Role of connectivity of β-phase in the superplastic deformation of Ti-3Al-2.5 V alloy

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Previous work by Grade *et al.* [1] considers the importance of a continuous β matrix for optimum superplasticity in ZIRC ALLOY 2 and 4. They found that the superplastic deformation in the above alloys was entirely accommodated in the soft β-phase at the $\alpha + \beta$ interface boundaries. A similar situation was reported by Herriot *et al.* [2] in two phase Cu-P alloys in which the hard Cu_3P phase is distributed in a softer Cu rich phase. The deformation in the softer continuous phase was found to be rate controlling. Little literature is available on the effects of connectivity of the softer phase in the microstructure on superplastic behavior of two phase alloys. However, while studying the effects of alloy additions in Ti-6Al-4 V to obtain higher β-phase volume fractions at lower temperatures, Leader *et al.* [3] also discussed the importance of connectivity of β-phase in the microstructure in the case of superplastic deformation of two-phase titianium alloys.

In previous studies of the same author [4, 5], it has been shown on the basis of flow stress, strain rate, and strain rate sensitivity data that the Ti-3Al-2.5 V alloy is superplastic in the temperature range 750 to 910 °C, optimum response being at 880 °C. The present work was aimed at studying the role of β-phase proportion alongwith its connectivity in the microstructure in the superplastic behavior of this alloy.

The specimens were tested by the method of crosshead speed cycling in an Instron Universal testing machine with a Mays three zone furnace. The specimens were then sectioned longitudinally over the gauge length sections. After polishing and etching, the specimens were examined in "cam scan" scanning electron microscope. An etching soluting of 2% HF and 2% HNO_3 (by volume) in distilled water was used for the specimens. Volume fractions of the β-phase at different temperatures were determined by point counting method. Transmission electron microscopy (TEM) was performed using a Jeol 200CX instrument. After grinding, 80–100 μm thick discs were thinned from both sides simultaneously, using a Material Science North West automatic jetting rig, by means of two equidistant jets, with platinum wires in the solution in close proximity to the jets, acting as cathodes. A 5% perchloric acid in methanol was used in the apparatus maintained at a temperature −60 °C to −45 °C. Electropolishing was achieved using conditions at 20 volts and a current of 40 mA. Foils were washed in several baths of methanol and were stored and dried in a specimen storage box, prior to examination in TEM.

Microstructures of the specimens of Ti-3Al-2.5 V alloy tested at 800, 850 and 880 °C are given in Figs 1–3. Volume fractions of β-phase at different test temperatures are given in Table I. It may be seen from Fig. 1 that the softer β-phase in the microstructure is not connected around α grains. As the test temperature is increased to 850 °C (Fig. 2), the β-phase appears to be connected almost 100%. The same connectivity of the β-phase is also seen in the microstructure of the specimen deformed at 880 °C (Fig. 3). TEM micrographs of the specimen tested at 850 °C, given in Fig. 4a and b show connectivity of β-phase around α grains more clearly. It may be observed from Figs 1 to 4 and Table I that connectivity of the β-phase increases with increase in the temperature, reaching a maximum of 100% at 850 °C. The corresponding volume fraction of β-phase at this temperature is 31%. With further increase in temperature, the volume fraction of β-phase further increases reaching 38% at 880 °C and 48% at 910 °C respectively. However, the connectivity is obviously not affected at temperatures higher than 850 °C. The author has previously shown that the superplastic response in Ti-3Al-2.5 V alloy increases with increase in temperature up to 880 °C, which corresponds to a β-phase proportion of about 38% (Table I) and then decreases with further increase in temperature, due to grain growth in β-phase. However, it appears that connectivity of the β-phase in the microstructure also has a role in the superplastic deformation of such $\alpha + \beta$ alloys. Therefore, it may be considered that a β-phase volume fraction of 38% is necessary but not a sufficient condition for optimum superplastic response in Ti-3Al-2.5 V alloy. A 100% connectivity of β-phase would also be required at the same time. In the present work, a 100% β-phase connectivity

TABLE I Volume fractions of β-phase

Temp. (°C)	1	2	3	Ave.	S.D.
800	22.40	21.73	21.96	22.03	0.34
850	29.69	30.25	30.53	30.15	0.43
880	38.32	37.53	38.37	38.07	0.47
910	48.51	47.70	48.73	48.31	0.54

