

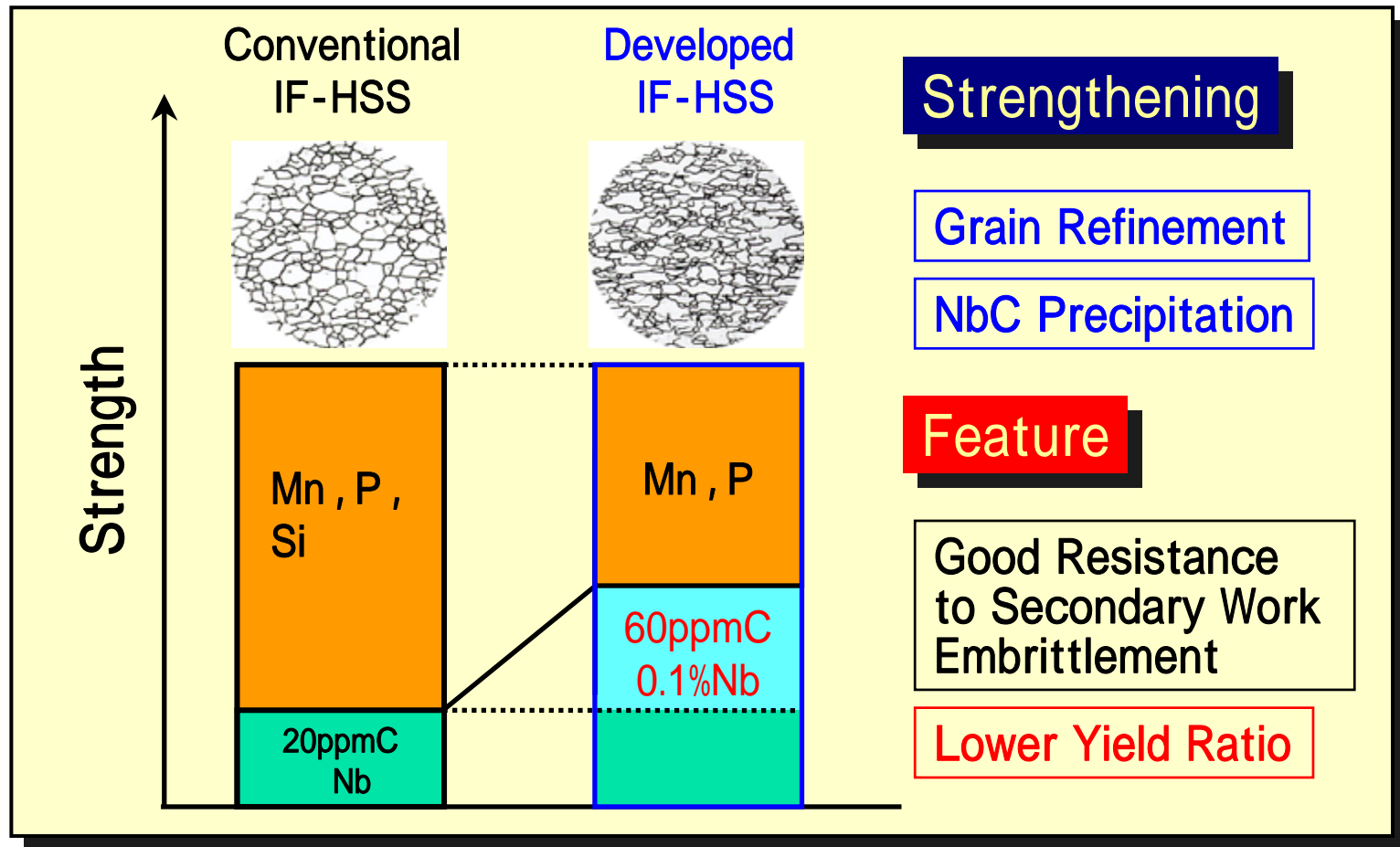
**Change in precipitates distribution
of Nb-bearing cold-rolled high strength steel sheet
under slowly-heated annealing condition**

