Effect of Intercritical Annealing Time on γ→α Transformation during Cooling in Cold-rolled Dual Phase Steels

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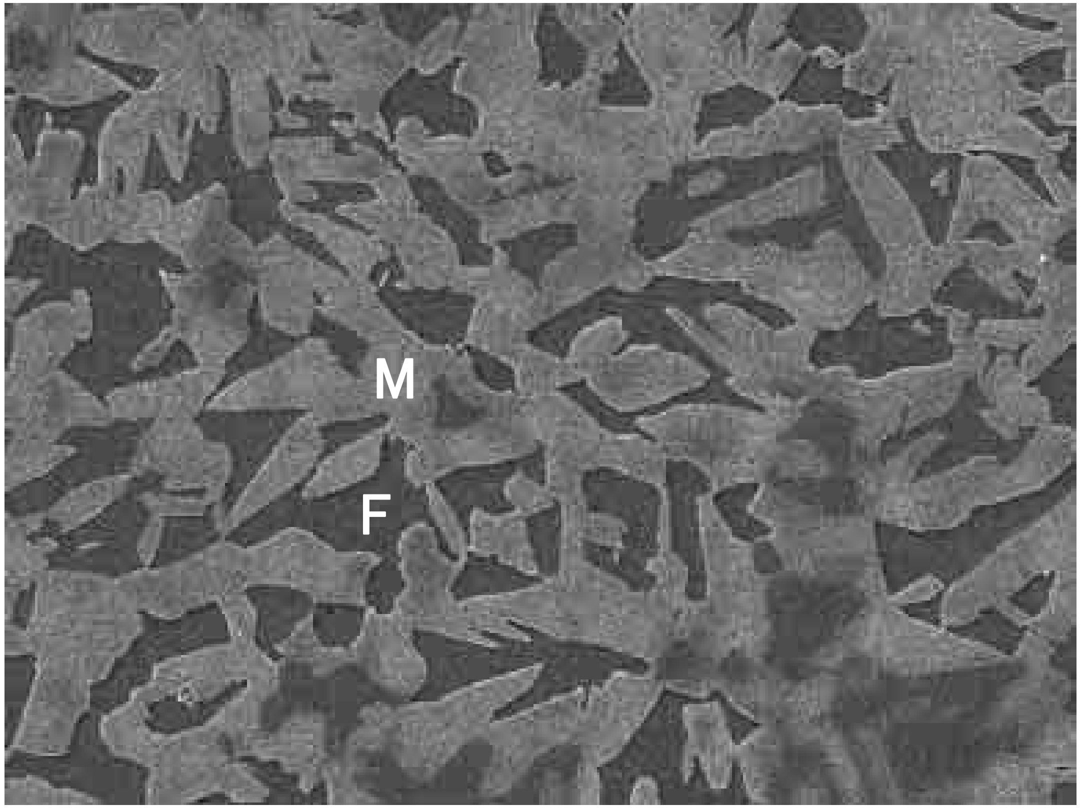
Introduction

Cold-rolled Dual Phase steels (DP steel)

・・・excellent balance with high strength and good formability

⇒ from manufacturing prospective,

the stability of mechanical properties is important to achieve high accuracy of car parts

