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ON THE OCCURRENCE OF ε-CARBIDE IN IRON

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MINES BRANCH
RESEARCH REPORT

R 21

PRICE 25 CENTS

REPRINTED FROM ACTA CRYSTALLOGRAPHICA,
VOL. 11, PART 1, JANUARY 1958

Reprinted from Acta Crystallographica, Vol. 11, Part 1, January 1958

Research Report R 21

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ABSTRACT

Quenched and aged alpha iron specimens have been examined by electron diffraction after polishing and etching to leave carbide particles in relief. Specimens aged at 200°C for 2 hours gave patterns typical of hexagonal epsilon iron carbide and those aged at 400°C for 1 hour gave patterns typical of cementite.

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It is well known that ε-iron carbide forms during the first stage of tempering hardened steel (Jack, 1951a; Roberts, Averbach and Cohen, 1953; Lement, Averbach and Cohen, 1954). Single-crystal X-ray work (Roberts et al., 1953; Kurdjumov and Lyssak, 1947, 1949) on this material has shown that the ε-carbide phase exists in metastable equilibrium with martensite containing about 0.25 wt. % carbon and it was concluded (Roberts et al;, 1953) that ε-carbide would not form from martensite containing less than this amount of carbon. It thus appeared unlikely that ε-carbide would form directly from supersaturated ferrite. This view was supported by kinetic measurements (Dijkstra, 1949; Wert, 1949) on the precipitation of carbon from quenched iron containing about 0.02 wt. % carbon which gave no indication of the existence of a metastable phase prior to the formation of cementite. It was thus somewhat surprising when Tsou, Nutting and Menter (1952), using electron-diffraction methods, reported the existence of ε-carbide in iron containing 0.026 wt. % carbon. This is a brief report of further electron-diffraction experiments on iron which support the conclusions of Tsou et al.

Both commercial grade (Armco) iron with a nominal carbon content of 0.01 wt. % and high-purity vacuum-melted

iron also containing 0.01 wt. % carbon were examined. The results obtained from the two materials were identical. Electron-diffraction patterns were obtained from specimens immediately after quenching from 720°C after ageing at 200°C for 2 hr. and after ageing at 400°C for 1 hr. The quenched specimens gave only spotty patterns due to the iron itself. The additional face-centred cubic γ-iron phase reported by Tsou et al (1952) was not detected. Those specimens aged at 400°C gave patterns typical of cementite. However, the specimens aged at 200°C for 2 hr. gave rise to a markedly different pattern shown in Fig. 1. The spots are due to the ferrite matrix and measurements of the continuous rings lead to lattice spacings in agreement with those of ε-iron carbide as shown in Table I (Jack, 1951a). It is known from internal friction measurements (Kijkstra, 1949; Wert, 1949) that the carbon precipitation process in iron is essentially complete after ageing at 200°C for 2 hr., hence the most obvious interpretation of the above observations is that a carbide, namely ε-carbide, is present after this treatment.

Since the occurrence of ε-carbide in iron has not been detected except by electron diffraction experiments, other possible interpretations of the pattern obtained from the specimens aged at 200°C have been considered.

Table I. Comparison of the interplanar spacings obtained from iron quenched from 720°C and aged at 200°C for 2 hr., with those of ε-iron carbide

	Interplanar spacings (kX.)	
kkl	Iron aged at 200°C for 2 hr.	ε-Iron carbide*
100	2.39	2.36
002	Not resolved	2.16
101	2.08	2.07
102	1.59	1.60
110	1.35	1.36
103	1.22	1.23
200	1.17	1.18
112		1.16
201		1.14

*Calculated for a = 2.729, c = 4.326 kX. (Jack, 1951a).

The alternative explanations would be to postulate (a) that it was due to an iron nitride phase, or (b) that it was due to two-dimensional diffraction from cementite platelets only a few unit cells in thickness. The first postulate may be ruled out since the nitrogen content of the high-purity iron was only one-tenth that of the carbon content, and thus the intensity of any nitride pattern would be very small compared to that of the carbide. In any case the ε-nitride phase does not occur under these conditions (Jack, 1951b, 1952) and the presence of α''-iron nitride or γ'-iron nitride would not account for the observed pattern As regards the possibility of two-dimensional diffraction, this is also unlikely in view of the microscopically observed dimensions of the precipitate particles. Electron-microscopic examination of the high-purity iron specimen aged at

200°C for 2 hr. indicated the presence of precipitate particles which were in the form of thin platelets several thousand Angstrom units in the large dimension and a few hundred Angstrom units thick. It is not possible that cementite platelets of these dimensions could give rise to the patterns observed. It is therefore concluded that the existence of -carbide in iron containing as little as 0.01 wt. % carbon is the most reasonable interpretation of the diffraction patterns from the specimens aged at 200°C.

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