examined in a Nb steel. The strain induced ferrite transformation of Nb steel was significantly retarded compared with that of plain C–Mn steel, when Nb was mostly dissolved. When the grain boundary ferrite was present before deformation and strain free ferrite was formed during the following isothermal holding, abnormal grain growth occurred at the regions near the deformed ferrite by strain-induced boundary migration (SIBM). The SIBM was caused by the energy unbalance at the boundaries between deformed and strain free ferrite grains transformed from the deformed austenite. This rapid growth was not inhibited by the strain-induced NbC precipitates, which means the driving force for the abnormal growth was greater than the pinning force by the precipitates. However, the abnormal grain growth could be prevented by isothermal heat treatment in either fully transformed or untransformed structure. The ultrafine and polygonal ferrite grains were obtained by the recrystallization of ferrite and the grain growth was inhibited by strain-induced NbC precipitates during isothermal annealing at 650°C after deformation.

(cf. *ISIJ Int.*, **42** (2002), 1461)

Effects of nitrogen in 9Cr–3W–3Co ferritic heat resistant steels containing boron

E.El-Kashif et al.

Many researchers revealed that the addition of small amount of boron (B) significantly improves the creep strength of ferritic heat resistant steels. However the mechanism for such an effect caused by B has not been clarified yet. In the present study, the effect of nitrogen (N) on the behavior of B in 9Cr–3W–3Co base steels was examined using Alpha-particle Track Etching (ATE), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and creep test. It was confirmed that creep lives have significantly increased by lowering the N content in boron containing steels. The prediction of creep life using Larson–Miller parameter suggests that high N–high B steel shows lower creep strength compared with high N–low B, low N–low B and low N–high B steels. SEM showed that B increases the precipitates stability against coarsening. TEM revealed that the stability of the matrix against recovery reaches maximum in low N–high B steels, while this stability is very weak in high N-high B steel. ATE showed that B segregating along packet and block boundaries and free B homogeneously distributing in the matrix are more effective on strengthening than B contained in $M_{23}C_6$ carbides. In addition, B in steels of a suitable content of N is contributable to the enhancement of creep strength through increasing the amount and the stability of fine precipitates such as VN. High content of N is expected to reduce such effects of B probably through the precipitation of BN, although no experimental evidence has been obtained.

(cf. *ISIJ Int.*, **42** (2002), 1468)

Effect of nitrogen alloying on the pitting of type 310 stainless steel

H.Yashiro et al.

The effect of nitrogen alloying on the pitting behavior of type 310 stainless steel has been investigated through measurements of pitting potential (E'_{pit}) as a function of temperature and concentration of NaCl (C_{NaCl}). Nitrogen was effective to shift E'_{pit} to nobler direction especially at temperatures below critical one. The critical pitting temperature was defined as the temperature below which the usual linear relationship between E'_{pit} and logarithm of C_{NaCl} did not stand. Alloying the stainless steel with nitrogen increased the critical pitting temperature. Below the critical temperature where E'_{pit} did not follow the usual dependency on C_{NaCl}, pitting was retarded most effectively by nitrogen except when C_{NaCl} was so high that E'_{pit} lay below *ca.* 400 mV. Although the whole mechanism of nitrogen is not still clear, nitrogen is most likely to suppress acidification of pitting site through formation of ammonium ion. Nitrogen in a metal matrix and nitrate in a solution seemed to have a common feature with respect to the potential dependency of inhibition efficiency. The fact that nobler potentials were more favorable for both nitrogen in metal matrix and nitrate in a solution for inhibition seemed to indicate that oxidation of nitrogen to nitrate might also be involved in the inhibition mechanism.

(cf. *ISIJ Int.*, **42** (2002), 1477)

Deformation behavior of low carbon TRIP sheet steels at high strain rates

I.D.Choi et al.

