DEFORMATION BEHAVIOR OF TiAl COMPOUNDS WITH THE TiAl/Ti$_3$Al LAMELLAR MICROSTRUCTURE

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ABSTRACT. In the last few years, substantial progress has been made in our understanding of the microstructure and the deformation and fracture behavior of TiAl compounds. We have made uniaxial tension tests of specimens of the TiAl compounds whose lamellar orientation is controlled so that shear deformation occurs parallel to the lamellar boundaries only in the TiAl lamellae. Then, the TiAl phase itself, which is in equilibrium with the Ti$_3$Al phase, has been found to be easily deformable, and yet brittle fracture occurs in the TiAl phase when the specimens fail. This paper reviews such a deformation and fracture behavior of the TiAl phase together with some key aspects of the progress that was made on TiAl compounds with the TiAl/Ti$_3$Al lamellar microstructure.

1. INTRODUCTION

TiAl possesses a wide composition range. However, it extends primarily on the Al-rich side and the TiAl compounds, with nearly stoichiometric or Ti-rich compositions, exhibit a two-phase microstructure composed of the TiAl phase and a small volume fraction of the Ti$_3$Al phase. The so-called TiAl-based alloys, on which there has been a recent enormous increase in the research and development activity, are such two-phase compounds rather than Al-rich single-phase compounds (for recent reviews, see [1]~[5]). This is because the two-phase compounds are somewhat more ductile than the single-phase compounds [6]. However, the room-temperature tensile ductility of the two-phase compounds is limited to 2-3%. Why is the room-temperature ductility limited to 2-3%? Is it an inherent property of the TiAl phase which is the major constituent phase of the two-phase TiAl
compounds? How does the lamellar structure affect the deformation behavior of the TiAl phase itself? For further improvement in their ductility, studying these questions should be given the highest priority.

When the two-phase TiAl compounds are prepared by usual ingot-metallurgy methods, TiAl and Ti₃Al phases constitute a lamellar structure. Ingots are usually composed of randomly oriented grains with such a lamellar structure. However, when such ingots are remelted and unidirectionally solidified at an appropriate rate, single-crystal-like ingots (PST crystals) composed of only a single grain with the lamellar structure can be obtained. We have made a systematic study on the deformation behavior of such PST crystals in order to find answers to the above mentioned questions.

The results obtained so far can be summarized as follows:

1. Yield stress depends strikingly on the angle between the lamellar boundaries and loading axis. It is high when the lamellar boundaries are parallel or perpendicular to the loading axis and it is very low for intermediate orientations [1,7].

2. The above result indicates that two deformation modes, i.e. hard and easy modes, can occur in PST crystals of TiAl. The hard and the easy modes of deformation were found to correspond to shear deformation across the lamellar boundaries and shear deformation parallel to the lamellar boundaries, respectively [7]. The easy mode of deformation is found to be the deformation of the TiAl phase itself in equilibrium with the Ti₃Al phase.

3. Tensile elongation at room temperature can be as large as 20% for specimens which deform in the easy mode. Furthermore, when PST crystals of TiAl are oriented such that the easy mode of deformation is operative and produces length strain during rolling, they can be rolled to about 50% reduction in thickness at room temperature. Thus, the TiAl phase coexisting with the Ti₃Al phase is seen to be easily deformable.

Then, why is the room-temperature ductility of polycrystalline compounds with the TiAl/Ti₃Al two-phase structure limited to 2-3%? We still continue our systematic study on PST crystals of TiAl to find the answer to this question. The principal part of this paper is devoted to the review of recent results from our systematic study. We do not consider the Al-rich single-phase TiAl compounds whose deform-

Since numerous thin twin related TiAl lamellae are contained in the single-crystal-like ingots, we call these ingots polysynthetically twinned (PST) crystals from analogy with the phenomenon, polysynthetic twinning which is often observed in mineral crystals.