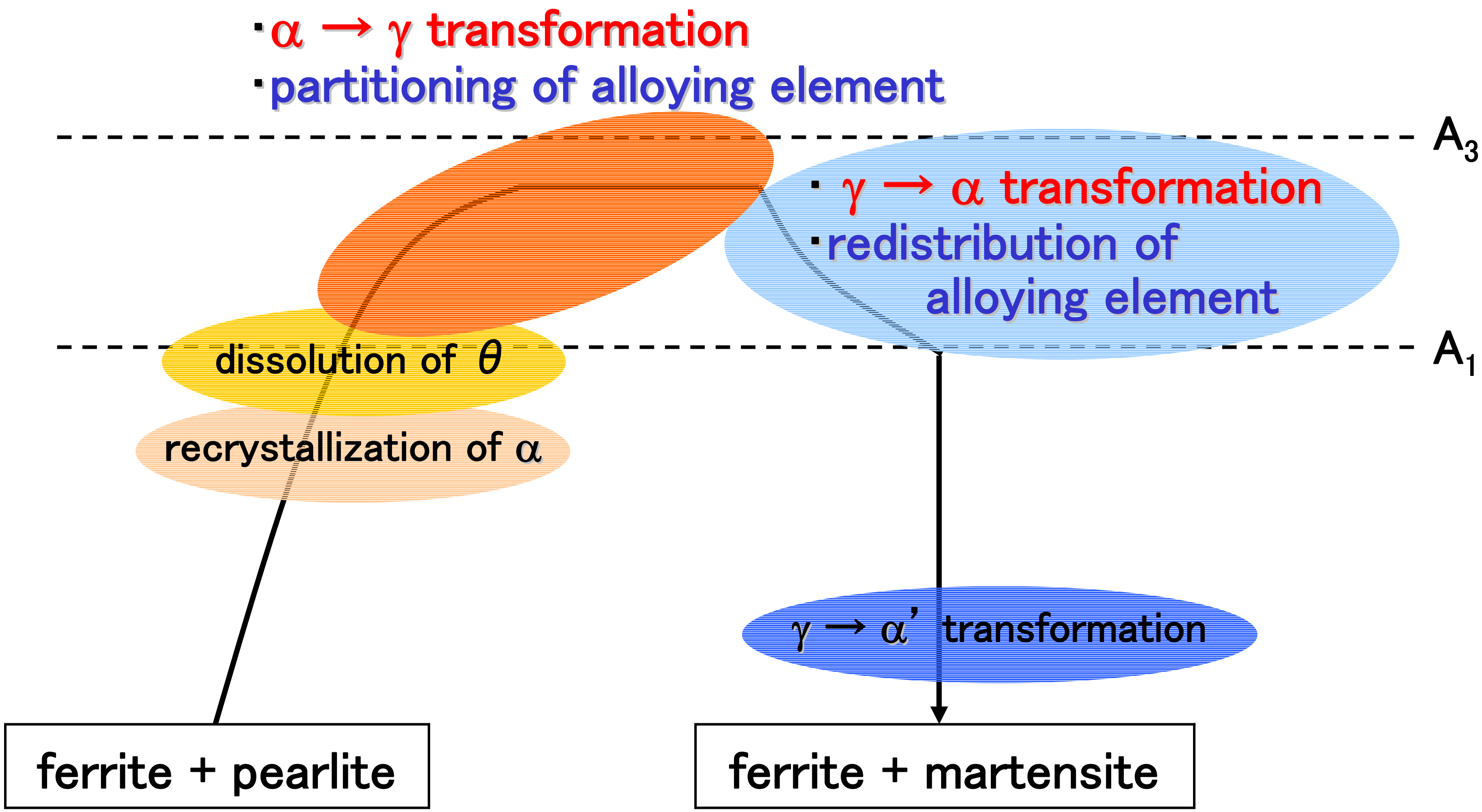


F : Ferrite
M : Martensite

Introduction

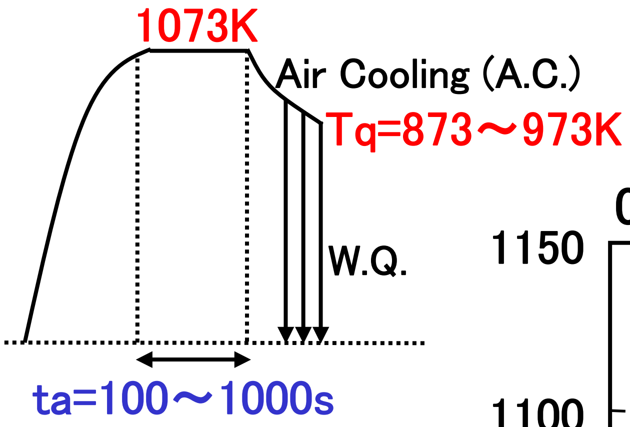
To control the mechanical properties,

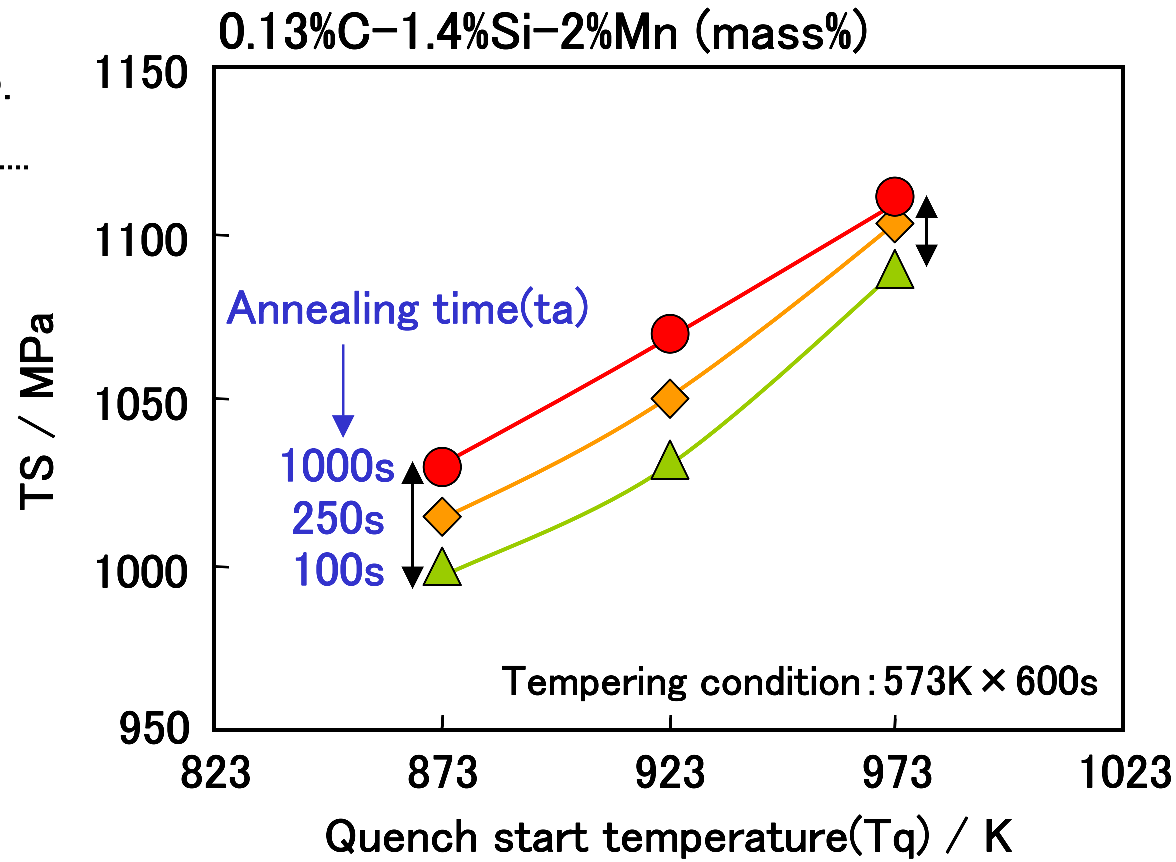
<u>Precise microstructural control during continuous annealing lines is necessary</u>



Effect of intercritical annealing time on TS

Toji et al. (IS³–2007)