Two high strength transformation-induced plasticity (TRIP) sheet steels with 0.10 wt% and 0.14 wt% carbon were produced with retained austenite volume fractions varying from less than 3% up to 16%. These TRIP steels were tensile tested at strain rates ranging from 10^{-3} to $2.5\times10^{2}\,s^{-1}$ to determine the effects of strain rate and retained austenite volume fraction on tensile properties. Increasing the retained austenite volume fraction increases UTS, total elongation, uniform strain and total absorbed energy, but decreases yield strength and absorbed energy below 10% engineering strain. Increasing strain rate increases yield strength and UTS, and creates a better-defined yield point, but has little effect on strain hardening behavior for TRIP steels with 11% or less retained austenite. The TRIP steel with 16% retained austenite shows increasing strain hardening rate with strain rate at low strains.

(cf. *ISIJ Int.*, **42** (2002), 1483)

Ultrafine grained low carbon steels fabricated by equal channel angular pressing: microstructures and tensile properties

D.H.Shin et al.

Equal channel angular pressing (ECAP) was conducted on the two grades of low carbon steel, with or without vanadium, in order to produce an ultarfine grained structure. As a result, the ferrite grains were refined from 30 μm to 0.2~0.3 μm. The strength of the ECAPed steels increased remarkably, over twice of the strength of the steels before ECAP. A series of static annealing experiments showed that the increment of ECAP strain and the dilute addition of microalloying element such as vanadium were very effective on enhancing thermal stability of the ultrafine gained low carbon steels produced by ECAP in terms of microstructure and tensile properties. This enhanced thermal stability resulted from; (a) presence of excessive carbon content in the ferrite matrix by carbon dissolution from pearlitic cementite during ECAP; (b) preservation of high dislocation density due to addition of vanadium, providing the effective diffusion path for dissolved carbon atoms; (c) precipitation of excessive carbon as the form of nano-sized cementite particles during subsequent annealing and its effect on suppressing grain growth.

(cf. *ISIJ Int.*, **42** (2002), 1490)

Microstructural investigations on Type IV cracking in a high Cr steel

S.K.Albert et al.

In the present study, microstructural changes that lead to Type IV cracking in a high Cr ferritic steel (11Cr–0.5Mo–2WCuVNb) weld joint has been investigated. Microstructure of the heat affected zone (HAZ) of a weld joint made by gas tungsten arc welding (GTAW) process was systematically studied in the as-welded condition, after different post weld heat treatments (PWHT) and after creep test. In addition, HAZ microstructures were simulated both by heat treatment and by using a weld simulator and creep tests were conducted using specimens with simulated HAZ microstructures. Results showed that, undissolved precipitates present in the fine grained HAZ (FGHAZ) and intercritial HAZ (ICHAZ) accelerate the tempering of these zones during PWHT and microstructural deterioration during creep. Creep tests of HAZ simulated specimens indicated that the creep was minimum for the specimens in which peak temperature of simulation was close to Ac_3. Results also suggested that differences in creep properties observed between an actual weld joint and that of a simulated Ac_3 microstructure could be due to mechanical constraints present in the weld joint in which a narrow zone of lower creep strength (FGHAZ) is sandwiched between zones of higher creep strength (coarse grained HAZ (CGHAZ) and weld metal on one side and base metal on the other side).

(cf. *ISIJ Int.*, **42** (2002), 1497)

Martensitic/ferritic super heat-resistant 650°C steels—design and testing of model alloys

V.Knezevic et al.

In the recent two decades advanced martensitic/ferritic 9–12% Cr steels are recognized to be the most potential materials for 650°C Ultra Super Critical (USC) Power Plants. The critical issues are the improvement of long-term creep strength and corrosion resistance. The aim of the present research is to design new super heat-resistant 12% Cr martensitic/ferritic steels using basic principles and concepts of physical metallurgy, to test and optimize model alloys and to investigate and clarify their behavior under long-term creep conditions with emphasis on microstructural stability and corrosion resistance.

Fine distributions of stable precipitates, which block the movement of subgrain boundaries ($M_{23}C_6$ carbides, Laves phase) and dislocations (MX car-