Short Communication

Plastic accommodation of martensite in disordered and ordered iron–platinum alloys

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The degree of order in iron–platinum austenite can be changed by heat treatment. Highly ordered austenite tends to transform into thermoelastic martensite, whereas non-thermoelastic martensite is formed from disordered austenite. This is because the ordered austenite is able to accommodate elastically the shape deformation brought about by the growth of martensite. In the present study, atomic force microscopy has been used to establish the nature of the shape deformation caused by both types of martensite. It is confirmed that the extent of plastic accommodation is larger when disordered austenite is induced to transform into martensite.
MST/3232

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Introduction

Iron–platinum alloys with a composition close to Fe_3Pt transform into thermoelastic martensite when the parent phase (austenite) is ordered. However, they transform into non-thermoelastic martensite when the austenite is disordered.[1–5] In addition, the martensite start temperature is drastically reduced when the transformation occurs from ordered austenite, despite the two types of martensite having identical crystallography.[3]

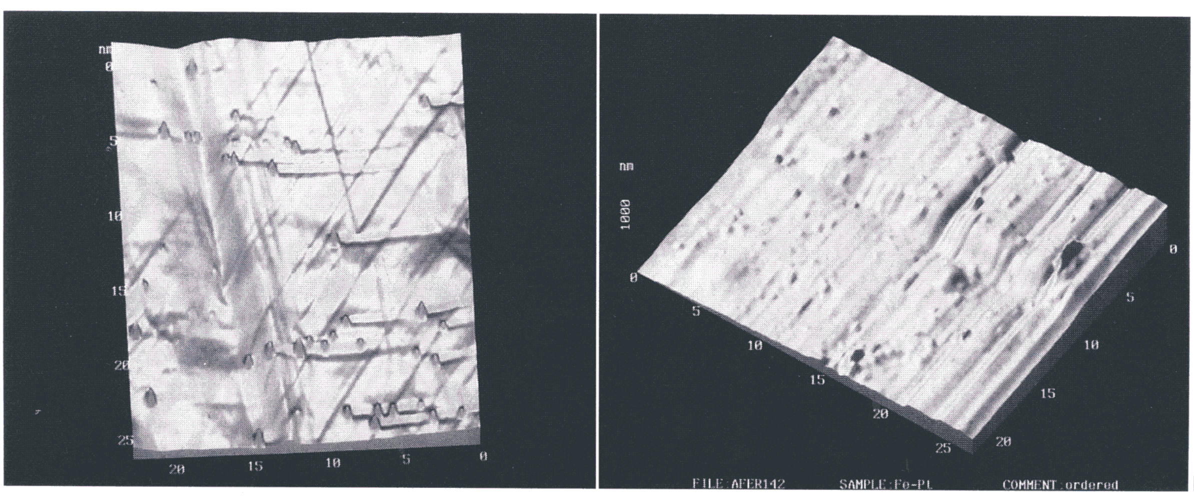
Martensitic transformation produces a change in the shape of the transformed region; this shape deformation is an invariant-plane strain with a relatively large shear component, and a dilatational component of strain directed normal to the invariant plane. The shape deformation must be accommodated by the surrounding matrix. In this context, the difference in transformation behaviour of austenite as a function of the degree of ordering has been explained theoretically[6,7] by the elastic shear modulus of Fe_3Pt austenite decreasing and its flow stress increasing on ordering. The shape deformation of martensite can therefore be largely accommodated elastically when the transformation is from the ordered austenite. On the other hand, disordered austenite with its larger elastic modulus and lower flow stress is unable to tolerate elastically the shape deformation; the plate of martensite is therefore surrounded by a substantial zone of plastically deformed austenite.

In the present paper the change in the extent of plastic accommodation as a function of the degree of order in the parent austenite is demonstrated.

Experimental technique

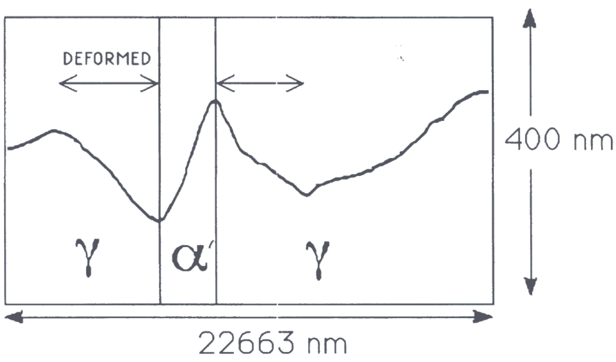
The alloy studied is the same as that used in Ref. 5, with a chemical composition Fe–24Pt (at.-%). It was homogenised at 1200°C for 7 days. All heat treatments were carried out with the sample sealed in a quartz tube filled with pure argon.

