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ACCURATE ORIENTATION RELATIONSHIPS BETWEEN FERRITE AND CEMENTITE IN PEARLITE

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Introduction

In most previous work [1~5], the interlamellar interface between pearlitic ferrite and cementite is considered to have a low energy and dislocations have been observed at the interfacial boundary, in both plain carbon steels [2] and high manganese steels [3, 4]. This implies that an orientation relationship (OR) exists between pearlitic ferrite and cementite. Over the past decades, there have been a number of experimental determinations of the OR in pearlite [6~11], but only three have been consistently reported in the literature. They are:
The Isaichev OR:

$$(\bar{1}03)_Z \| (110)_F$$
$$[010]_Z \| [1\,\bar{1}\,\bar{1}]_F$$
$$[311]_Z \ 0.91° \text{ from } [1\,\bar{1}\,1]_F$$

The Bagaryatskii OR:

$$(001)_Z \| (11\bar{2})_F$$
$$[100]_Z \| [0\,\bar{1}\,1]_F$$
$$[010]_Z \| [1\,\bar{1}\,\bar{1}]_F$$

The Pitsch-Petch OR:

$$(001)_Z \| (5\,\bar{2}\,\bar{1})_F$$
$$[100]_Z \ 2.6° \text{ from } [13\,\bar{1}]_F$$
$$[010]_Z \ 2.6° \text{ from } [113]_F$$

where the subscripts Z and F refer to cementite and ferrite, respectively.

Since all these three ORs were determined by using selected area electron diffraction (SAD), the accuracy is limited and experimental errors can be as large as ±3 to 5° [12]. In the work of Dippenaar and Honeycombe [13], the experimentally determined ORs show a scatter of about 10°. Thus, it is impossible to distinguish small differences between ORs by the SAD technique. For example, because the Bagaryatskii OR and the Isaichev OR are related by a rotation of only 3.59° about the common axis

$[010]_Z \| [1\bar{1}\bar{1}]_F$, the Isaichev OR was often considered as an effect of experimental error and came to be regarded as an approximation to the Bagaryatskii OR, which can be expressed simply using only the 3 crystallographic axes of cementite. As the Bagaryatskii OR and the Pitsch-Petch OR were also observed in bainite [14, 15] and tempered martensite [16], they have been universally accepted as the true ORs between cementite and ferrite matrix. Recently, Zhou and Shiflet [3, 4] have compared habit planes and concluded that the Isaichev OR is a true OR and differs from the Bagaryatskii OR.

Are the Bagaryatskii OR and the Isaichev OR, actually, the same OR, or different ORs? Which one is real? Is the commonly accepted Pitsch-Petch OR a true OR between cementite and ferrite? What is relationship between all these ORs? To answer these questions more accurate determinations of the OR are required. In the present paper convergent beam Kikuchi line diffraction patterns (CBKLDP) are used to reveal the true ORs between cementite and ferrite in pearlite, to an accuracy of ±0.5°.

Experimental

Three commercial plain carbon steels with different carbon content were examined. Their chemical compositions are listed in Table 1.

All the samples for these three steels were cut into small blocks from the hot rolled rods. After a homogenising anneal at 1170°C for 72 hours under nitrogen, the blocks were austenitized at 1000°C and furnace cooled to obtain pearlite or pearlite + proeutectoid phases. Then, they were slowly sliced to thin plates with thickness of 0.6~0.8 mm using a diamond cutting blade. Specimens for TEM were jet polished in 8 pct perchloric acid and acetic acid mixture at 15°C with a voltage of 35 V, after carefully mechanical thinning to 0.08 mm. All thin foils were examined either in a JEOL 4000FX or a FEOL 1210.

The orientation relationships were determined using CBKLDP as described in reference [17, 18].

Results

Careful specimen preparation and operation of the electron microscopes ensured that the Kikuchi patterns were clear and sharp. Consequently, very accurate results were obtained. Fig. 1 shows the typical Kikuchi patterns obtained from pearlitic ferrite and cementite, and their corresponding indices. The indices are expressed using the middle lines (the planes traces)between the Kikuchi pairs.

Eutectoid Steel

A fully pearlite microstructure was obtained in the eutectoid steel. Two ORs, namely the New-2 OR and the New-3 OR, which are close to the Pitsch-Petch OR, were observed. They are shown in Figs. 2 and 3, and can be expressed as follows:

New-2 OR:

$$(\bar{1}03)_Z \| (\bar{1}01)_F$$
$$[010]_Z \text{ 8.5° from } [131]_F$$
$$[3\bar{1}1]_Z \| [1\bar{1}1]_F$$

New-3 OR:

$$(0\bar{2}2)_Z \| (\bar{1}01)_F$$
$$[100]_Z \text{ 2.4° from } [1\bar{3}1]_F$$
$$[311]_Z \| [1\bar{1}1]_F$$