Steel Research Laboratory
JFE Steel Corporation

T. Kobayashi, Y. Ono, T. Fujita,
Y. Nagataki, Y. Funakawa

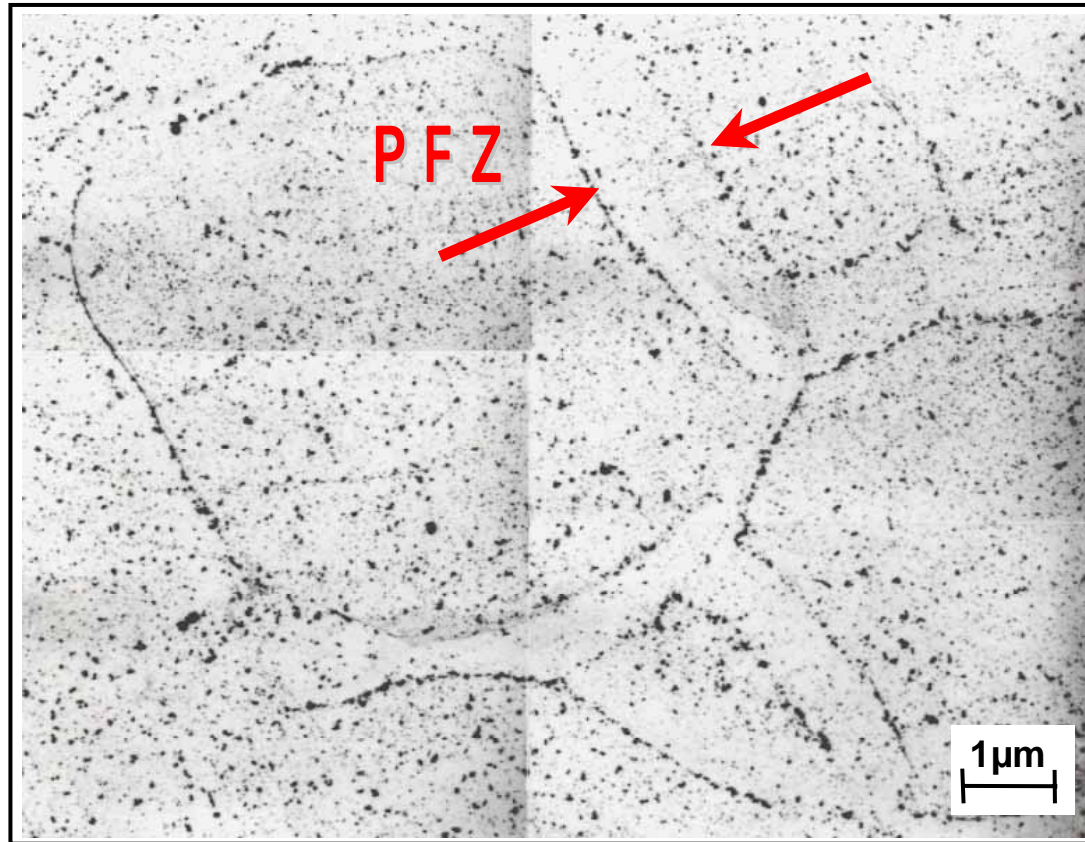
Introduction

60ppmC-0.1%Nb bearing IF-HSS



Distribution of Precipitates

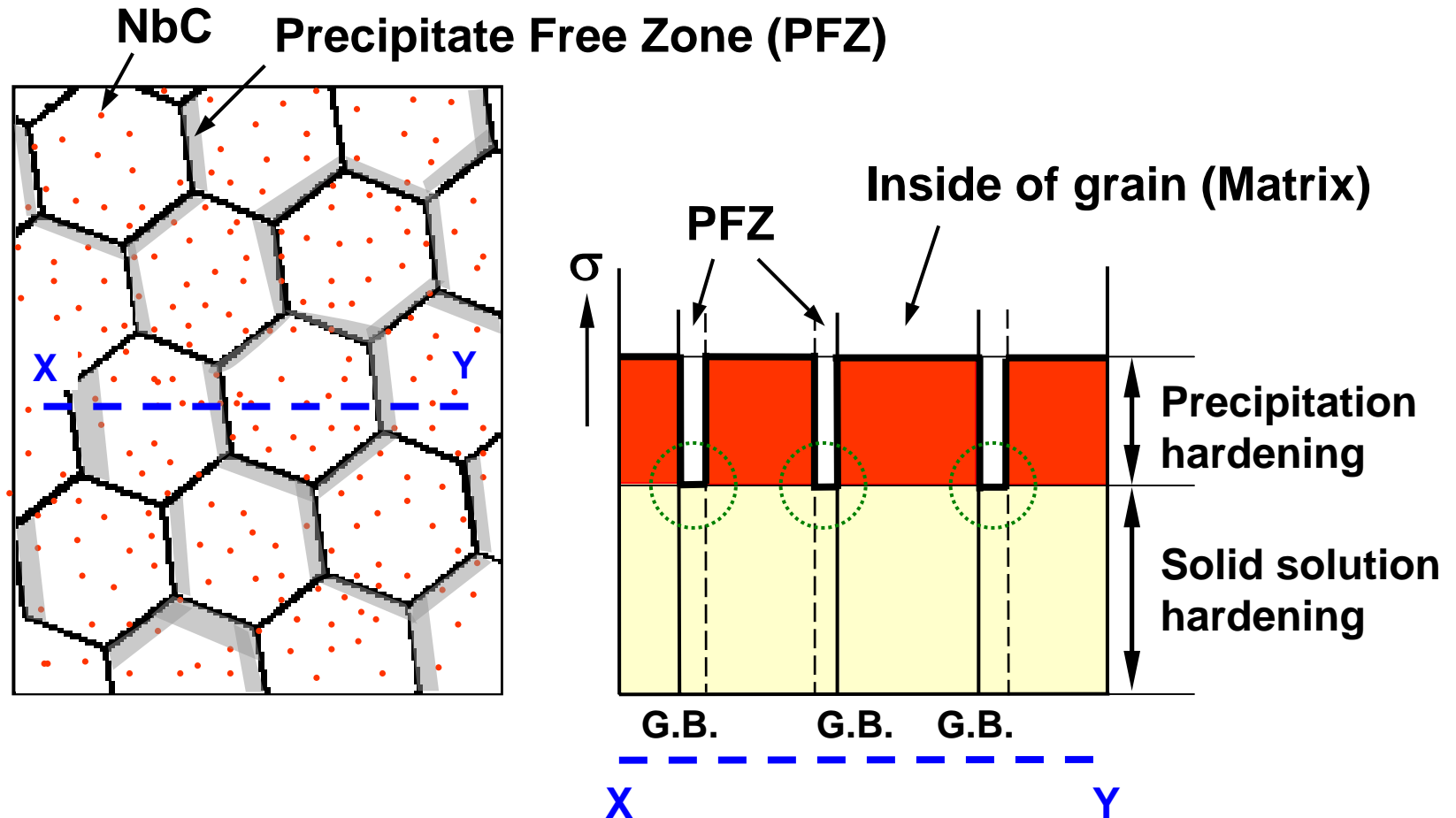
NbC in 60ppmC-0.1%Nb bearing IF-HSS



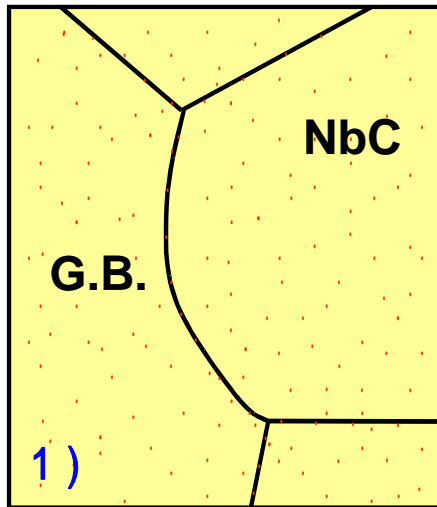
