Orientation relationships between ferrite and Fe_4N nitride in hypoeutectoid iron-nitrogen binary alloy

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Summary – In this study, a hypoeutectoid Fe-N binary alloy was prepared by nitriding in autenitic domain at 840 °C. The slow cooling of this alloy led to the Ferrite + Fe_4N microstructure which is similar to the pearlite in Fe-C system. This pearlitic microstructure has been characterized by electron microscopy. The crystal structure of Fe_4N has been identified by electron microdiffraction. In this pearlitic microstructure, the Nishiyama-Wassermann orientation relationship is developed between the ferrite and the Fe_4N nitride.

1. Introduction

Investigations on iron-carbon pearlite have already extended for many years, and wealth of crystallographic data has been obtained. But with iron-nitrogen binary alloys, which also undergo a eutectoid reaction, similar observations have seldom been made. In this case, the austenite decomposes at eutectoid point (592 °C and 2.4 wt.%) to the ferrite and FCC nitride Fe_4N. This eutectoid product, labelled nitrogen pearlite, is similar to the carbon pearlite.

In this study, Scanning and Transmission Electron Microscopy (SEM and TEM) were used to investigate the nitrogen pearlite in an hypoeutectoid iron-nitrogen binary alloy. Electron Microdiffraction method was used to characterize the crystal structure of the Fe_4N nitride and to determine the orientation relationship between the ferrite and the Fe_4N nitride.

2. Experimental

Sheets of pure iron were nitrided in ammonia-hydrogen gas mixture in austenitic domain at 840 °C. After nitriding, specimens were maintained at 840 °C at different holding time up to 2 hours and then were slowly cooled in the furnace. These heat treatments allow a uniform nitrogen distribution. Nitrogen contents (around 0.2 wt.%) were measured by a thermobalance.

3. Characterisation of nitrogen pearlite

The SEM image (Fig. 1) shows clearly the structure of hypoeutectoid Fe-N alloy. Lamellar aggregates of nitrogen pearlite are distributed throughout the proeutectoid ferrite. A dark field TEM image (Fig. 2) shows the lamellar pearlitic structure which is composed of ferrite and a nitride. This microstructure is similar to that of hypoeutectoid carbon steels.

The crystallographic features of the nitride were determined from the recorded microdiffraction patterns by a systematic method given in detail elsewhere [1, 2]. This investigation led to the conclusion that the nitride belongs to $Pm\bar{3}m$ space group with a lattice parameter a=3.79 Å, . The latter has been determined by X-ray diffraction. Based on these results, this nitride corresponds to γ'-Fe_4N.
The microdiffraction patterns (Fig. 3-4) have revealed the well-known Nishiyama-Wassermann (N-W) orientation relationship [3, 4] between the ferrite and the Fe_4N nitride in the nitrogen pearlite, i.e.:

$$(011)\alpha \;//\; (111)\gamma' \,;\, [100]\alpha \;//\; [1\bar{1}0]\gamma' \,;\, [0\bar{1}1]\alpha \;//\; [\bar{1}\bar{1}2]\gamma'$$

The figure 4 points out a departure from the exact N-W orientation relationship. This departure could be related to the fact that the specimen has been slowly cooled in the furnace, leading to a local nitrogen depletion of the ferrite.

4. Conclusion

This investigation shows that the slow cooling of a hypoeutectoid Fe-N alloy leads to an eutectoid product which is composed of ferrite and Fe_4N nitride. As far as we are aware, the crystallographic Nishiyama-Wassermann orientation relationship between the ferrite and the Fe_4N nitride is the first data published on this topic.

