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DISLOCATIONS AND MECHANICAL TWINS OBSERVED IN Ti-Ta MARTENSITES

M. CEYLAN, O. ADIGÜZEL and T.N. DURLU*

Department of Physics, Faculty of Arts and Sciences, Fırat University, Elazığ, TURKEY

* *Middle East Technical University and Ministry of State, Ankara, TURKEY*

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ABSTRACT

The dislocations formed during the martensitic transformation in Ti-62 % Ta alloys were examined by using transmission electron microscope. Burgers vector of these dislocations which have the same character as the screw dislocations was found as $<0001>_{hcp}$ and $<\overline{1}\overline{1}0>_{bcc}$ in the product and parent phases, respectively. On the other hand, mechanical twins were also investigated and they were also found to have $\{0112\}$ $<0\overline{1}11>_{hcp}$ and $\{112\}$ $<1\overline{1}\overline{1}>_{bcc}$ twinning systems in the product martensite and matrix austenite phases.

INTRODUCTION

In an earlier work Barnard, Smith, Sarıkaya and Thomas (1981) showed that austenite is stabilized under a number of circumstances. It is obvious that some linear imperfections, such as slips, twins and dislocations, in parent and product phases are produced as a result of strains and stresses occured during the martensitic transformation. Christian and Bywater (1972) have examined the martensitic product occured in various Ti-Ta alloys and found some crystallographic properties. It was also found in a previous study that the martensites of hcp structure produced in Ti–62 % Ta alloy have transformation twins sometimes even on two different twinning systems, by Adıgüzel, Ceylan and Durlu (1982). Although the theories developed by Wechsler, Lieberman and Read (1953), Bowles and Mackenzie (1954), Acton and Bevis (1969) and Ross and Crocker (1970) on the crystallography of austenite-marten-

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site transformations give sufficient explanations of the tranformation in some cases there is still no a unique theory which is applicable to all alloys.

Various crystal imperfections observed in parent and product structures both before and after transformation are associated with martensite nucleation and these observations have been achieved by theoretical and experimental studies by Olson and Cohen (1976) and Staudhammer, Murr and Hecker (1983). In the present study, the dislocations produced during the martensitic transformation in Ti-62 % Ta alloys, widely used in aeronautical industry, were examined by using transmission electron microscope. The Burgers vectors of dislocations were obtained by using electron micrographs and corresponding diffraction patterns. In addition, mechanical twins in martensites formed in several parts of the same alloy were investigated. Twinning systems were also determined by using electron diffraction technics.

EXPERIMENTAL PROCEDURE

The alloy used in the present study were supplied by the Royal Aircraft Establishment, U.K. and have a composition Ti-62 % Ta. After homogenizing for 3 hours at 870 °C, the β parent phase region tensile specimen with a gauge of 250 μm length and 3 mm diameter were machined. Martensitic transformation was generated by quenching in water at 0 °C. Transformed specimens were examined by transmission electron microscopes operated at 75 and 125 kV.

OBSERVATIONS AND RESULTS

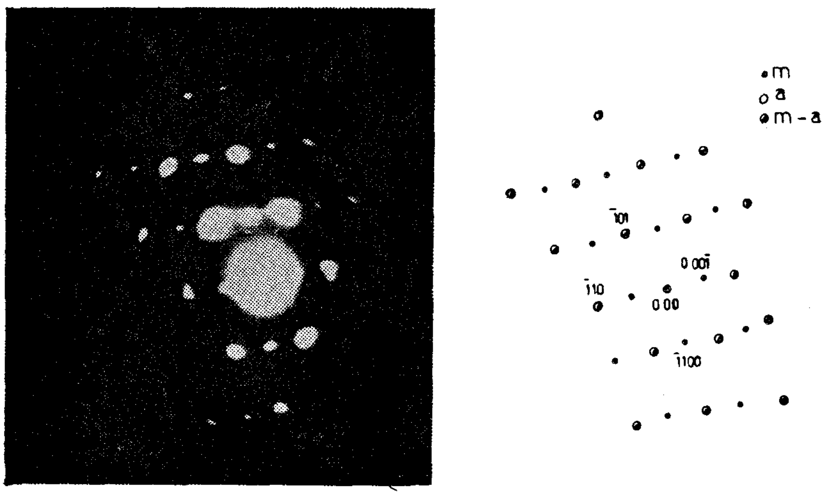
1. Dislocations in Ti-62 % Ta Alloy

Martensitic transformations can be achieved by various methods. When martensite production by the deformation effect in some ferrous alloys examined, it was observed that dislocation density had increased after a critical deformation rate and the product martensite phase was formed as shown by Durlu (1977). The crystal lattice imperfections observed in the parent phase before transformation and in both parent and product phases after transformation showed that dislocations in the lattice are directly related with Burgers vectors. The increase of dislocation density to a critical limit in the parent phase can be interpreted as parent phase is about to undergo to transformation. It means that atomic movements in the austenite matrix may support phase transition. As some crystal lattice imperfections, such as slips and twins, are concerned with dislocation movements, the basis of martensite nucleation is also related with dislocations as reported earlier by Christian (1975). In general, in the crystals of bcc and hcp structures, completely and partly produced dislocations are observed (Smallman, 1976). In the Ti-62 % Ta alloy investigated, parent austenite phase has crystal structure of bcc while product martensite phase has hcp (Adıgüzel, Ceylan and Durlu, 1982). Figure 1 shows a transmission electron micrograph containing both phases. In this micrograph, thin dark area shows product martensite phase, and the grey area around martensites belongs to austenite matrix. Dislocations are also visible in the same micrograph. Diffraction pattern of the same region and its indexed key diagram are given in Figures 2a and 2b. As shown in these figures some of martensite band structures have slipped along the surface lines of dislocations. These dislocations were found as the screw dislocations with the Burgers vector of $b = <1\bar{1}0>_{bcc}$. The same dislocations continue in the product phase with the Burgers vector $b = <0001>_{hcp}$. These Burgers vectors and their determinations by using dislocation lines and related diffraction patterns are shown in Figures 2a and 2b. At the same time, these results are also obtained by using diffraction pattern for the condition given as $\bar{g}.\bar{b} = 0$, where $\bar{g}$ is reciprocal lattice vector and $\bar{b}$ is also Burgers vector of dislocation.