P F Z : Precipitate Free Zone

Hypothesis for Lower Yielding

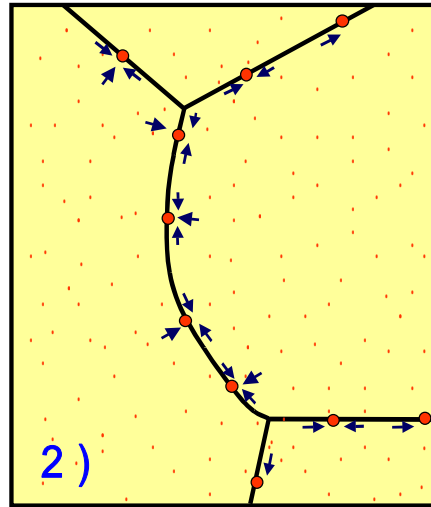
PFZ as prior yielding region



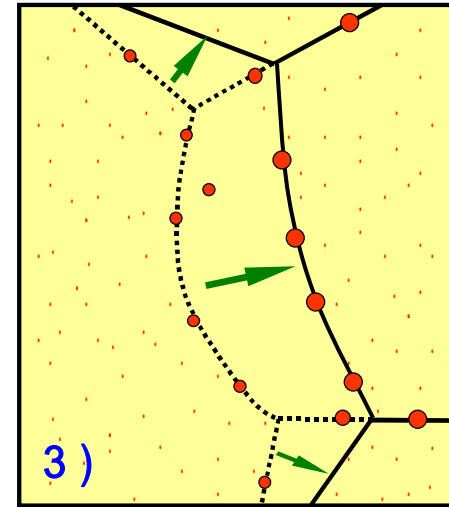
Mechanism of PFZ Formation



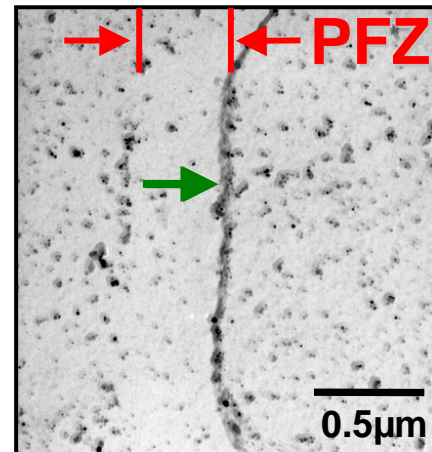
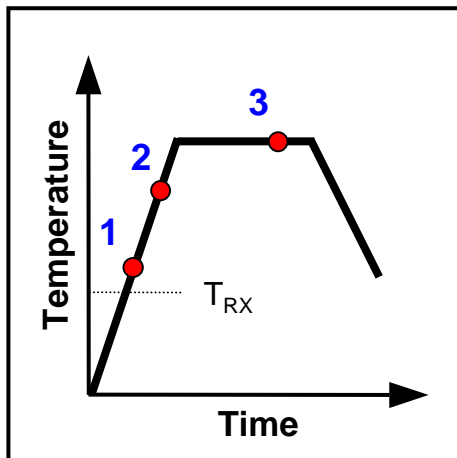
Recrystallization



Precipitates
coarsening
at G.B.



