Matrix Phase in Lower Bainite and Tempered Martensite

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THAT bainite formed near the M_s temperature bears a striking resemblance to martensite tempered at the same temperature has been shown by the electron microscope.¹ By means of electron diffraction,² it has been established that ϵ carbide and cementite are present in bainite formed at 500°F (260°C); these carbides are also found in martensite tempered at 500°F (260°C).^{2, 3}

The investigation reported here is concerned with an X-ray study of the matrix phases in lower bainite and tempered martensite. These phases have turned out to be dissimilar in structure; the matrix of bainite is body-centered-cubic while that of tempered martensite is body-centered-tetragonal.

A vacuum-melted Fe-C alloy containing 1.43 pct C was studied. Specimens of 1/8 in. diam were sealed in evacuated silica tubing and austenitized at 2300°F (1260°C) for 24 hr. One specimen was quenched into a salt bath at 410°±7°F (210°±4°C), held for 16 hr, and cooled to room temperature. The structure consisted of about 90 to 95 pct bainite, the remainder being martensite and retained austenite. A second specimen was quenched from the austenitizing temperature into iced brine and then into liquid nitrogen. It consisted of about 90 pct martensite and 10 pct retained austenite. The latter specimen was tempered for 10 hr at 410°±2°F (210°±1°C).

The specimens were then fractured along prior austenite grain boundaries (grain size about 2 mm diam) by light tapping with a hammer. Single austenite grains, mostly transformed, were etched to about 0.5 mm diam and mounted in a Unicam single crystal goniometer, which allowed both rotation and oscillation of the sample. Lattice parameters were measured by the technique of Kurdjumov and Lyssak.⁴ This method takes advantage of the fact that martensite and lower bainite are related to austenite by the Kurdjumov-Sachs orientation relationships.⁵ Thus, the (002) and the (200) (020) reflections can be recorded separately, permitting the c and a parameters to be determined without interference from overlapping reflections.

According to these findings, the matrix phase in bainite is body-centered-cubic and, within experimental error, has the same lattice parameter as ferrite (2.866Å). On the other hand, martensite, tempered as above, retains some tetragonality, with a c/a ratio of 1.005±0.002.

Most workers in the past have assumed that bainite is generated from austenite as a supersaturated phase, but the nature of this product has not been established. The question arises as to

whether bainite initially has a tetragonal structure and then tempers to cubic, or if it forms directly as a cubic structure. If it forms with a tetragonal lattice, it might well be expected to temper to the cubic phase at about the same rate as tetragonal martensite.

The martensitic specimen used here was given approximately the same tempering exposure, 10 hr at 410°F, as suffered by the greater part of the bainite during the isothermal transformation. About 50 pct bainite was formed in 6 hr at 410°F. On tempering at this temperature, martensite reduces its tetragonality within a few minutes to a value corresponding to 0.30 pct C.⁶ Further decomposition proceeds slowly, and after 10 hr the c/a ratio is still appreciable, i.e., 1.005. Thus, even if the bainite were to form as a tetragonal phase with a tetragonality corresponding to only 0.30 pct C, which might be assumed to coexist with ϵ carbide,⁷ it would not be expected to become cubic in this time. It seems very likely, therefore, that bainite forms from austenite as a body-centered-cubic phase and does not pass through a tetragonal transition. The carbon content of the cubic phase has not been determined, but it could easily be as high as 0.1 pct, within the experimental uncertainty of the lattice-parameter measurements.

It has been postulated⁸ that retained austenite decomposes on tempering into the same product as martensite tempered at the same temperature. There is now considerable doubt on this point. The isothermal transformation product of both primary and retained austenite at the temperature in question here is bainite,⁹ and the present findings show that bainite and tempered martensite do not have the same matrix.

Acknowledgments

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