Metallographically polished samples were sealed in quartz tubes and austenitised at 1300°C for 10 min. One of these specimens was directly quenched into water to obtain martensite in disordered austenite. Another was transferred into a furnace at 550°C for 108 h to order the austenite (order parameter $S \sim 0{\cdot}7$ from Ref. 5) before quenching into water. Consistent with previous work,[5] this specimen only transformed to martensite on cooling to -90°C. The martensite start temperatures of identical samples subjected



a disordered sample; *b* ordered sample

1 Solid models of surface displacements caused by formation of relatively isolated plates of martensite



martensite plate boundaries shown by vertical lines; austenite adjacent to boundaries is plastically deformed, shown by ↔

2 Atomic force microscope trace across plate of martensite α' in disordered austenite γ (order parameter $S=0$)

to these heat treatments have been reported to be 12 and −82°C for the disordered and ordered conditions, respectively.[5]

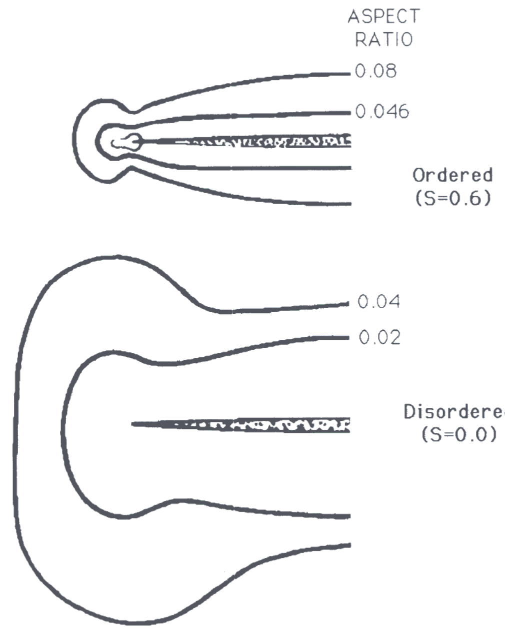
The surface relief caused by martensitic transformation was examined using a Seiko atomic force microscope.

Results and discussion

The martensite plates in general tended to form in clusters with little intervening austenite. The presence of austenite is necessary in quantities large enough to define an unaffected reference surface, to enable displacements caused by martensitic transformation to be clearly characterised. The studies were therefore confined to the few plates that could be found in isolation. Figure 1 illustrates typical solid models of such plates, a 'solid model' meaning that the surface topography is plotted in a way which illustrates the three-dimensional shape.

Figure 2 shows a trace across a plate in the disordered sample. The austenite adjacent to the plate of martensite is clearly deformed into a configuration which accommodates the shape deformation of the martensite plate. The severity of the plastic accommodation is emphasised by it extending (in a direction normal to the martensite habit plane) over a distance which is at least twice the thickness of the plate itself.

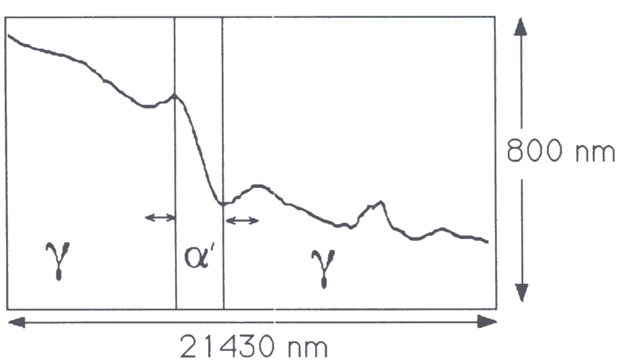
These observations are in sharp contrast with the trace illustrated in Fig. 3, which is across a plate of martensite in the ordered sample. Plastic accommodation effects are clearly evident in the austenite adjacent to the martensite, but they extend over a much smaller distance into the austenite. This is direct confirmation of the theory and experimental data discussed previously,[1–8] that ordered alloys transform to plates of martensite which are accommodated predominantly elastically.



4 Calculations showing contours where matrix satisfies yield criterion as function of aspect ratio of martensite plate and degree of ordering S: only half of martensite plate is shown because results are symmetrical about vertical centreline (After Ref. 7)

Figure 4 reproduces some of the results of Ling and Owen[8] which are consistent with the present work. For $S=0$, and for a given plate aspect ratio, the plastic zone extends over a much larger volume of austenite when compared with the calculated plastic zone for the ordered martensite.

The volume change accompanying martensite formation in the ordered alloy is known to be negligibly small, whereas that in the disordered alloy is significant (about 1·4%, from Ref. 8). Ling and Owen indicated that this dilatational strain causes the plastic zone around the martensite plate to be asymmetrical in the disordered austenite, but is predicted to be symmetrical in the ordered austenite. Consistent with this, the profile illustrated in Fig. 2 shows that the extent of plastic strain in the austenite is different on either side of the martensite plate, whereas the profile for the ordered sample (Fig. 3) is obviously more symmetrical.



martensite plate boundaries shown by vertical lines; austenite adjacent to boundaries is plastically deformed, shown by ↔

3 Atomic force microscope trace across plate of martensite α' in ordered austenite γ ($S=0{\cdot}7$)

Conclusions

Consistent with theoretical predictions[6–8] and a variety of experimental data,[1–8] the severity of plastic accommodation of the shape deformation of martensite is found to be much larger in a disordered Fe_3Pt alloy, compared with the same alloy in a partially ordered state.

Acknowledgements

The authors would like to thank the Royal Society and Professor R. W. Cahn for arranging a fellowship so that Dr Vevecka could work in Cambridge. They would also like to thank the EPSRC for financial support, the 'Atomic

Arrangements: Design and Control Project' (a collaborative venture between the University of Cambridge and the Research and Development Corporation of Japan), and Professor Colin Humphreys for the provision of laboratory facilities. The authors are also grateful to Dr C. Hetherington, Dr E. Swallow, and Dr R. Thomson for helpful discussions.

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