G.B. migration





Purpose of This Study

**To clarify the unique yielding mechanism
with precipitate free zone**

View Points

- **Effect of annealing conditions
on PFZ formation**
- **Effect of PFZ
on mechanical properties**

Experimental Procedures

Table. Chemical composition of steel used.

C	Si	Mn	P	S	Nb	sol.Al	N
0.0068	0.02	0.99	0.052	0.009	0.101	0.052	0.0025

(mass%)

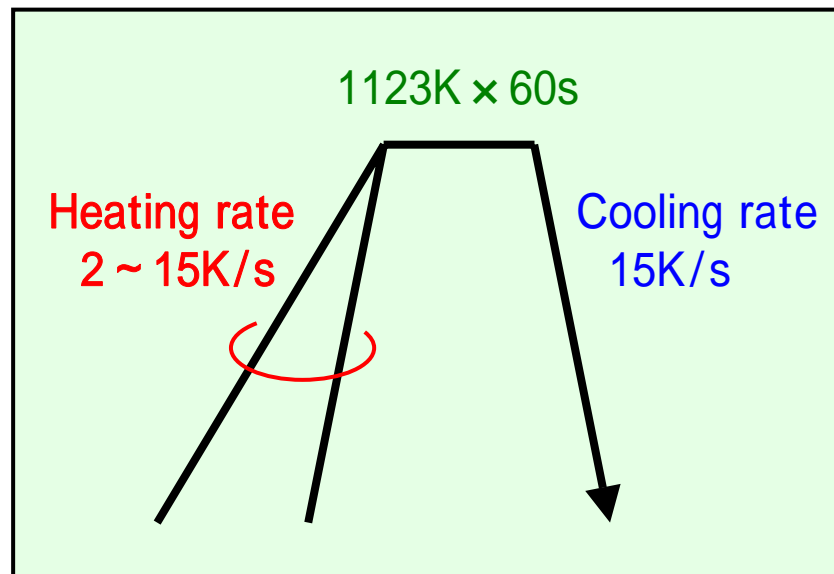
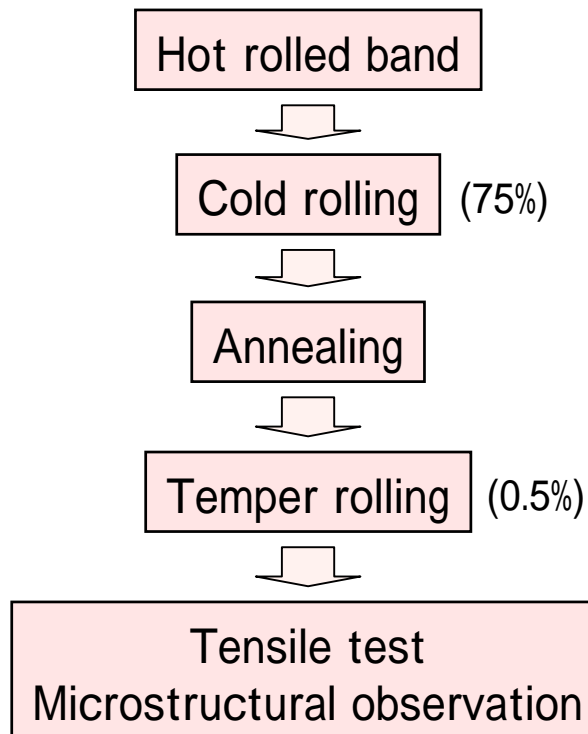
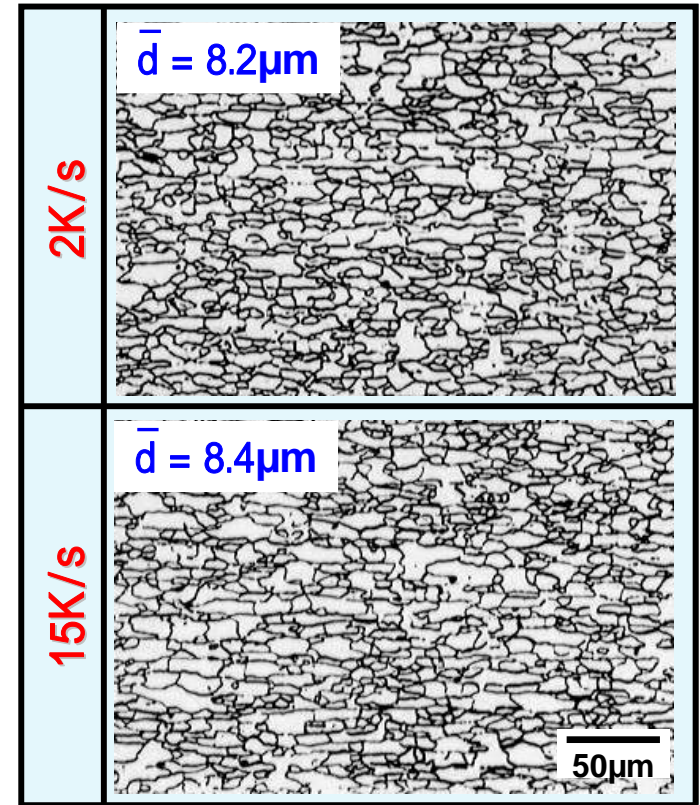
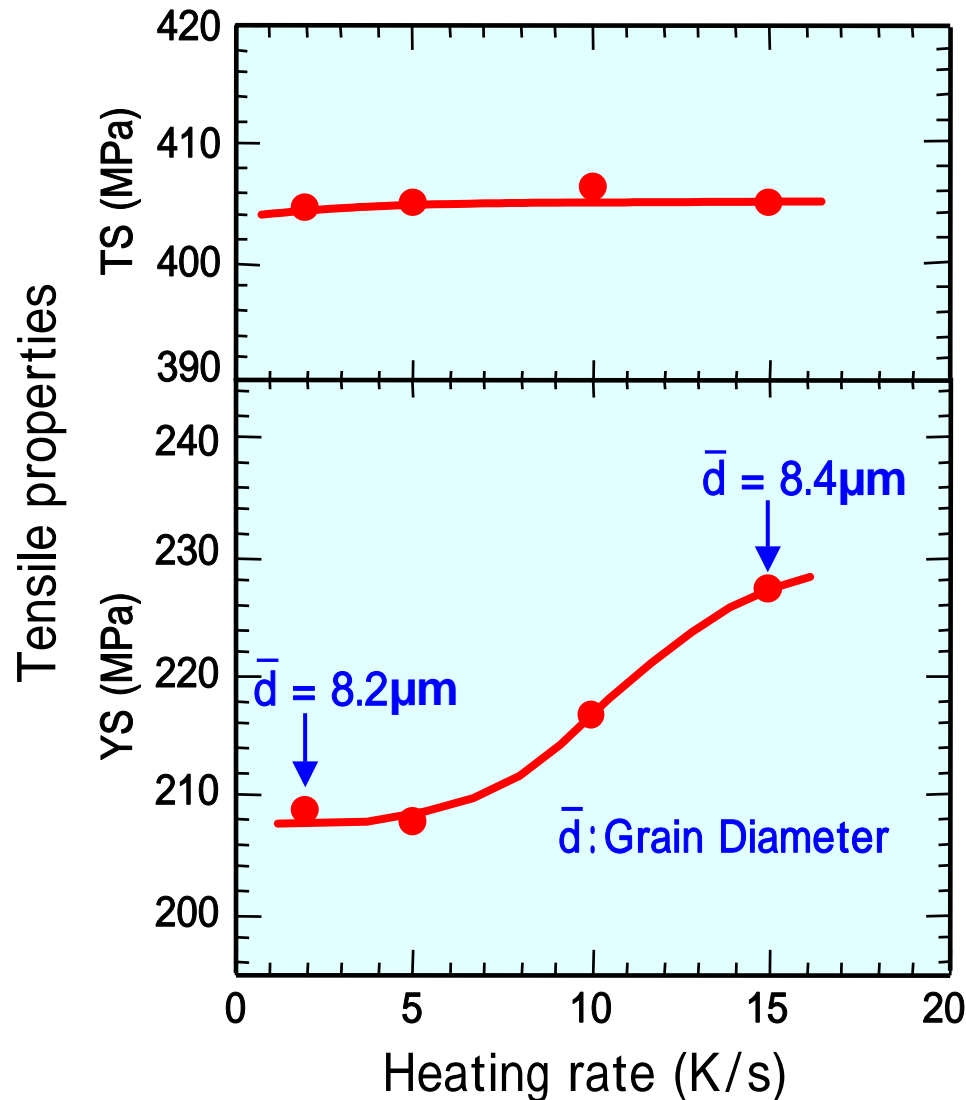