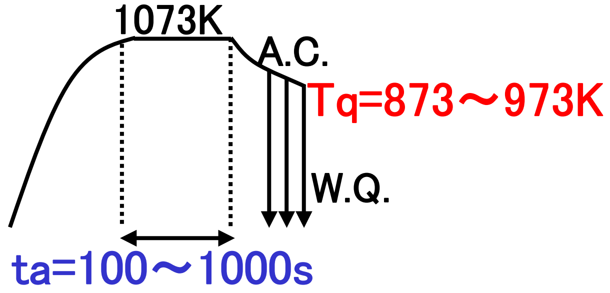


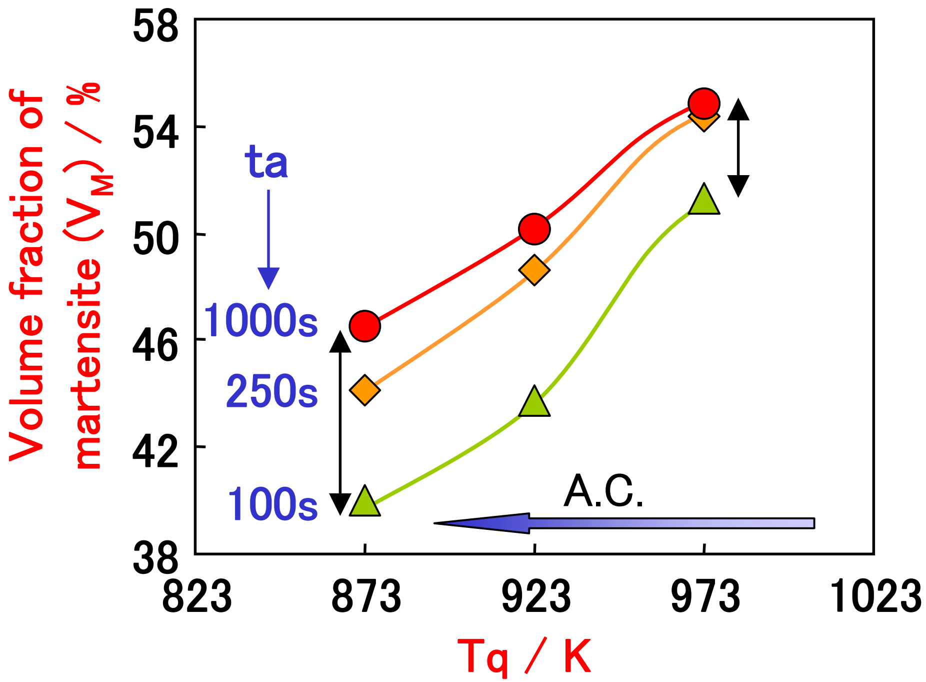


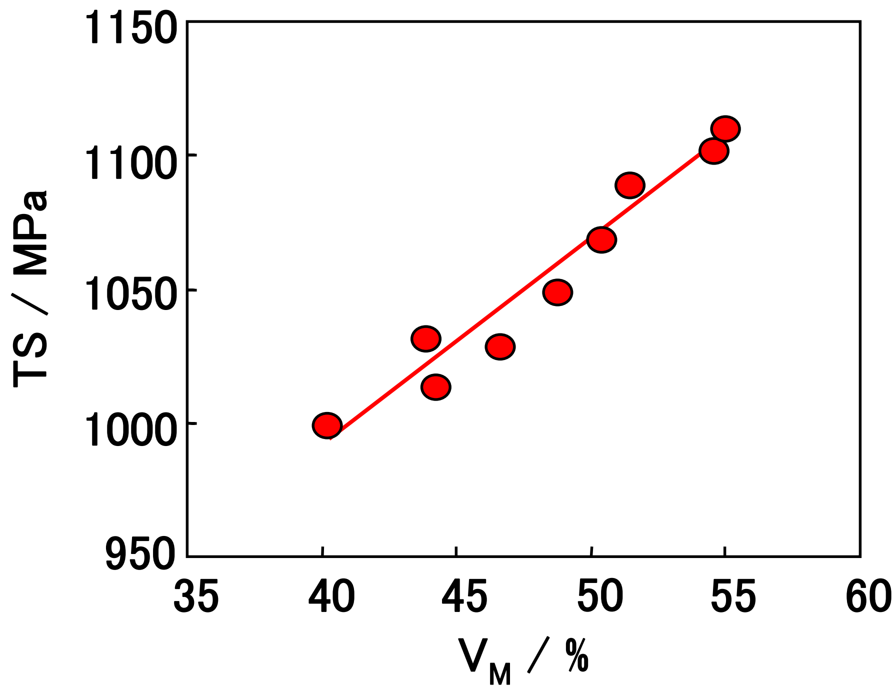
- TS decreases with a decrement of annealing time
- Difference of the TS between specimens with different annealing time is larger at a lower Tq

Effect of intercritical annealing time on microstructure

Toji et al. (IS³–2007)







Change in V_M shows a good agreement with the influence of annealing time on TS

→Change in TS with the annealing time is mainly caused by a change in V_M

Intercritical annealing time at 1073K affects the mechanical properties of cold-rolled DP steels through the change of microstructure

Objective of this study

To clarify the effect of the intercritical annealing time on microstructures of cold-rolled DP steels

(1) $\alpha \rightarrow \gamma$ transformation during intercritical annealing

(2) Subsequent $\gamma \rightarrow \alpha$ transformation during cooling

Experimental procedures

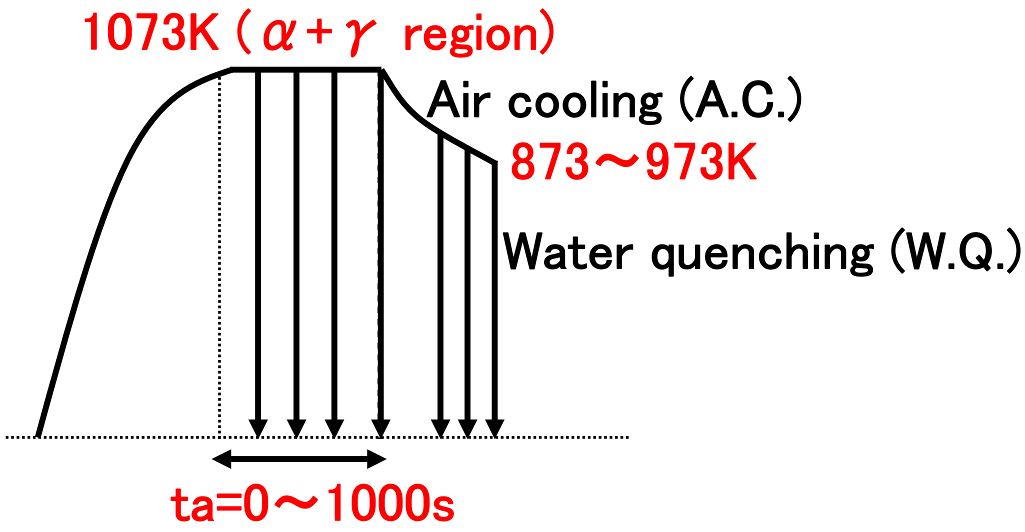
◆ Chemical composition

(mass%)

C	Si	Mn	P	S	Al	N	Fe
0.125	1.40	1.98	0.016	0.001	0.032	0.0034	Bal.

