

**Fundamentals of High Temperature Processes****Evaluation of thermodynamic activity of a metallic oxide in a ternary slag from the sulphide capacity of the slag**M.HAYASHI *et al.*

The correlation between the activity of a metallic oxide in a ternary slag system and the sulphide capacity of the slag was investigated. The solubility of sulphur in the binary systems CaO–SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>–CaO along with its sulphide capacity of the Al<sub>2</sub>O<sub>3</sub>–CaO–SiO<sub>2</sub> system respectively have been used to estimate the activities of CaO at the compositions of some Al<sub>2</sub>O<sub>3</sub>–CaO–SiO<sub>2</sub> intermediate compounds. Estimation has been carried out assuming that the Gibbs free energy of fusion for the ternary composition is additive of those for pure substances. The estimated values of the activities are in good agreement with the measured values. This correlation is not only used to evaluate the activity but also, by comparing the estimated activities with the measured ones, it is possible to elucidate the applicability of Henry's law to the activity of a metallic sulphide and to determine the order in the affinity of a cation to sulphur between two metallic oxides in a slag.

(cf. *ISIJ Int.*, **44** (2004), 1783)**Swinging motion of bath surface induced by side gas injection**T.SATO *et al.*

Cold model experiments were carried out to understand a swinging motion of the bath in the AOD process. Water and air were used as the working fluids. A water bath contained in a cylindrical vessel was agitated by side gas injection using an L-shaped lance. Under a certain blowing condition the surface of the bath swung in the vertical direction like a liquid column oscillating in a U-shaped tube. The preferable occurrence condition of this swinging motion was correlated with the size of a plume eye on the bath surface and the vessel diameter. Empirical equations were proposed for the period and amplitude of the swinging motion.

(cf. *ISIJ Int.*, **44** (2004), 1787)**Improvements in surface tension measurements of liquid metals having low capillary constants by the constrained drop method**J.LEE *et al.*

Accurate measurements of surface tension of liquid metals having low capillary constants (the ratio between density ( $\rho$ ) and surface tension ( $\sigma$ ),  $\rho/\sigma$ ) have been attempted using the constrained drop method. High accuracy of surface tension measurements was obtained by making a large zaxi-symmetric liquid drop and adopting a developed image capturing system composed of a high-resolution charge-coupled device (CCD) camera, an additional CCD camera to adjust the level of the metal drop and a He–Ne laser.

(cf. *ISIJ Int.*, **44** (2004), 1793)**Numerical analysis on Si deoxidation of molten Fe–Ni and Ni–Co alloys by quadratic formalism**T.MIKI *et al.*

Relation between the activity coefficient expressed by Darken's quadratic formalism and the excess Gibbs energy change of mixing described with Redlich–Kister type polynomial was discussed on Si deoxidation of Fe–Ni and Ni–Co alloys. The activity coefficients of Si and O in metal expressed by quadratic formalism have been converted into formula using interaction parameters  $\Omega_{i-j}$  under the condition where concentration of Si and O are dilute.

Numerical analysis on Si deoxidation of molten Fe–Ni and Ni–Co alloy has been carried out. It has been found to be outstanding in the agreement of equilibrium Si and O contents in molten Fe–Ni and Ni–Co alloy analyzed in the present work with the experimental results. The deoxidation equilibrium of not only one component metal but also alloy can be analyzed numerically using the formula determined in the present work.

(cf. *ISIJ Int.*, **44** (2004), 1800)**Sulphide capacity and sulphur solubility in CaO–Al<sub>2</sub>O<sub>3</sub> and CaO–Al<sub>2</sub>O<sub>3</sub>–CaF<sub>2</sub> slags**S.BAN-YA *et al.*

The sulphide capacity and the solubility limit of CaS in CaO–Al<sub>2</sub>O<sub>3</sub> and CaO–Al<sub>2</sub>O<sub>3</sub>–CaF<sub>2</sub> slags have been studied at the temperatures from 1823 to 1923 K by the equilibrium measurement of gas–slag reaction. The sulphide capacity and the solubility of CaS in these two slag systems increase with increasing CaO content and decreasing ratio of  $N_{Al_2O_3}/N_{CaF_2}$ . The sulphur in CaO–Al<sub>2</sub>O<sub>3</sub>–CaF<sub>2</sub> slag negatively deviated from Henry's law in the high concentration range of sulphur in slag, and the activity coefficient of sulphur in slag varies with sulphur content, slag composition and temperature. It was confirmed that the sulphide capacity was unable to be applied as a real measure of the slag basicity theoretically.

