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EVOLUTIONARY MECHANISM OF ULTRA-FINE BAINITE FERRITE DURING REHEATING

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Abstract: Using thermal simulation test and along with SEM and TEM observation, the evolutionary mechanism of ultra-fine bainite ferrite in low carbon microalloyed steel during reheating at 700 °C has been studied. The experiment results show that the dislocations inside bainite ferrite laths polygonization play a precursor to the evolution of microstructures during reheating and holding, followed by granulation of the retained austenite and gradual disappearance of lath boundaries caused by dislocation climb. Finally, recrystallization happens and polygonal ferrite appears.

1. INTRODUCTION

With novel techniques such as strain induced ferrite transformation [1], grain diameter of ferrite in commercial steels have been lowered to about 1 μm accompanied by double of strength and toughness of these steels. Further needs for higher strength and toughness have caused steels with fine non-equilibrious microstructures occuring. By employing a recently developed relaxation-precipitation controlling transformation (RPC) process, micron scale intermediate transformation microstructures such as bainite ferriete have been obtained [2,3]. Due to their large interface area and high free energy, the fine non-equilibrious microstructures will exhibit a spontaneous trend to evolving into coarse equilibrious ones in accord with thermodynamical principles. Some published works [4,5] suggest that fine martensite will evolve into equilibrious microstructures through recovery and recrystallization, when they are reheated below equilibrious transformation temperature. Cooled subsequently, the deformed austenite would transform under unrecrystallized state so that fine transformation microstructures can be obtained [6,7]. Up to now, the majority of the work has been done on the obtained this fine intermediate microstructure and far less research was carried out on the evolutionary process of them during reheating. Thus, the objects of this paper aim to the phenomenon and mechanism of microstructure evolution during reheating.

2. EXPERIMENTAL

The composition of the steel (wt.%) is 0.04 C, 0.35 Si, 1.35 Mn, 0.045 Nb, and balanced by Fe. Cylindrical specimens with size φ12×20 mm were machined. With a Gleeble-1500 simulator, the samples were heated to 1250 °C at 40 °C s^{-1}, held for 5 min, then cooled to 850 °C at 5 °C s^{-1}. After undergoing a true strain $\varepsilon = 0.25$, the samples were isothermally held (relaxation) for 60 s and then cooled in water. Finally, the specimens were airproofed in vacuumized quartz tubes and reheated at 700 °C for 0.5-20 hours respectively. The samples

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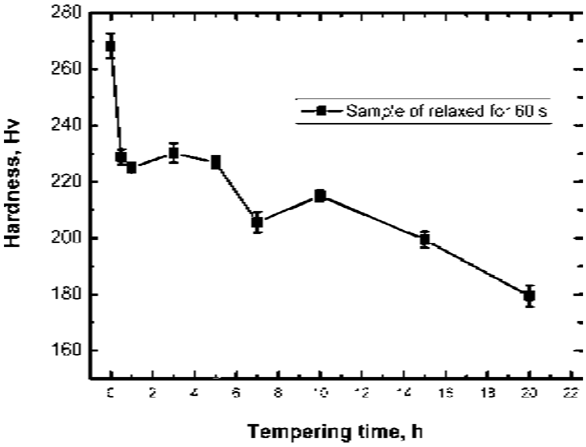

Fig. 1. Hardness change of samples relaxed for 60 s during reheating at 700 °C.

for SEM examination were etched with a 3% nital. TEM specimens were electrolytically thinned by double-jet method carried out at -20 °C and 50 V, using a 5% perchloric acid absolute alcohol electrolyte. The transmission electron microscope employed in this investigation is H-800, which was operated at 200 kV.

3. RESULTS AND DISCUSSION

3.1. Hardness change of samples during holding at 700 °C

Fig. 1 shows the hardness-time relation of samples relaxed for 60 s during holding at 700 °C. After holding for half an hour, the hardness of the samples decreased dramatically. With farther holding, the hardness of samples for 60 s did not change obviously, until reheated for 10 h, while the hardness decreased rapidly again.

