Microstructural Evolution and Silicide Precipitation Behavior of (TiBw+TiCp)/ Titanium Matrix Composite During Multi-Directional Forging

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Abstract: In this study, (TiBw+TiCp)/ titanium matrix composite underwent multi-directional forging deformation to investigate the microstructure evolution and silicide precipitation behavior. The results shown that the microstructure is mainly composed of fragmented TiBw and TiCp, equiaxed α phases, and silicides after deformation. The accumulation of strain during hot deformation and the formation of high-density dislocations near the reinforcement induce and promote the precipitation of silicides. Silicides are mainly distributed in the reinforcement and grain boundaries of low nucleation energy.

Keywords: Titanium matrix composite, Multi-directional forging, Microstructural evolution, Precipitation behavior of silicide;

1 Introduction

Titanium matrix composites (TMCs) have broad application prospects in the aerospace field due to their high specific strength, specific stiffness, and excellent high-temperature resistance [1]. Among the numerous reinforcements in TMCs, TiBw and TiCp reinforcement prepared by in-situ melt casting method have attracted the attention of many researchers. The in-situ casting method has the advantages of simple process and low cost, and is widely used in the preparation of TMCs. However, the obtained composite materials have problems such as reinforcement segregation and room temperature brittleness. Multi-directional forging(MDF) can effectively eliminate the defects and greatly improve the mechanical properties of the TMCs [2]. Silicon is an important matrix alloy element in TMCs, which can significantly improve their strength and creep resistance, generally exists in the form of solid solutions and silicides. The silicides precipitated during the deformation process can significantly affect the microstructure, thermal stability, and creep performance of TMCs [3]. Therefore, it is necessary and feasible to study the influence of multi-directional forging on microstructure and the precipitation of silicides during deformation.

2 Experimental procedure

In this study, the matrix alloy is a new near α titanium alloy Ti-6.5Al-2.5Sn-9Zr-0.5Mo-1W-1Nb-0.25Si (wt.%). The reinforcements are TiCp and TiBw. Firstly, a water-cooled copper crucible induction melting furnace is used to prepare composite material ingots, and The β transformation temperature of the ingot determined by metallographic method is approximately 1085 ± 10 ℃. Then, decreasing MDF was carried out sequentially at three temperatures: 1100 ℃, 1050 ℃, and 1035 ℃.

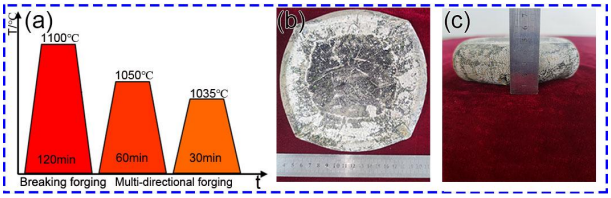

Fig. 1 Schematic diagram of the process of MDF

3 Result and discussion (Bold, 10 pt., Arial)

3.1. The microstructure of as-cast TMCs

As shown in Fig. 2, shows the OM and SEM images of the as-cast (TiBw+TiCp)/Ti composite, the matrix microstructure of as-cast (TiBw+TiCp)/Ti composite is a typical widmanstatten structure. Moreover, TiBw and TiCp have a high aspect ratio, which is not conducive to the improvement of titanium alloy properties.

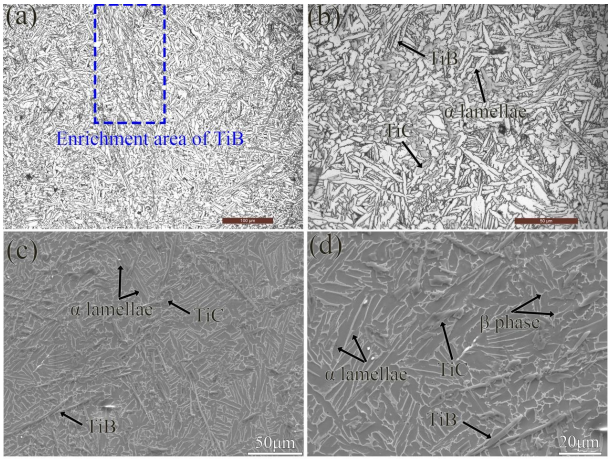

Fig. 2 The microstructures of as-cast (TiBw+TiCp)/Ti composite: (a), (b) OM images; (c) (d) SEM images

