On the Carbon Kinetics in Martensite, relevance to Nanosegregation at Dislocations and Grain Boundaries

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Abstract

This short communication is devoted to the room temperature processes of diffusion and redistribution of dissolved carbon atoms in martensite to the nanosegregation regions at dislocations and grain boundaries. It is related to the DF7 contribution of M. Lavrskyi et al. on the carbon kinetics in martensite [1] and to the DF7 contribution of Yu. Nechaev on the compound-like nanosegregation at dislocations and grain boundaries in metallic materials [2].

Keywords

Martensite, carbon diffusion, nanosegregation, dislocations, grain boundaries

1. Introduction

In study [1] the Atomic Density Function (ADF) theory has been applied to model the room temperature kinetics of carbon redistribution in martensite phase. According to [1], at early stage of aging the carbon kinetics is governed by the spinodal decomposition and small carbon rich zones appear. Then during further growth these zones are elongated to some special crystallographic directions to minimize the elastic energy of system. The simulated images of carbon redistribution in tempering materials are shown in Figure 1a (in [1]). It is also noted [1] that these simulation results are in very good agreement with experimental data (Figure 1b in [1]) obtained by Atomic Probe Tomography (APT).

But in study [1] the related results [3-5], including the APT ones [5], on diffusion and redistribution of the dissolved carbon atoms in martensite to the nanosegregation regions at dislocations and grain boundaries have not been taken into account. The results [5] on the carbon segregation at dislocations in martensite were analysed and interpreted in [3, 4] (as the carbide-like nanosegregation, but not as “the Cottrell atmospheres”).

Such an analysis, with relevance to data [1] on the room temperature kinetics of carbon redistribution in martensite phase, along with using results [3-5], has been carried out in the present study.

2. Methods, Results and Discussion

2.1. Methods

In the present study the methods of thermodynamic analysis [2-4, 6-9] of a number of related data are used. Such an approach gives some new results.

2.2. Results

Some results of analysis of data [1], along with using data [3-5], are presented below.

2.2.1. Evaluation of the characteristic diffusion length (L), relevance to data [1]

Figure 1 in [1] is devoted to redistribution of carbon atoms in the martensite aged 7 days (t) at room temperature ($T \approx 300$ K). The characteristic carbon diffusion length (L) can be evaluated (with accuracy of order of magnitude), by using the known equation:

$$L \approx \sqrt{D \cdot t}, \qquad (1)$$

where D is the diffusion coefficient for carbon atoms in the martensite lattice at room temperature; according to the experimental data (considered in [3-5]), $D = (4 \pm 1) \cdot 10^{-17}$ cm^2s^{-1}.

Hence, one can evaluate the desired quantity $L \approx 5 \cdot 10^{-6}$ cm.

2.2.2. Evaluation of the dislocation density ($\rho_\perp$), by using the obtained value of L

The possible dislocation density ($\rho_\perp$) in the martensite phase [1] can be evaluated (with accuracy of order of magnitude), by using the obtained value of L and the known equation:

$$\rho_\perp \approx L^{-2}. \qquad (2)$$

Hence, one can evaluate the desired quantity $\rho_\perp \approx 4 \cdot 10^{10}$ cm^{-2}.

The obtained value of $\rho_\perp$ is of one order less, than the density value ($\rho_\perp \approx 3 \cdot 10^{11}$ cm^{-2}) of dislocations (with the carbide-like nanosegregation) in martensite [5] evaluated in [3].

2.3. Discussions

In the APT study [5] the large-angle nanograin boundaries, highly segregated by carbon, in martensite, aged 24 hours at room temperature, have been observed.

Taking into account this result [5], along with the above noted results on values of L for martensite [1] and $\rho_\perp$ for martensite [5], one can suppose the following:

1) the carbon kinetics during aging (at room temperature) of martensite [1] can be governed by diffusion of the dissolved carbon atoms to the carbon nanosegregation regions at dislocations and/or the large-angle grain boundaries;
2) the experimental images of carbon redistribution in tempering martensite, shown in Figure 1b [1], can be related to the carbon nanosegregation regions, mainly, at the large-angle grain boundaries observed in [5].
3) the probable process of the diffusional redistribution of carbon from the nanosegregation regions at dislocations to the nanosegregation regions at the large-angle grain boundaries could be taken into account, on the basis of results [9, 10].

3. Conclusions

The carbon kinetics during aging of martensite [1] can be governed by diffusion of the dissolved carbon atoms to the carbon nanosegregation regions at dislocations and/or the large-angle grain boundaries.

The experimental (APT) images of carbon redistribution in tempering martensite [1] can be related to the carbon nanosegregation regions, mainly, at the large-angle grain boundaries.

In study [1] the related results [3-5] on the dissolved carbon atoms diffusion and redistribution in martensite to the carbon nanosegregation regions at dislocations and the large-angle grain boundaries should be taken into account.

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