◆ Heat-treatment

Cold-rolled steel sheet
(1.4mmt, ferrite-pearlite) →



◆ Microstructure ･･･ SEM ⇒ the volume fraction of martensite

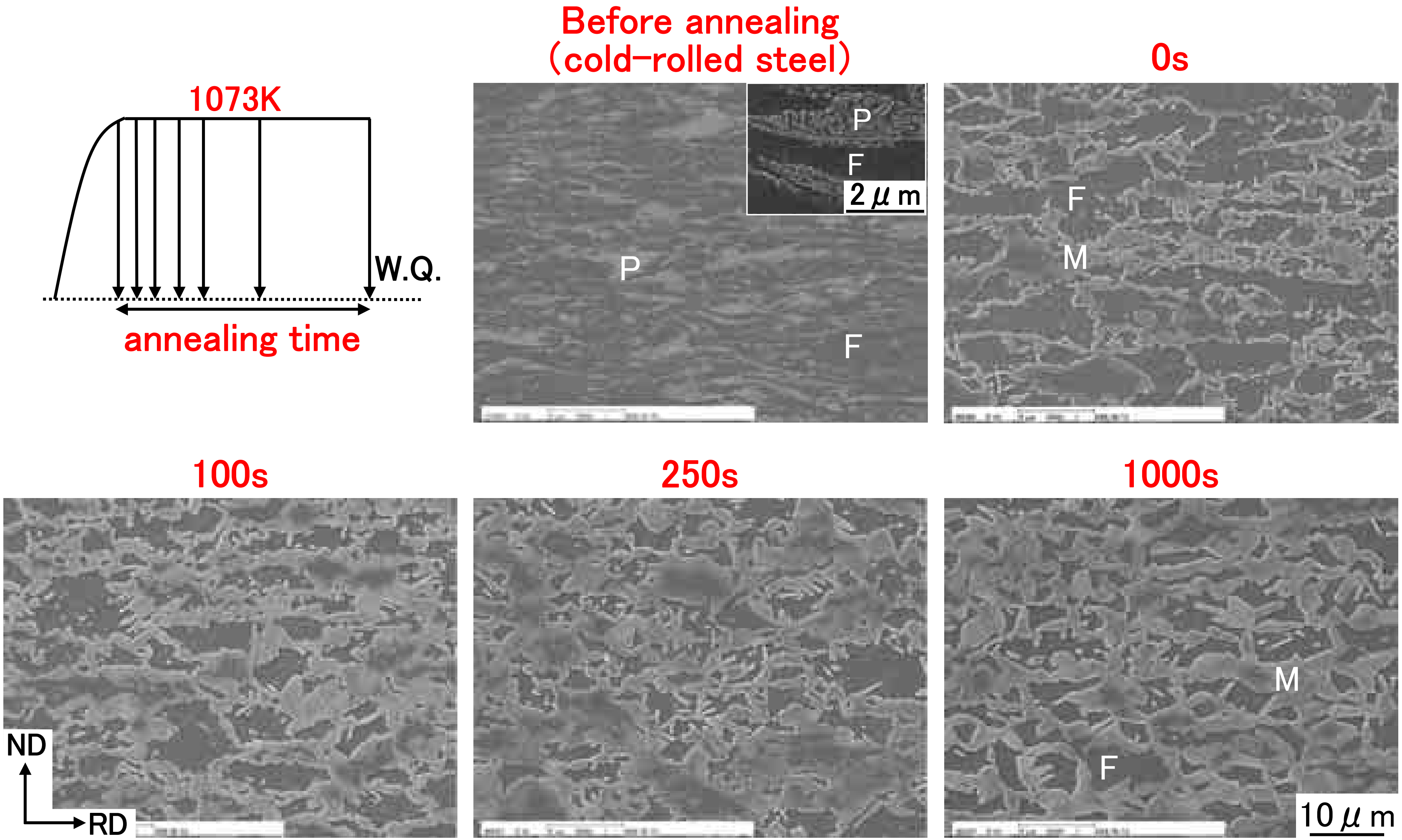
◆ Elemental analysis ･･･ EPMA ⇒ the distribution of alloying elements

Contents

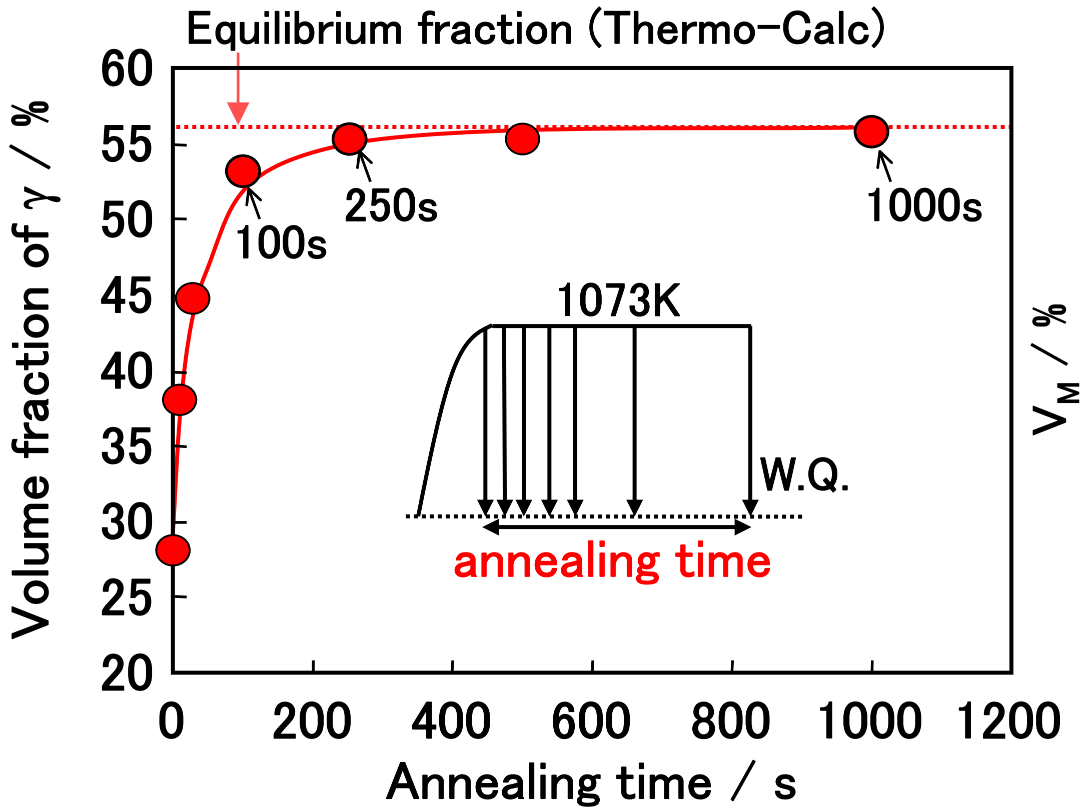
(1) $\alpha \rightarrow \gamma$ transformation during intercritical annealing