The microstructure of as-forged TMCs

Fig. 3 shows the microstructure of (TiBw+TiCp)/Ti composite after MDF. According to the Fig. 3a and 3b, after forging deformation, the microstructure is changed from widmanstatten structure to near equiaxed α structure.

The reinforcements with high aspect ratio fractures are broken, resulting in a decrease in the aspect ratio and they are uniformly distributed in the matrix. In addition, a large amount of white precipitates were precipitated during the forging process (as shown in Fig. 3c and 3d).

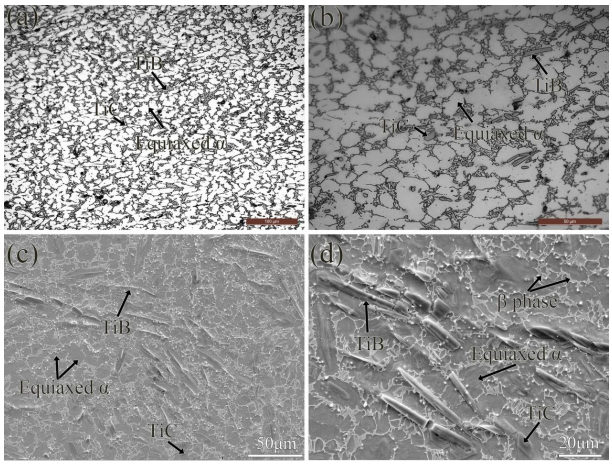

Fig. 3 The microstructure of as-forged (TiBw+TiCp)/Ti composite: (a), (b) OM images; (c) (d) SEM images

As shown in Fig. 4a, it can be further observed that the precipitates are mainly distributed at the reinforcements and grain boundaries. Fig. 4b shows the EDS point scan analysis results of the precipitated phase. The diffraction peaks of Ti, Si, and Zr elements dominate, indicating that the precipitate is mainly composed of these three elements. Therefore, it can be inferred that the precipitate is a silicide. Notably, silicides are mainly distributed at grain boundaries and reinforcements, as the formation of silicides during deformation mainly depends on the diffusion channels provided by dislocations and grain boundarie. During the deformation process, the reinforcements will act as a pinning dislocation to promote the precipitation of silicides. Due to the low nucleation energy at crystal defects, silicides always precipitate in these places [4].

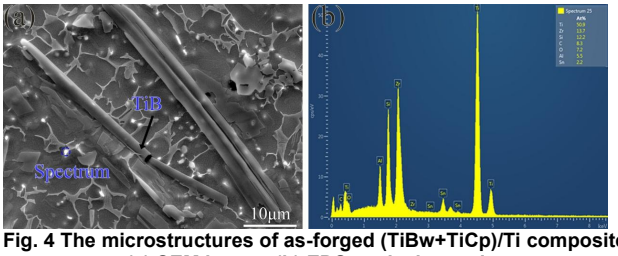

Fig. 4 The microstructures of as-forged (TiBw+TiCp)/Ti composite: (a) SEM image; (b) EDS analysis results

4 Conclusion

(TiBw+TiCp)/Ti composite was prepared, and the as cast matrix structure is a widmanstatten structure with high aspect ratio reinforcements. After multi-directional forging, the grain size and reinforcements are significantly refined, and the microstructure is changed to near equiaxed α structure. The precipitation of silicides during the forging process is mainly located in the aggregation area of the reinforcement and grain boundaries of low nucleation energy.

5 Acknowledgments

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