treatment of initially quenched or initially deformed samples [1,2]. The Pt₈V superlattice belongs to the A₈B ordered structures, which can occur in alloys of an element from group VIIIC (Ni, Pd, Pt) with an element from group IVA, VA or VIA (Ti, Zr, Hf, V, Nb, Ta, Cr, Mo and W) [3]. The prototype structure is Pt₈Ti [4] and the bravais lattice is body centered tetragonal (bct). The lattice is more conveniently described as face centered tetragonal (fct) for easy comparison with the parent platinum based solid solution which is face centered cubic [4]. Previous work on alloys exhibiting A₈B order have focused on the formation of the superlattice; relatively little work has been reported on the effect of order on properties such as strength [5], which can be significantly influenced by ordering. The degree of strengthening in ordered alloys has been shown to depend on the type of dislocation (single or superdislocations) which are active in the alloy [6,7,8,9]. Triple dislocations have been reported in ordered Ni₈Nb and Ni₈Ta alloys [10,11]. The present study was carried out to determine the type of dislocations that form in ordered Pt₈V alloys.

In long range ordered alloys, the passage of a single dislocation generally results in disordering; to restore order multiple dislocations have to pass through [10]. The number of dislocations that will restore order depends on the order arrangement of the slip plane of that alloy: in A₈B ordered alloys, three successive dislocations must move in the (111)ₘₑₙ or (331)ₘₑₙ slip plane and [110]ₘₑₙ slip direction to restore order as shown in figure 1.

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2. Experimental procedures

Platinum 11 at.% vanadium sheets were heat treated at 1200°C for 3 hours followed by quenching into water and were designated “initially quenched” alloys. These quenched specimens were subsequently heat treated at 700°C for varying times. All the heat treatments were carried out in a vertical vacuum furnace in an argon atmosphere and were terminated by quenching in water. Electron diffraction and dark field transmission electron microscopy (TEM) were used to determine the size of the ordered domains after heat treatment. Specimens of each heat treatment condition were then deformed by 2% using a laboratory rolling mill. These specimens were studied using electron diffraction and bright field TEM. Specimens were prepared for TEM by grinding, then dimpling the 3 mm discs which were punched out of the bulk material. An electron transparent area was achieved by milling the dimpled specimens using a GATAN Precision Ion Polishing System. TEM was carried out using a JEOL 200CX microscope operating at an accelerating voltage of 200kV.

3. Results

Figure 2 shows a [110]_{fcc} zone axis electron diffraction pattern for the initially quenched alloy before any subsequent heat treatment was carried out. The zone axis shows only fundamental reflections associated with a disordered fcc structure, demonstrating that the alloy is in a disordered state after quenching and before further heat treatment. Figure 3 shows a bright field image of the initially quenched alloy after 2% deformation, showing single dislocations.
Figure 3. Bright field image of initially quenched alloy after 2% deformation.

Figure 4(a) shows a dark field image of an initially quenched alloy after heat treatment at 700°C for 3 hours. The image was obtained using the arrowed reflection on the inset [110] fcc zone axis electron diffraction pattern. The image shows ordered domains of about 15 nm diameter in bright contrast. A bright field image of the same alloy, heat treated at 700°C for 3 hours and deformed by 2%, is shown in figure 4(b). The image shows grouped dislocations, with an average separation of 35 nm within a group.

Figure 4(b). Bright field image of (a) after 2% deformation.

Figure 5(a) shows dark field image of an initially quenched alloy after heat treatment at 700°C for 168 hours obtained using the arrowed reflection on the [110] fcc zone axis electron diffraction pattern. The image shows a fully ordered structure with large domains separated by antiphase domain boundaries. A bright field image of the same alloy deformed by 2% is shown in figure 5(b). The dislocations appear in groups of three and the dislocation separation is observed to have decreased to 20 nm.

Figure 5(a). Dark field image of initially quenched alloy after heat treatment at 700°C for 168 hours (b) bright field image of (a) after 2% deformation.
4. Discussion

The number of dislocations that make a superdislocation depends on the alloy and the nature of the ordered superlattice. The separation between the dislocations in a superdislocation decreases with an increase in the degree of order [9,11]. In Pt 11 at.% V alloys, a change from single dislocations to superdislocations occurs as a result of ordering, the separation between dislocations decreasing as the degree of order increases. A transition of the dislocation structure from single dislocations to grouped dislocations was observed on development of small (15 nm) ordered domains. The completely ordered alloy, with a domain size of 500 nm, showed only triple dislocations, with a dislocation separation of approximately 20 nm. This is consistent with the triple dislocations observed in Ni3Ta in which the observed dislocation separation in a fully ordered alloy was reported to be 16 nm [11].

5. Conclusions

Deformation of fully ordered Pt 11 at.% V alloys takes place by the movement of triple dislocations, as required to restore order in the Pt3V superlattice.

6. References

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