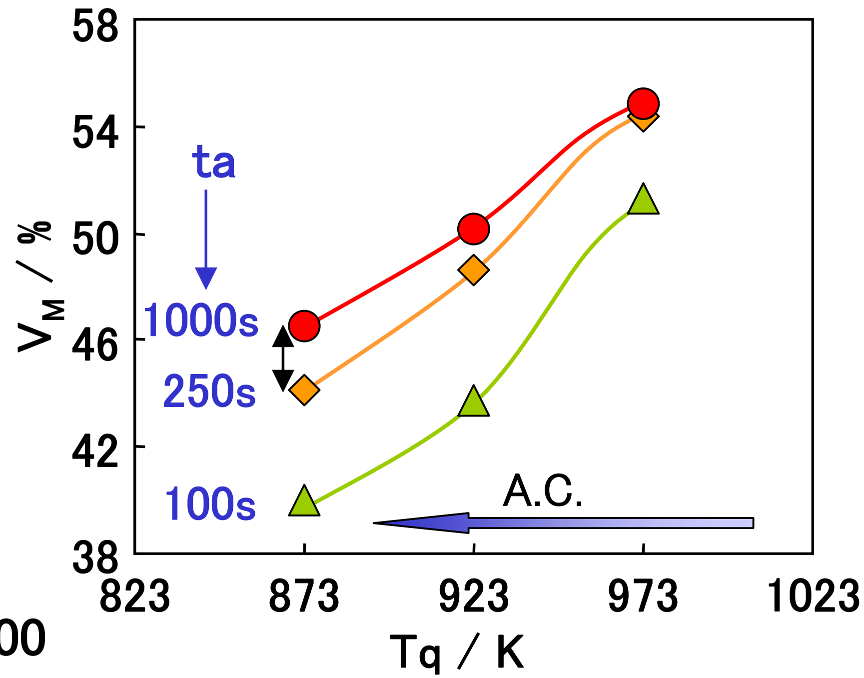
(2) Subsequent $\gamma \rightarrow \alpha$ transformation during cooling

α → γ transformation during annealing



Relationship between V_γ and annealing time





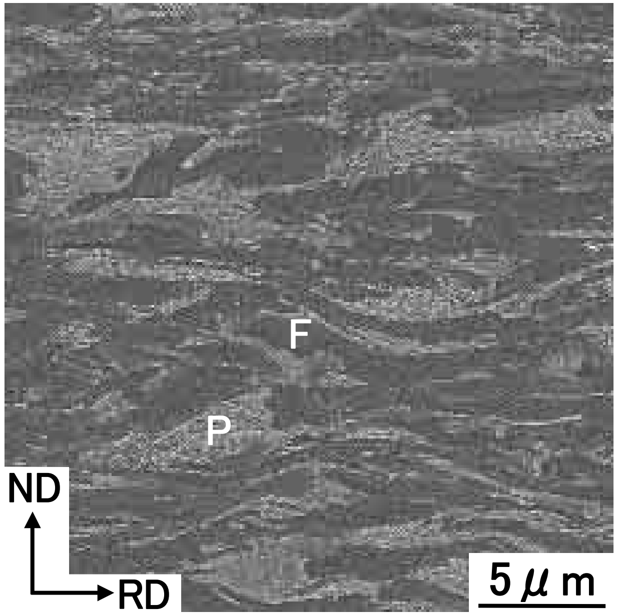
Volume fraction of γ is almost saturated more than 250s

➡ It can't be explained only by the volume fraction of γ during annealing

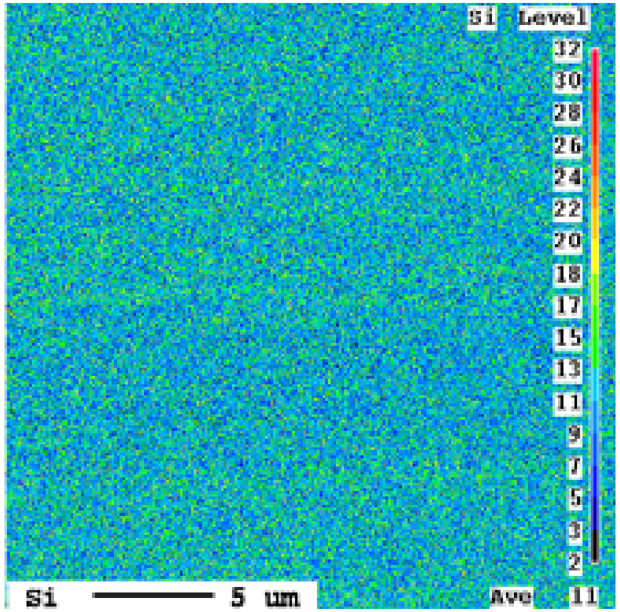
➡ Change in the distribution of Mn,Si during annealing was investigated