2. Mechanical Twins

Although twins in the martensitic regions of materials are generally formed athermally during the transformation process, in some alloys, twins are also produced isothermally. In general, these twins are called as transformation twins. However, some twins are also formed by the applied deformation which are called deformation twins. Mechanical twins are a kind of deformation twins and produced by the instantaneous strikes or by applying an external load. As can be seen from the appearances in martensite, the mechanical that are of thin band structure with sharp edge may be produced by the instantaneous effect of burst reaction. Dependence of these twins to the crystal lattice parameters of product phase are similar to deformation twins rather than transformation twins. A transmission electron micrograph taken from the region covered both phases is shown in Figure 3. In this Figure, product martensite phase region is darker than parent austenite. The band structures seen like narrow lamellae in the martensitic region are mechanical twins

FIGURE 1. Transmission electron micrograph of Ti-62 % Ta alloy showing dislocations. Thicker dark bands show plate martensites.



(a) (b)

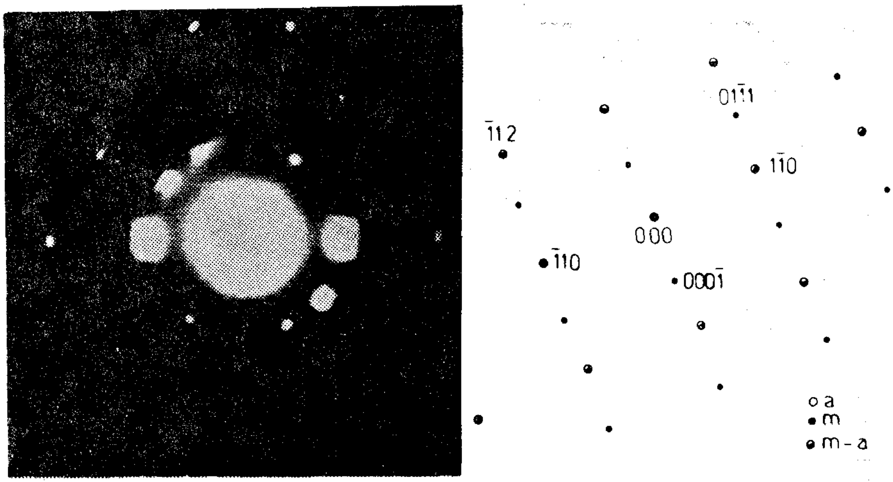
FIGURE 2. a) Diffraction pattern of both phases, and b) Indexed key diagram.

FIGURE 3. Electron micrograph of austenite-martensite region. Dark area shows the massive martensites in which mechanical twins formed.

and these twins have been formed by applying a constant load. An example of such mechanical twins in Ti-62 % Ta alloy is seen in Figure 3 with the corresponding electron diffnaction pattern taken from the same area in Figure 4a. Indexed key diagram and reciprocal lattice points of this pattern are given in Figure 4b. The direction of mechanical twins is obtained by utilizing bright field micrograph in conjuction with corresponding diffraction pattern, and it was found that these twins are on the $\{112\} < 111 >_{bcc}$ and $\{0112\}$ $<0\bar{1}11>_{hcp}$ systems of austenite and martensite, respectively.

DISCUSSION

In the present study, we have examined the dislocations and mechanical twins observed in Ti-62 % Ta alloy. Although straight looking screw dislocations are formed in the alloy, the screw dislocations are the components of the emitted loops which are left behind because the edge parts glide much faster. Many models given by Blum (1977), Illschner



(a) (b)

FIGURE 4. a) Diffraction pattern taken from austenite-martensite interface, b) Indexed key diagram.

(1965), Stüwe (1965), Lindroos and Miekkoja (1968) to describe the stage of creep consider that dislocation substructures maintain a steady state of equilibrium throughout the period in which strain rate remains constant. The inhomogenous structure of dislocation groups correspond to earlier observations of Morris and Martin (1984). The martensitic transformation and its crystallographic properties in various Ti-Ta alloys have been examined in the previous studies, but dislocations and mecnanical twins produced in the same alloy during the transformation have not been investigated before. In the present study, the Burgers vectors of dislocations observed in Ti-62 % Ta alloy were found as b $= <110>_{bcc}$ and b $= <0001>_{hcp}$ in parent and product phases, respectively. From these results, it can be stated that these dislocations correspond to complete dislocations in the product phase of hcp structure and partial dislocations in the parent phase of bcc structure. On the other hand, in the same alloy, mechanical twins were also investigated, and it was found that these had $\{0112\}$ $<0111>_{hcp}$ and $\{112\}$ $<11\bar{1}>_{bcc}$ systems in the product martensite phase and matrix austenite, respectively.

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