# Electron microscopic analysis of austenite transformation behavior in cold-rolled low carbon steel

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Most of the practical steels experience the austenite (γ-Fe) phase during the heat treatment processes. To understand influence of heat treatment and the deformation conditions on the phase transformation to γ-Fe phase will be informative to improve the material properties of practical steels. In a cold-rolled low carbon steel which is one of the practical steels, γ-Fe formation is influenced by ferrite (α-Fe) recrystallization during the heat treatment process[1]. It can be explained that grain boundaries introduced by α-Fe recrystallization one in contact with cementite (θ-Fe$_3$C) where diffusion of carbon atoms from θ-Fe$_3$C occurs preferentially and α+θ→γ transformation occurs. In this study, we investigated the location of θ-Fe$_3$C, grain boundaries and Mn-rich regions in a nanostructured Mn-containing low carbon steel by cold rolling. From the obtained results, we discussed α+θ→γ transformation behavior.

Two kinds of samples were prepared from cold-rolled Fe-0.1 mass%C-2.0 mass%Mn alloy. Sample (i) was heated up to 712 °C in 25 sec and quenched into water. In this sample, γ-Fe formation has not started. Sample (ii) was heated up to 750 °C in 26 sec and quenched into water. In this sample, γ-Fe formation has started. Since Mn concentrates in θ-Fe$_3$C, it is considered that the locations of θ-Fe$_3$C can be recognized by the Mn concentration distribution. Furthermore, the diffusion rate of Mn is lower than that of C in iron. If there is high Mn concentration in the iron matrix, it is possible that the locations where θ-Fe$_3$C originally existed can be recognized as Mn-rich regions in γ-Fe. Therefore, we acquired Mn map by energy-dispersive X-ray spectroscopy (EDS) in STEM. In addition, we visuallized grain boundaries by scanning precession electron diffraction (SPED). The grain boundary map was obtained by displaying the degree of matching of the PED intensity distribution between adjacent measurement points[2]. The phases, α, γ and θ were identified by the PED patterns. When we compared Mn maps and grain boundary maps and the PED patterns in sample (i), it was observed that the Mn-rich regions were θ-Fe$_3$C. This result shows that Mn map can show the location of θ-Fe$_3$C. On the other hand, in the Mn-rich regions for sample (ii), both θ-Fe$_3$C (region 1 and 2 in Fig.1 and Fig.2 and Fig.3(a) and (b)) and α-Fe (α'-Fe martensite) (region 3 in Fig.1 and Fig.2 and Fig.3(c)) were observed. The latter Mn-rich region 3 is interpreted to be originally θ-Fe$_3$C where C diffused and α+θ→γ transformation occured. In other words, the region 3 is considered as the preferential γ transformation site. This result shows that the preferential γ transformation site can be recognized by comparing Mn maps, grain boundary maps and the PED patterns. The Mn-rich region 3 of α(α')-Fe is wider than the Mn-rich regions 1 and 2 of θ-Fe$_3$C. Assuming that Mn diffused during α+θ→γ transformation, it was considered that Mn diffusion proceeded along grain boundaries.

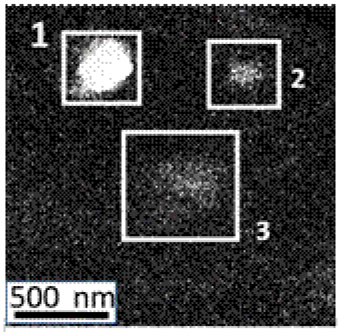

Fig.1 Mn map in sample (ii).

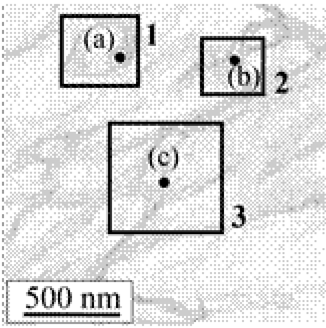

Fig.2 Corresponding grain boundary map in sample (ii).

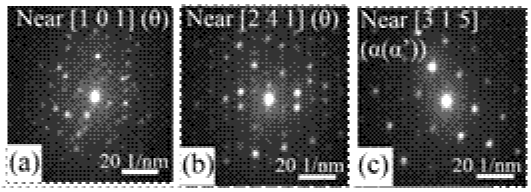

Fig.3 Corresponding PED patterns.

[1] H. Azizi-Alizamini et al., *Metall. Mater. Trans,* 42A, 1544 (2011).
[2] Ákos K. Kiss et al., *Ultramicroscopy,* 163, 31 (2016).

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