Distribution of Mn,Si before annealing

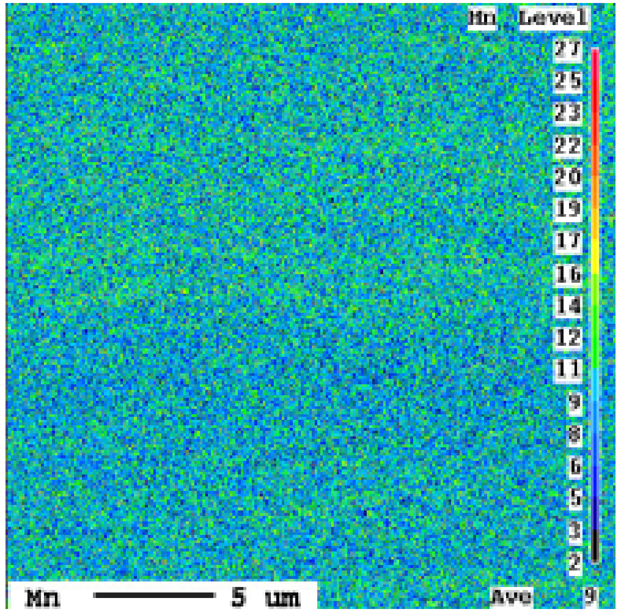
SEM



Si mapping



Mn mapping



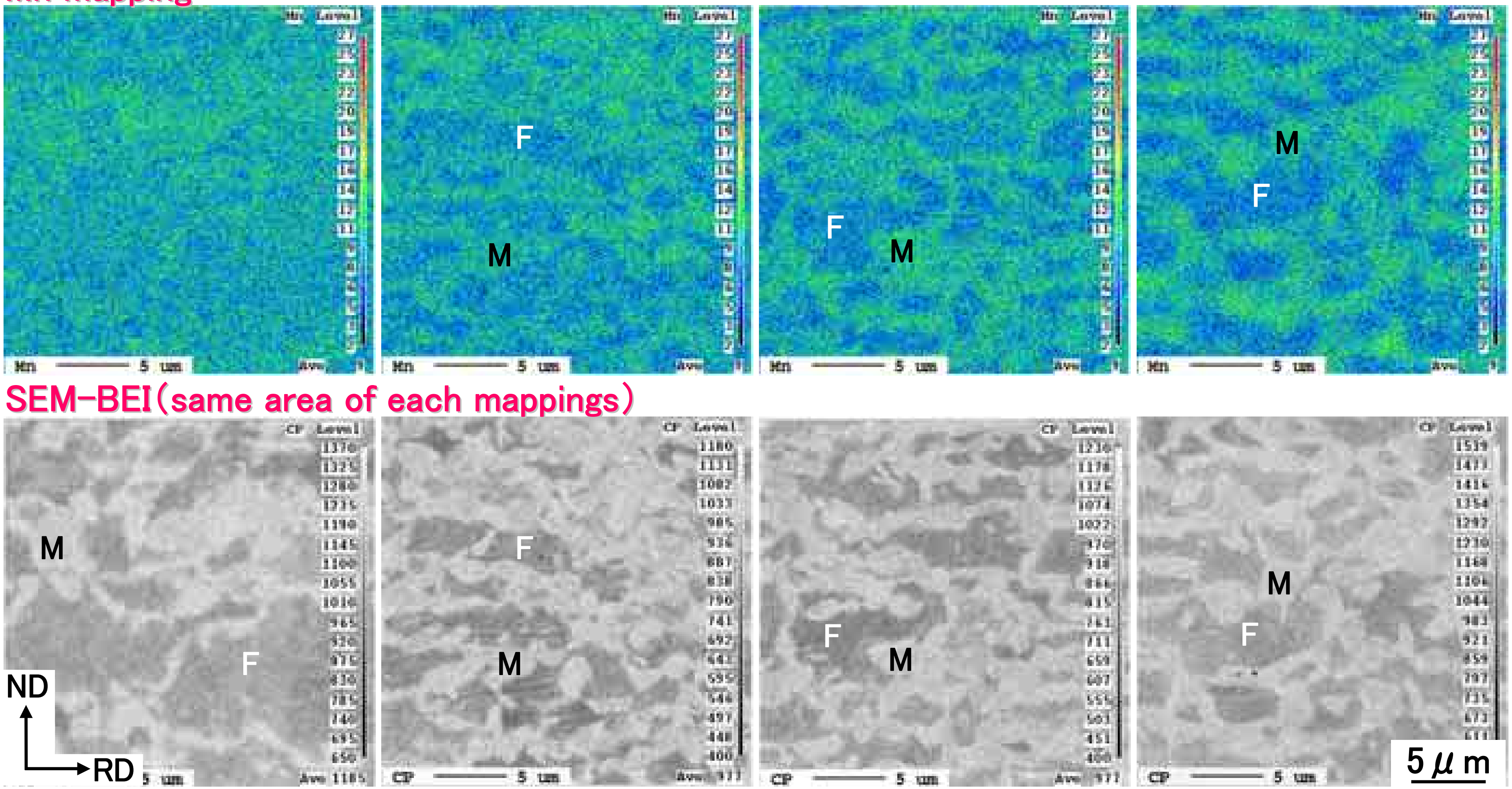
Before annealing, Si,Mn are distributed almost uniform

