Intrinsic fatigue cracking mechanisms of coherent and incoherent twin boundaries

Supported by the National Natural Science Foundation of China, Prof. Zhang Zhefeng and his team from the Materials Fatigue and Fracture Division, Shenyang National Laboratory for Materials Sciences, Institute of Metal Research, Chinese Academy of Sciences, reported their findings in fatigue cracking behaviors of individual coherent and incoherent twin boundaries (TBs), which were published in *Scientific Reports* (2014, 4: 3744), *Nature Communications* (2014, 5: 3536) and *Acta Materialia* (2014, 73: 167—176).

Grain boundaries (GBs) play crucial roles in the fatigue properties of materials. It is well-known that random high-angle grain boundaries (HAGBs) always crack while low-angle grain boundaries (LAGBs) never during the cyclic deformation of materials. In contrast, the intrinsic roles of coherent and incoherent TBs remain elusive which is an urgent and significant issue to be investigated. With the aid of successful preparation of Cu bicrystals with a sole coherent or incoherent TB, a series of fatigue experiments were carried out. It is found that the fatigue cracking mechanisms of coherent TBs vary with their orientations with respect to the loading direction. As summarized in Figure 1, when the coherent TB is nearly parallel or perpendicular to the loading direction, the fatigue crack nucleates along the slip band (SB) firstly; while the inclined coherent TB itself is the preferential fatigue cracking site for the rest cases. Unlike the HAGBs and LAGBs, the fatigue cracking mechanisms of coherent TBs are tunable, which provides opportunities for improving the fatigue cracking resistance of materials.

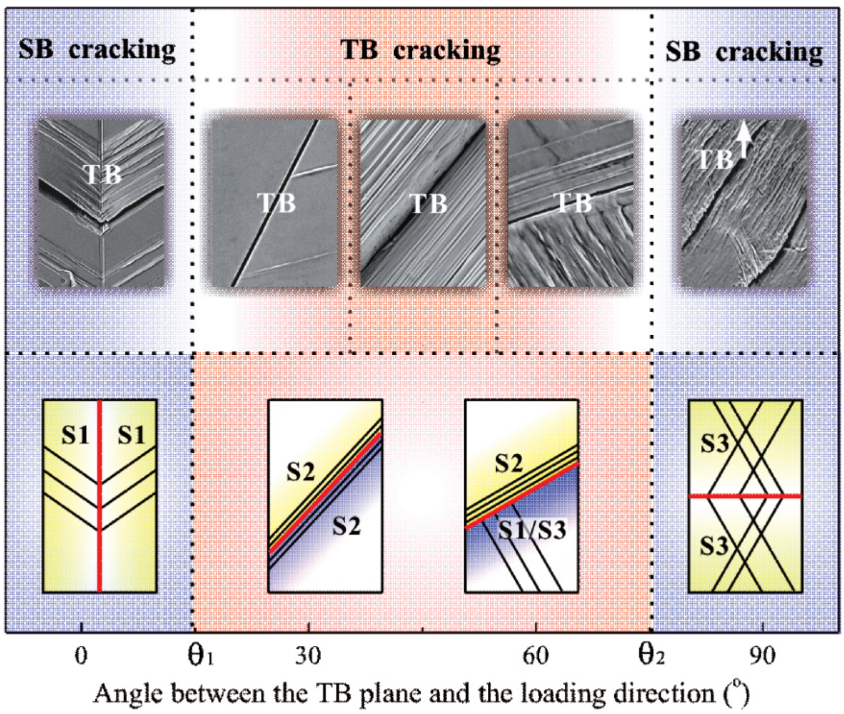

Figure 1 Fatigue cracking mechanisms of coherent TBs with different inclinations.

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In addition, coherent TBs are usually combined with incoherent TBs. Yet no one has investigated the intrinsic fatigue cracking mechanism of incoherent TBs so far. It is interesting to find by our experiment that under a certain circumstance, the SBs could transfer through the incoherent TB (Figure 2a, 2c and 2e); meanwhile, the incoherent TB could migrate with the motion of the partial dislocations (Figure 2d and 2f). Both the penetrability and mobility contribute to the higher fatigue cracking resistance of the incoherent TB and then the fatigue cracks nucleate along the SBs preferentially (Figure 2b). All these results could not only shed light on the fatigue cracking behaviors of coherent and incoherent TBs, but also provide new and important implications for the optimized interfacial design of the high-performance materials.

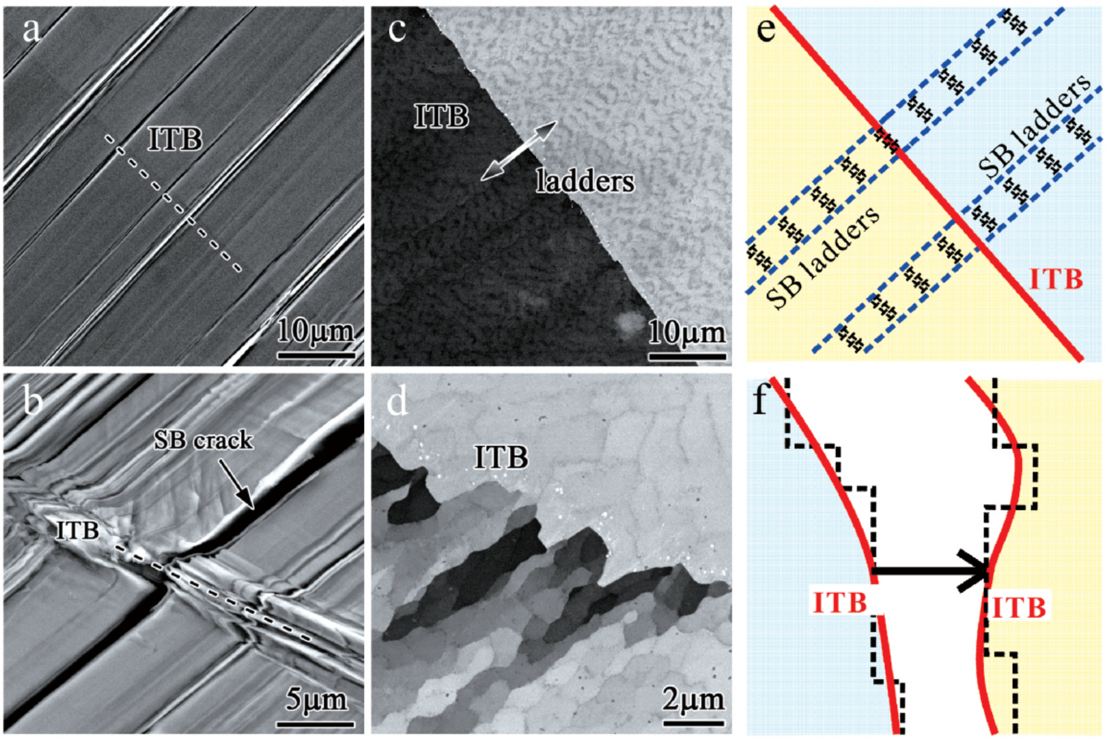

Figure 2 (a,b) The surface deformation morphology, (c,d) dislocation arrangement of the fatigued bicrystal and the sketches for (e) the dislocation penetration and (f) incoherent TB migration.