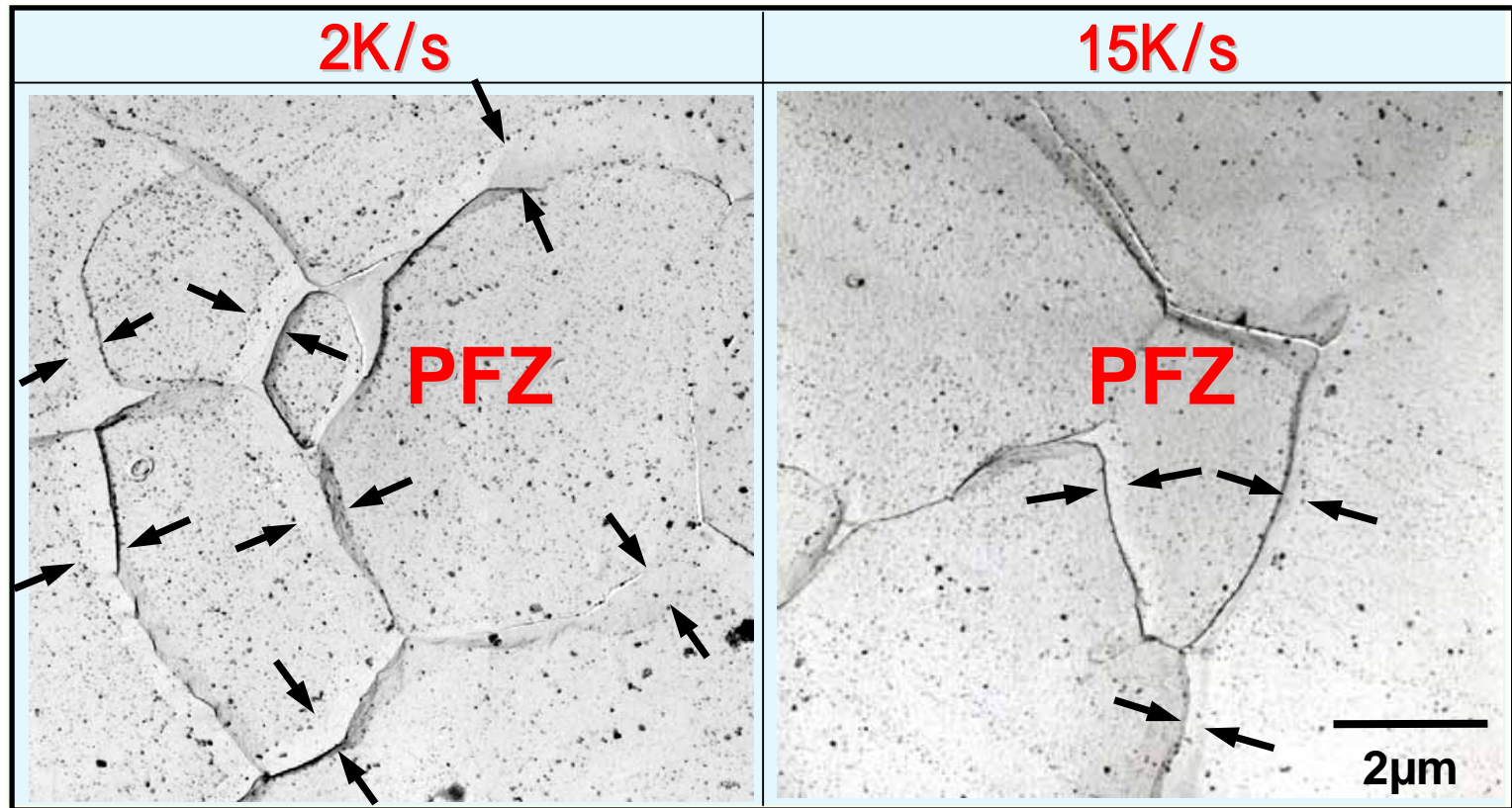
Fig. Annealing conditions

Effect of Heating Rate

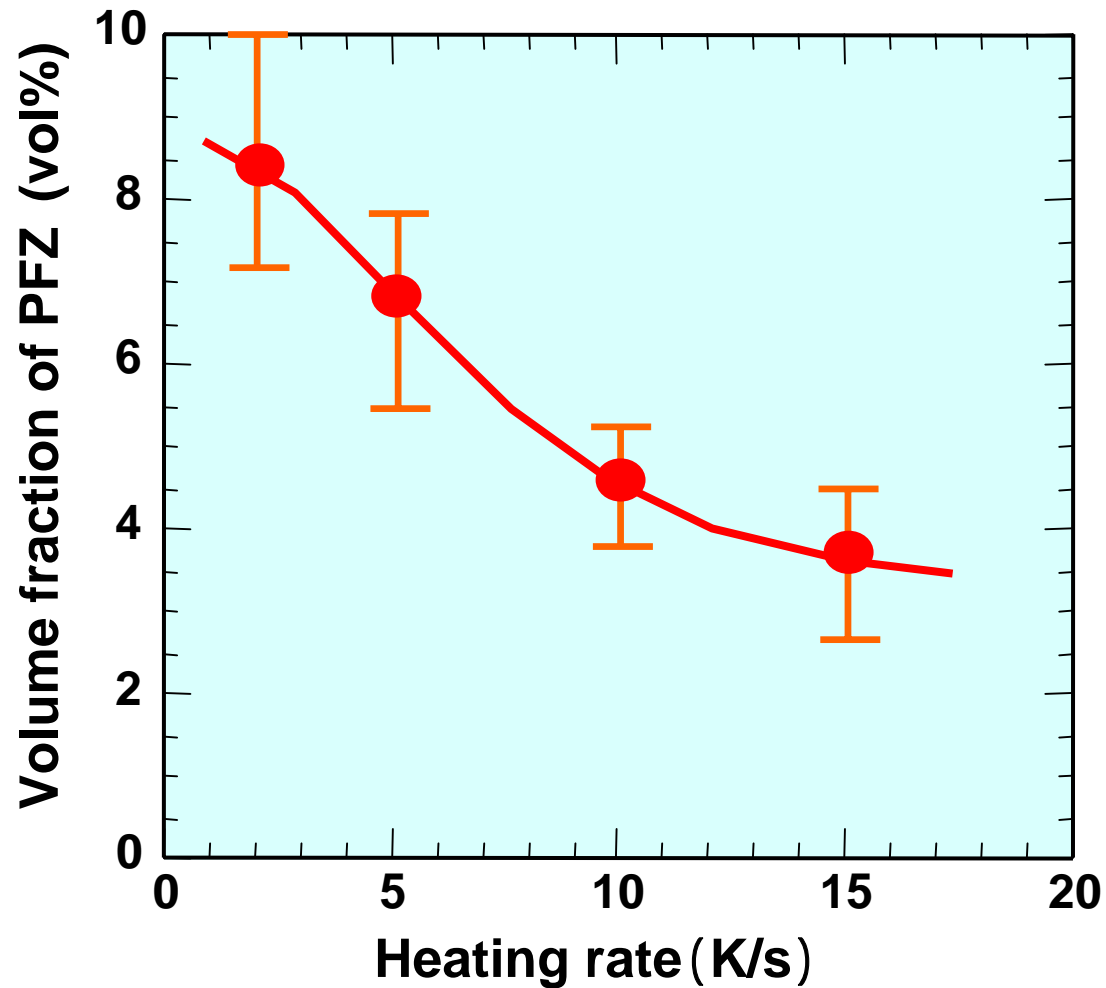