Partitioning of Mn during annealing

Annealing time at 1073K

30s 100s 250s 1000s

Mn mapping



<u>Mn concentrates into γ(M) following the nucleation and growth of γ</u>

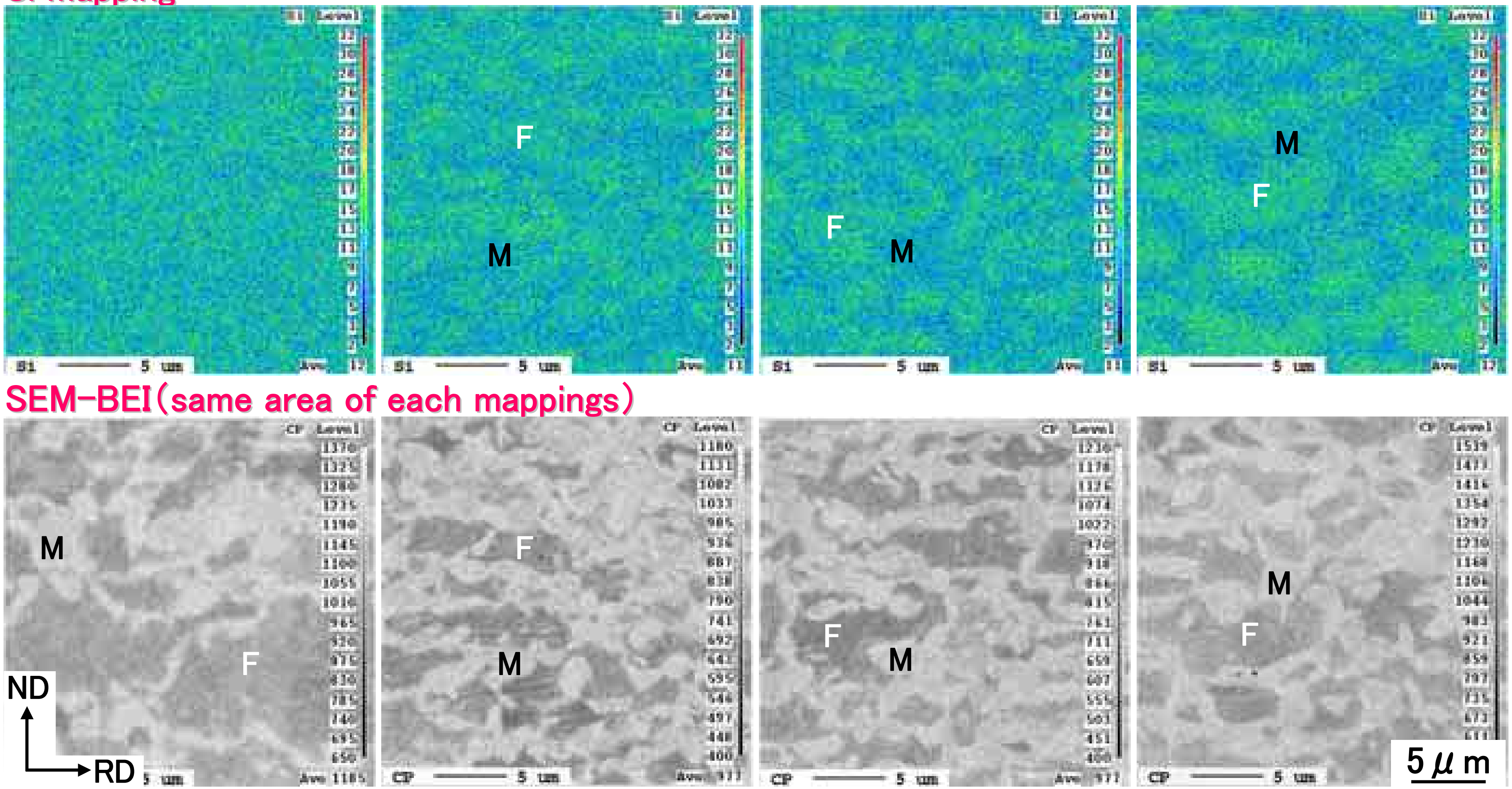
Partitioning of Si during annealing

Annealing time at 1073K

30s 100s 250s 1000s

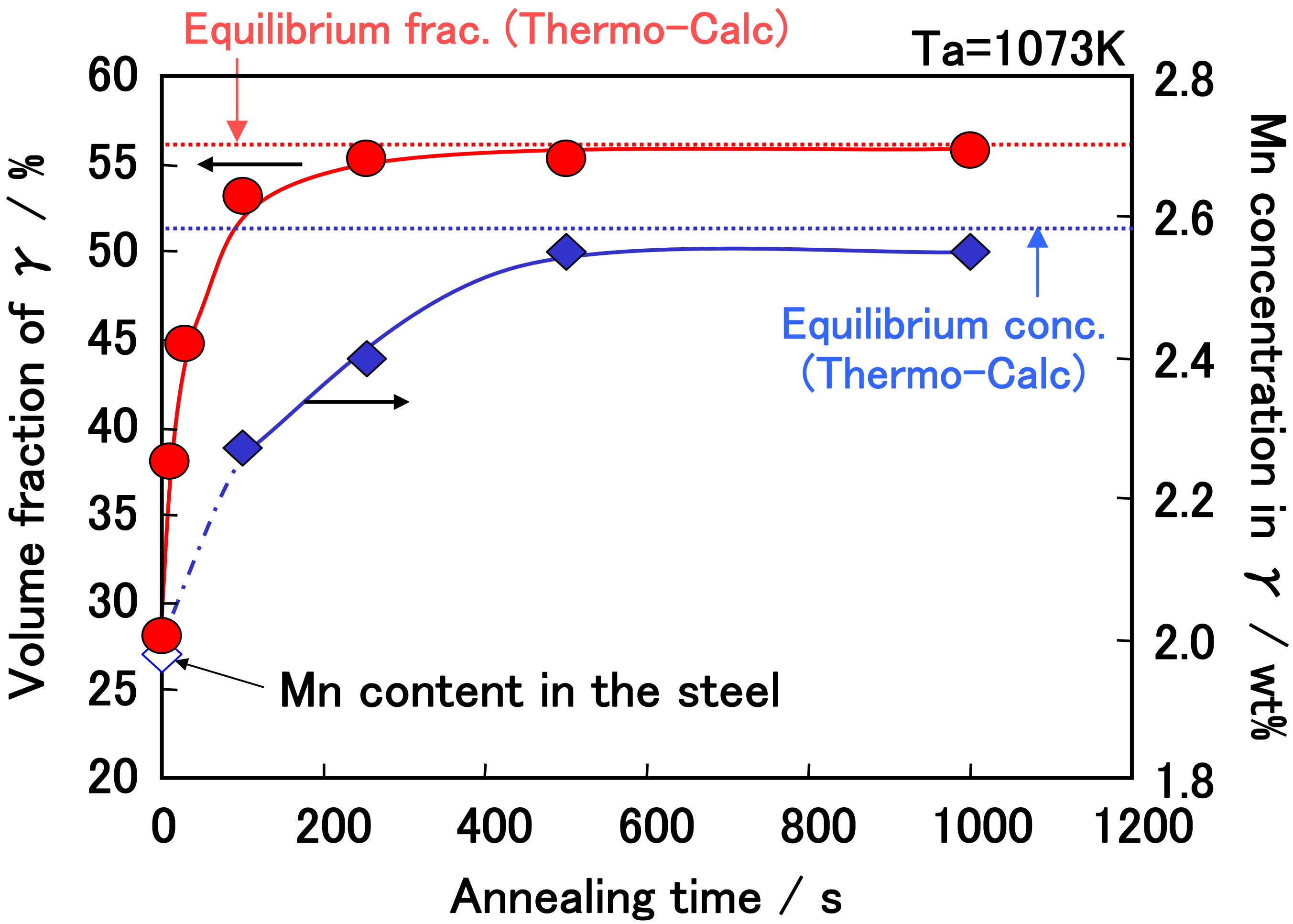
Si mapping

SEM-BEI(same area of each mappings)