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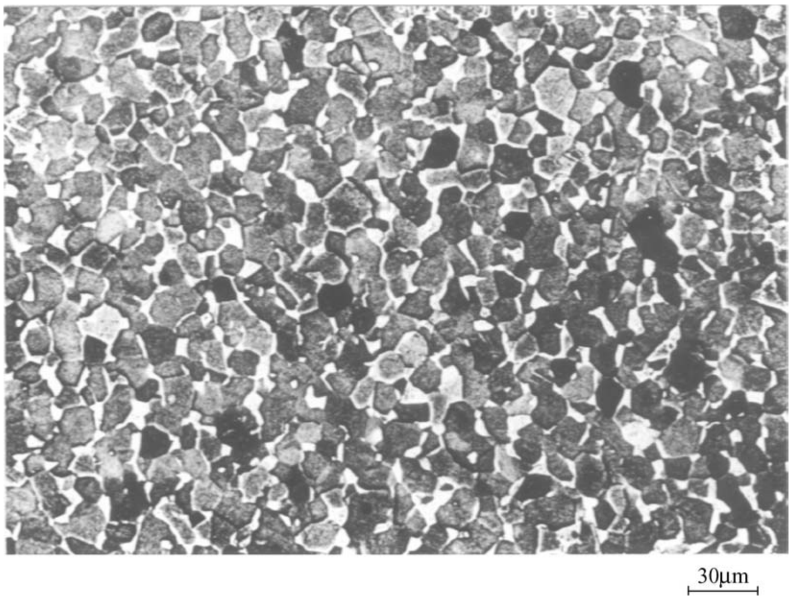

Figure 1 Post test microstructure of Ti-3Al-2.5 V specimen deformed at 800 °C. Gauge length, longitudinal section.

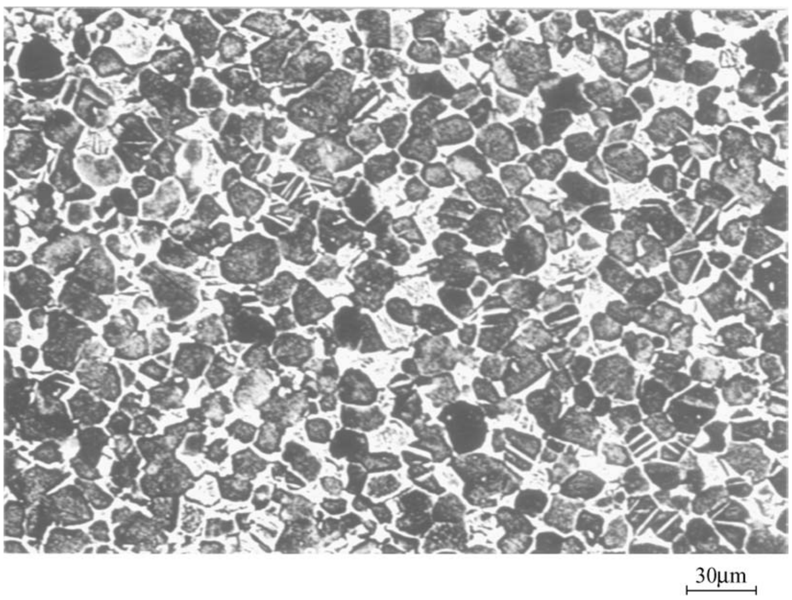

Figure 2 Post test microstructure of Ti-3Al-2.5 V specimen deformed at 850 °C. Gauge length, longitudinal section.

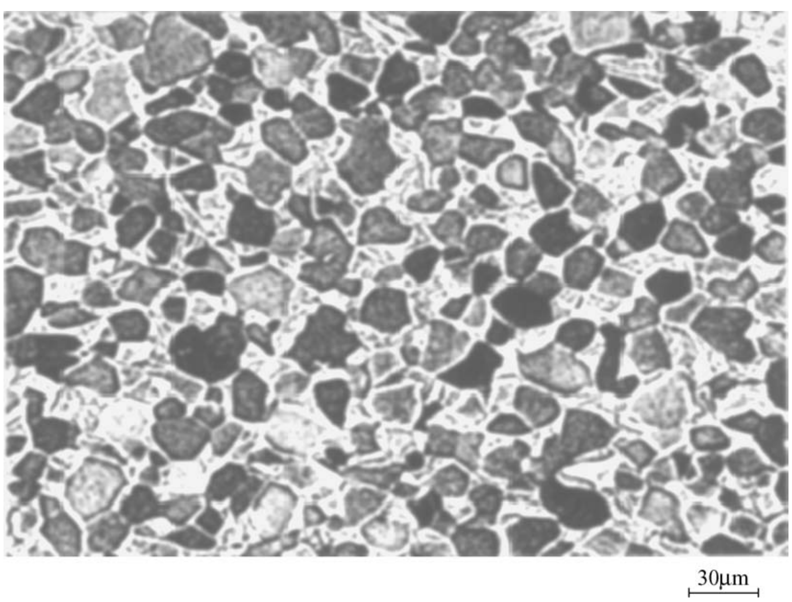

Figure 3 Post test microstructure of Ti-3Al-2.5 V specimen deformed at 880 °C. Gauge length, longitudinal section.