5. References

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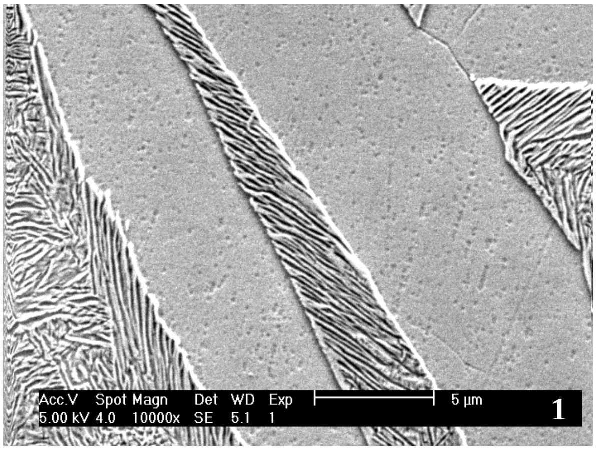

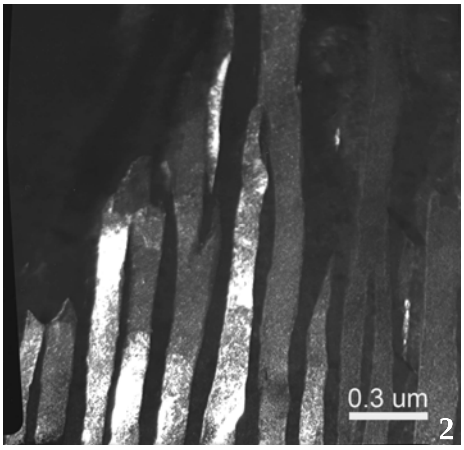

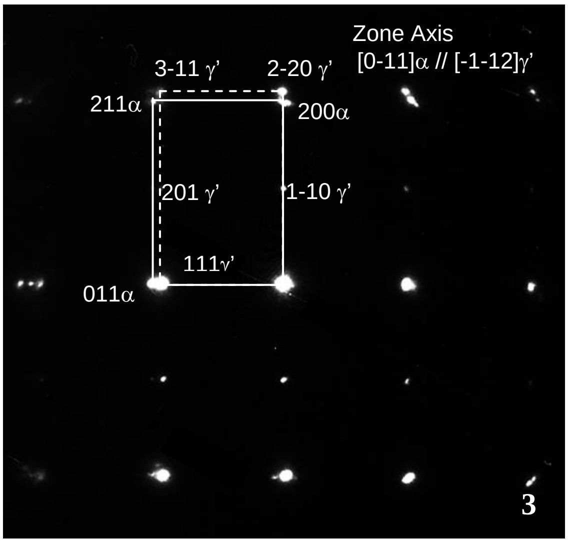

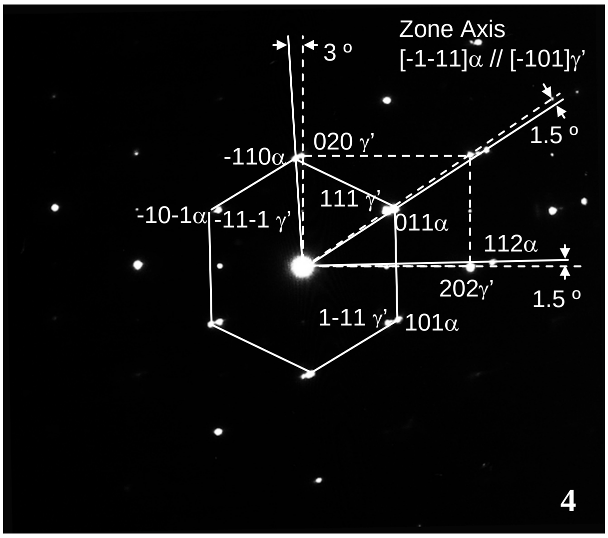

Fig. 1 *SEM image of nitrogen pearlite.*
Fig. 2 *TEM Dark Field image showing lamellar structure of nitrogen pearlite.*
Fig. 3 *Diffraction pattern [0-11]α (solid line) // [-1-12]γ' (dotted line) zone axis pointing out the N-W orientation relationship between ferrite and γ'-Fe_4N:*
[011]α// [111]γ', [100]α// [1-10]γ'
Fig. 4 *Diffraction pattern along [-1-11]α (solid line) // [-101]γ' (dotted line) zone axis pointing out a departure from the exact N-W orientation relationship:*
[011]α 1.5° from [111]γ', [112]α 1.5° from [101]γ'