Si concentrates into α following the nucleation and growth of γ

Change in γ fraction and Mn distribution during annealing



Before 500s, γ is considered to be in a metastable state

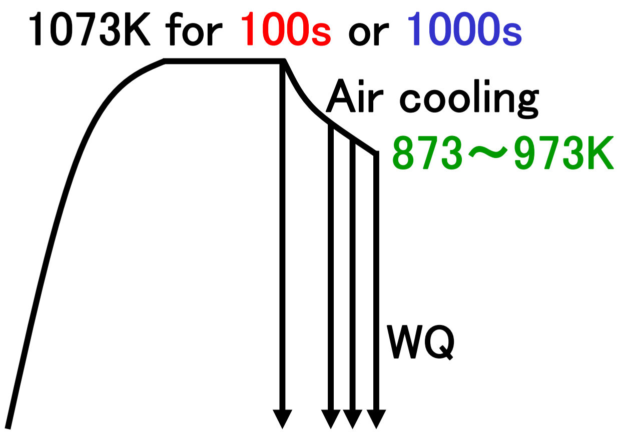
Difference of Mn concentration in γ affects the γ→α transformation

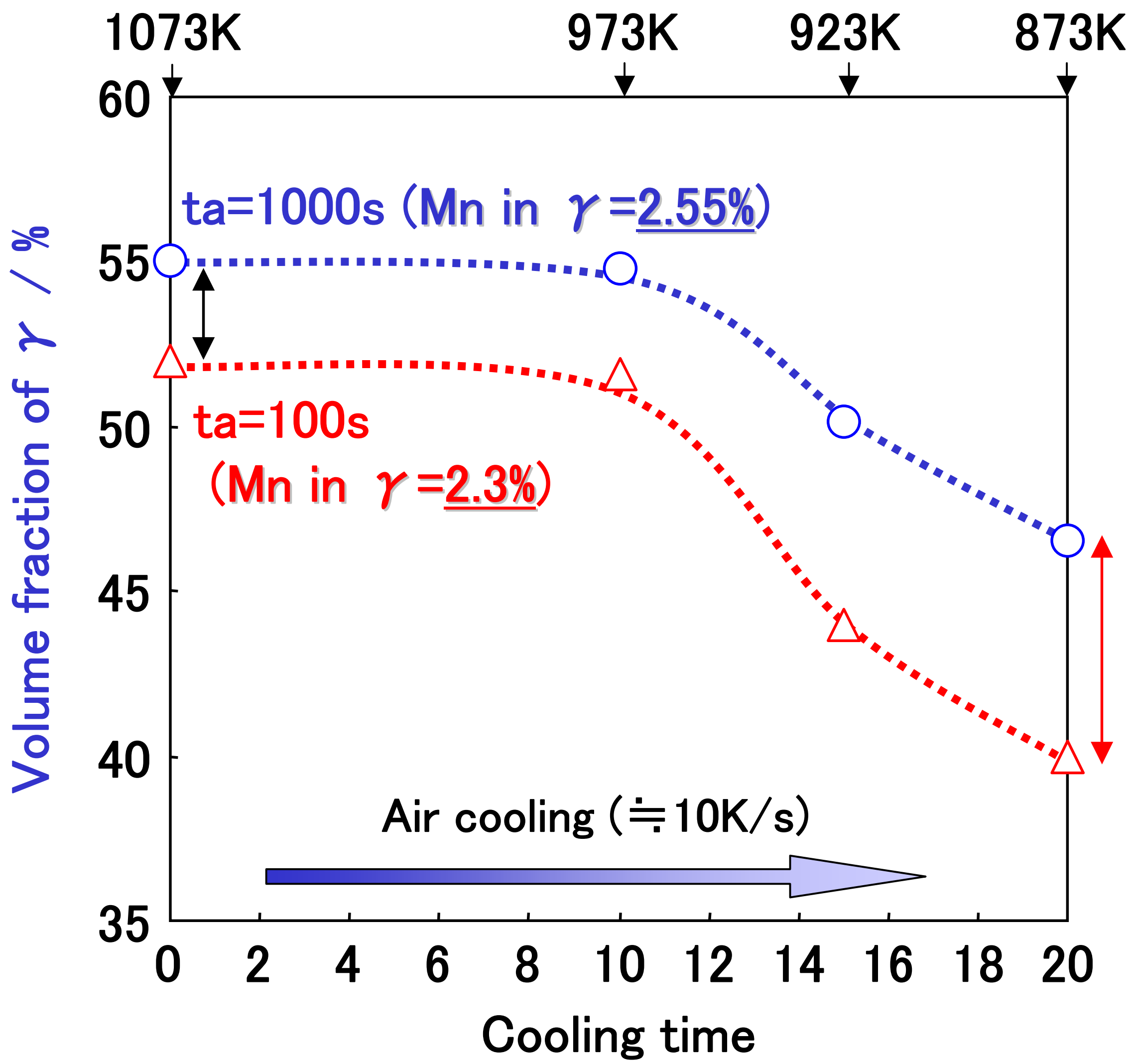
Contents

(1) $\alpha \rightarrow \gamma$ transformation during intercritical annealing

(2) Subsequent $\gamma \rightarrow \alpha$ transformation during cooling

Influence of Mn distribution on γ → α transformation during cooling





γ → α transformation rate is faster
in the specimen with low Mn concentraiton in γ

Conclusion

To clarify the effect of the intercritical annealing time on microstructures of cold-rolled DP steels, (1) $\alpha \rightarrow \gamma$ transformation during intercritical annealing, and (2) Subsequent $\gamma \rightarrow \alpha$ transformation during cooling were investigated

1. At the early stage of $\alpha \rightarrow \gamma$ transformation during annealing at 1073K, substitutional alloying elements hardly diffuses, and substitutionals continue to partition even after the volume fraction of γ reaches to equilibrium value.

2. Although the volume fraction of γ is almost same before cooling, the $\gamma \rightarrow \alpha$ transformation kinetics differs depending on the Mn concentration in γ. It was found that the specimen with lower Mn concentration in γ after annealing shows the faster transformation behavior.