Microstructures after annealing

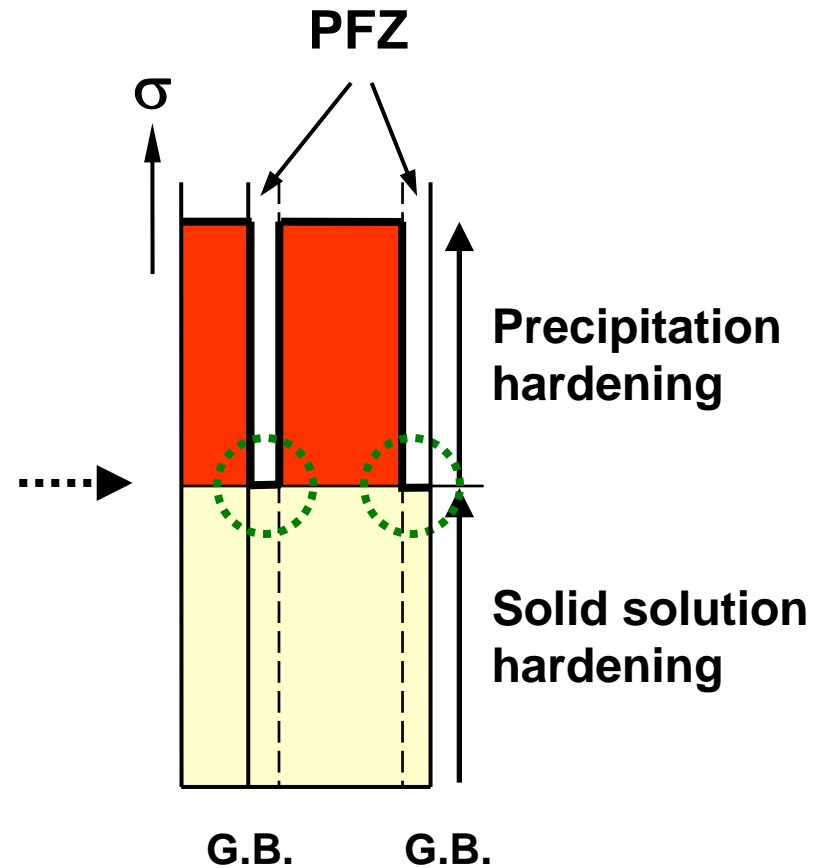
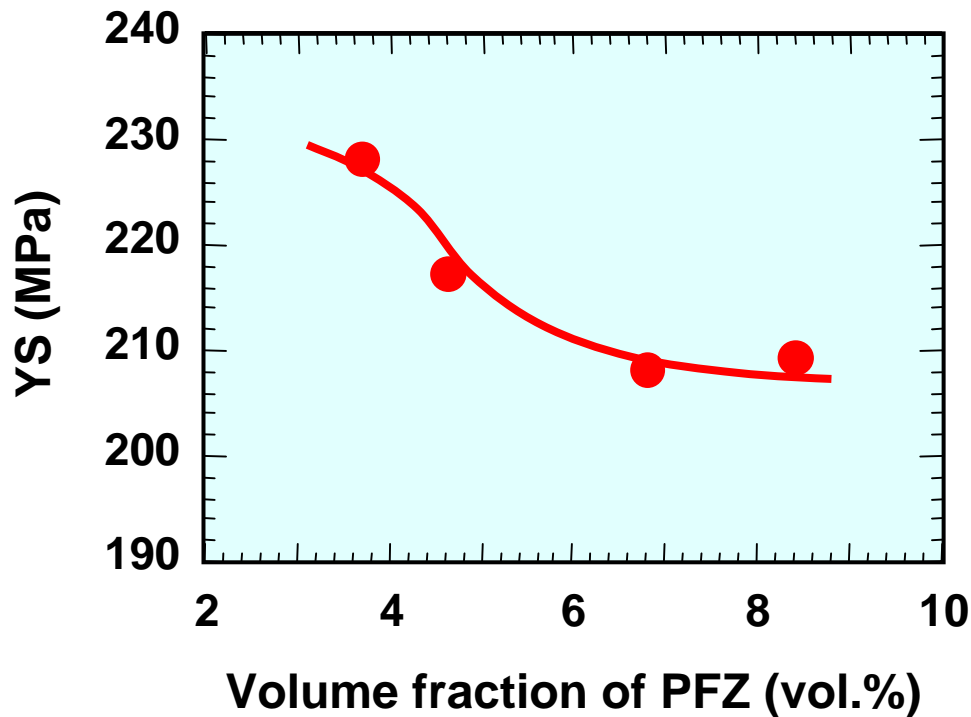
TEM Micrographs