3.2. The microstructures of samples before reheated and reheated for different time

It can be found that the samples was constituted by bainitic ferrite (Fig.1a, BF) along with acicular ferrite (Fig.1a, AF) by SEM before reheated. After holding for 0.5 h, no obvious distinction was detected between original samples except for the retained austenite (or its transformation products) has partly granulated (Fig. 2b), while hardness of latter was remarkably lower. Thus, the evolution must begin at first inside the bainitic laths. Parts of boundaries of bainite ferrite laths have disappeared and some polygonal ferrite were found in samples after holding for 10 h (Fig. 2c pointed by arrow). Polygonal ferrite appearance induced the hardness of sample decreased remarkably again. With farther holding, polygonal ferrite began to grow through annexing the neighbor grains. Most of bainitic ferrite transformed into polygonal ferrite after held for 20 h (Fig. 2d).

3.3. Evolution of dislocation configurations during reheating

It was observed by TEM that the dominant bainitic ferrite exhibited lath-like configuration (Fig. 3a) in

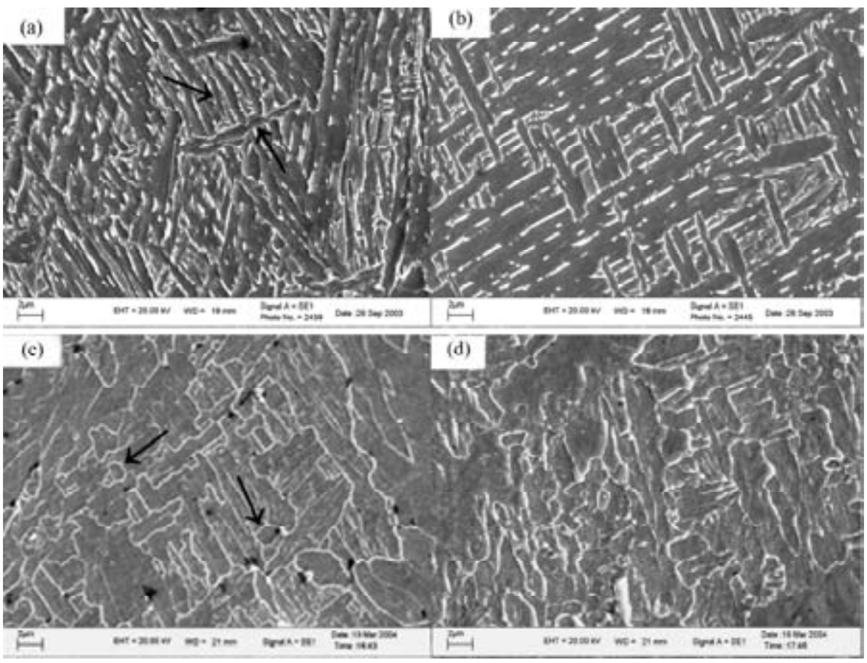

Fig. 2. Microstructures of samples before reheated and reheated for different time at 700 °C: (a) before reheated (b) reheated for 0.5 h (c) reheated for10 h (d) reheated for 20 h.