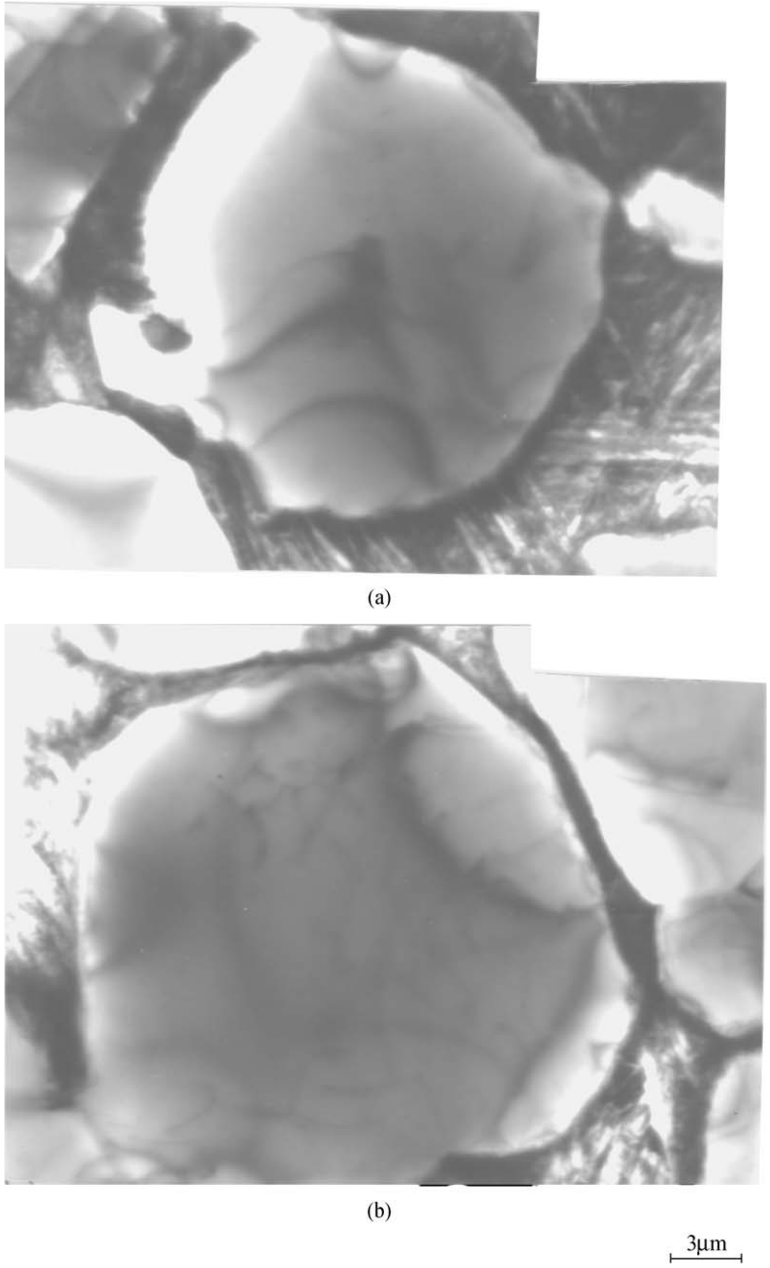

Figure 4 Post test microstructure of Ti-3Al-2.5 V specimen deformed at 850 °C. TEM micrographs representing the gauge length.

has been observed at 850 °C and above, which satisfies the condition of complete β-phase connectivity at 880 °C.

In conclusions:

1. Connectivity of the β-phase in the microstructure increases with increase in temperature (in the range 800–910 °C) during superplastic deformation of Ti-3Al-2.5 V alloy.
2. Connectivity of the β-phase is 100% at 880 °C, which corresponds to optimum superplastic response in the alloy.
3. It is considered that complete connectivity of the β-phase in the microstructure is a necessary condition for optimum superplastic response in the alloy.

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