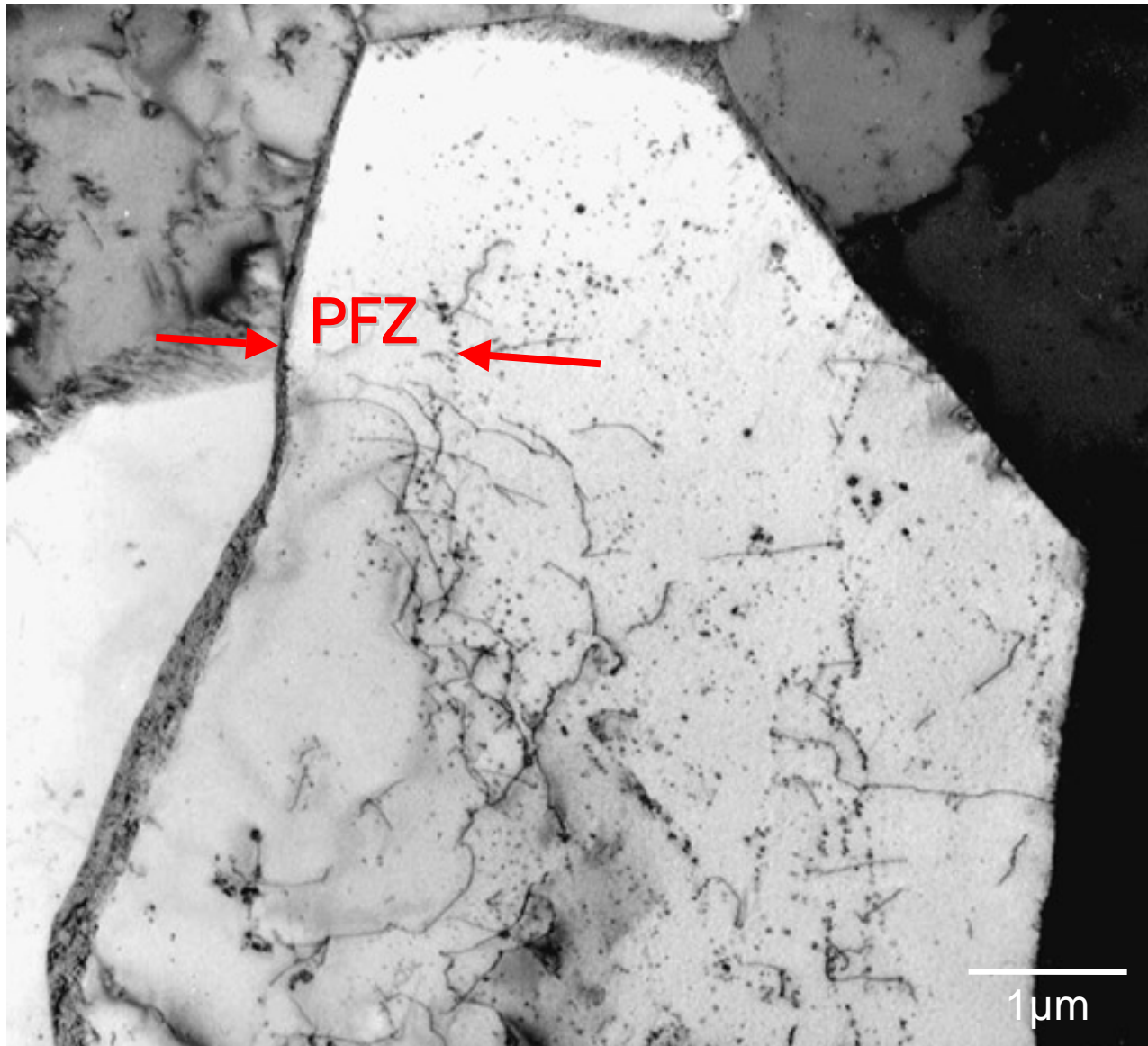
Effect of Heating Rate on PFZ



Effect of PFZ Fraction on YS



TEM Micrograph ($\phi=0.5\%$)





Conclusions

- 1) Yield stress of the Nb-bearing steel decreases and the volume fraction of the PFZ increases by reducing the heating rate of recrystallization annealing.
- 2) Strong correlation is found between the amount of PFZ and yield strength for the steel.
- 3) Easy generation and motion of dislocation at the grain boundary accompanied by PFZ are considered to be the essential reason of lower yielding.