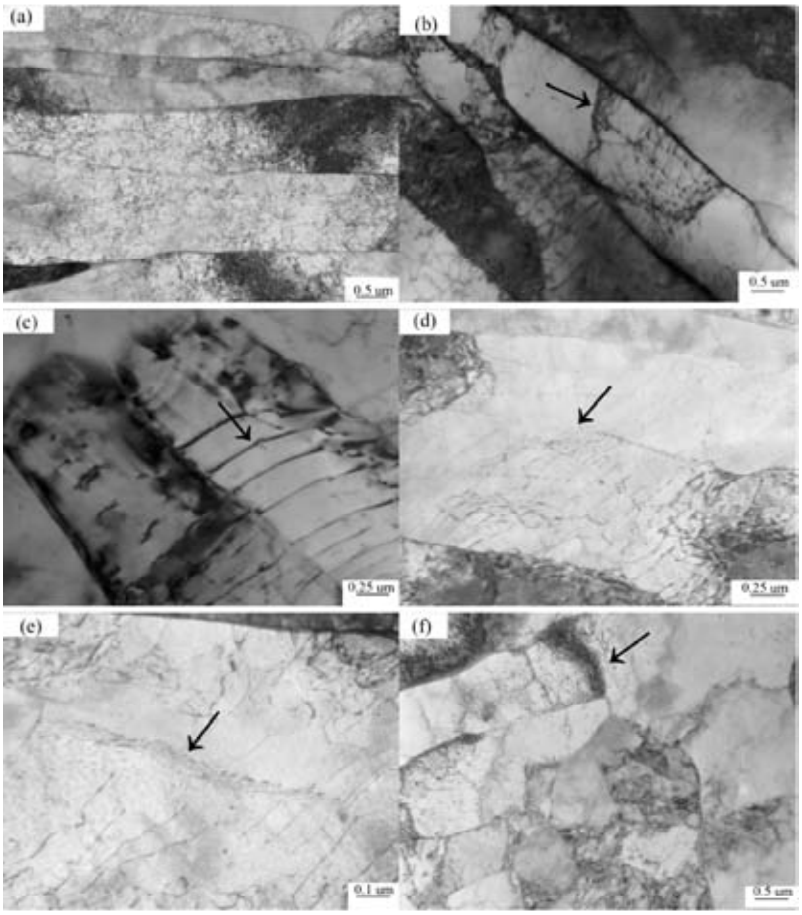

Fig. 3. Evolution of dislocation configurations before reheated and reheated for different time at 700 °C: (a) before reheated (b) reheated for 0.5 h (c) reheated for 7 h (d) and (e) reheated for 10 h (f) reheated for 20 h.

specimen before reheated. The dislocations occurred inside the laths were twisted and distributed randomly. In the evolution of bainite towards equilibrium, dislocation motion plays the role of precursor. After reheated and isothermally held at 700 °C for 0.5 h, dislocation density inside laths in specimens decreased in some degree and dislocation cells could be seen inside the laths (Fig. 3b pointed by arrows). It induced the hardness of samples decreased dramatically. With further holding to 7 h, many boundaries formed by dislocations could be found inside the laths, by which the laths were divided into finer cells (Fig. 3c pointed by arrows). By SEM examination, it was found that after long holding at elevated temperature, lath boundaries of bainitic ferrite would fade down followed by appearance of polygonal ferrite. To reveal micromechanism behind these phenomena, larger magnification and higher resolution were needed. There were some polygonal ferrite in specimen held at 700 °C for 10 h. By TEM, partial disappearance of lath boundaries was frequently found in remained lath-like microstructures (Fig. 3d, pointed by arrows). According to Fig. 3e, observing under larger magnification, it could be found that these boundaries, whose parts had disappeared, consisted of parallel dislocations. In term of these results, it is possible that climbing of boundary dislocations brings about disappearance of lath boundaries. Coalition of neighboring laths where recrystallization will nucleate. Finally, polygonal ferrite will form by recrystallization (Fig. 3f, pointed by arrows).

4. CONCLUSIONS

The evolution of bainite towards equilibrium microstructure progress in following sequence: polygonization of dislocations inside the laths of bainitic ferrite will occur accompany granulation of the retained austenite (or its transformation products), followed by disappearance of lath boundaries, which is a precursor to recrystallization. Finally, polygonal ferrite appearance and growth around lath boundaries. Disappearance of lath boundaries is possibly achieved by dislocation climbing.

REFERENCES

[1] P.J. Hurley and P.D. Hodgson // *Mater. Sci. Eng. A* **32** (2001) 206.

[2] S.W. Yang, X.M. Wang, C.J. Shang, X.L. He and Y. Yuan // *J.univ.sci. & techno.Beijing* **8** (2001) 214.

[3] X.M. Wang, X.L. He, S.W. Yang, C.J. Shang and H. B. Wu // I*SIJ Inter.* **42** (2002) 1553.

[4] Kyung-Tae Park , Yong-Seog Kimb, Jung Guk Lee and Dong Hyuk Shin // M*ater. Sci. Eng. A*. **293** (2000) 165.

[5] H.S. Dong, C.K. Byung, T.P. Kyung and Y.C. Wung // *Acta mater.* **48** (2000) 3245.

[6] H.B. Wu, S.W. Yang, S.Q. Yuan, C.J. Shang, X.M. Wang and X.L. He // *Mater. Sci. Forum.* **475-479** (2005) 121.

[7] S.W. Yang, C.J. Shang, X.L. He, X.M. Wang and Y. Yuan // *J. univ. sci. &techno.Beijing* **8** (2001) 119.