(cf. *ISIJ Int.*, **44** (2004), 1810)**Molecular dynamics simulation of the thermodynamic and structural properties for the CaO–SiO<sub>2</sub> system**W.-G.SEO *et al.*

The thermodynamic, structural and transport properties for the CaO–SiO<sub>2</sub> system were calculated by molecular dynamics (MD) simulation using the pairwise potential model with partial ionic charges. The interatomic potential parameters were determined by fitting the physicochemical properties of calcium oxide and calcium silicates with experimentally measured results. The calculated structural properties such as the pair distribution functions and the fractions of bonding types (bridging, non-bridging and free oxygen) of oxygen with silicon atoms in CaO–SiO<sub>2</sub> melts were in good agreement with observed results, and also the self-diffusion coefficients of calcium, silicon and oxygen ions have been calculated at 1873 K. The  $\Delta H^M$ ,  $\Delta S^M$  and  $\Delta G^M$  for the CaO–SiO<sub>2</sub> system were calculated based on the thermodynamic and structural parameters obtained from MD simulation. The phase diagram for the CaO–

SiO<sub>2</sub> system estimated by calculated Gibbs energy of mixing shows good agreement with observed result in the range above 50 mol% CaO and the liquid–liquid immiscibility region in the CaO–SiO<sub>2</sub> system have also been assessed by MD calculation.

(cf. *ISIJ Int.*, **44** (2004), 1817)**Ironmaking****An application of Bingham model to viscous fluid modeling of solid flow in moving bed**H.NOYAMI *et al.*

Solid flow plays important roles in a moving bed reactor, for example, it determines the path and the residence time of the solid reactants as well as the stress distribution. The continuum models are useful for the kinetic based process analysis since their simplicity and computation load, although the discrete element approach is capable of estimating not only the particle motion but also the stress distribution in the bed. One of the continuum approaches is viscous fluid model. It is able to estimate solid flow pattern although it needs to appropriately determine the shape of stagnant region and viscosity before the simulation. In this study the Bingham model, which is the simplest shear rate–shear stress model of plastic fluid, is applied to the viscous fluid model of bulk solid flow within packed bed. This model successfully reproduce solid flow pattern in packed bed without setting stagnant zone, and the rheological properties can be obtained from simple preliminary experiments. Therefore, the viscous fluid model with the Bingham model is considered as a useful solid flow model for process analysis of moving bed reactors.

(cf. *ISIJ Int.*, **44** (2004), 1826)**Factors influencing carbon dissolution from cokes into liquid iron**S.T.CHAM *et al.*

In a blast furnace carburisation of iron is one of the most important reactions and must be better understood if the blast furnace is to be made more sustainable. Identifying the key mechanisms governing the rate of carburisation of liquid iron is complicated by the intricate nature of the carbonaceous materials used. In this study two cokes prepared from coals of similar rank, ash yield and carbon crystallite structural parameters were investigated. It is found that the apparent carbon dissolution rate in molten iron at 1823 K for the two cokes differed by over an order of magnitude. Coke 1,  $K=14.7 \times 10^{-3} \text{ s}^{-1}$ , carburised molten iron much faster than Coke 2,  $K=1.1 \times 10^{-3} \text{ s}^{-1}$  and the difference is attributed to differences in the composition of their mineral matter.

(cf. *ISIJ Int.*, **44** (2004), 1835)**Casting and Solidification****Experimental study on mould oscillation-less continuous casting process under high frequency amplitude-modulated magnetic field**Z.LEI *et al.*

In order to investigate the influence of high frequency magnetic fields on surface quality of billets

in the soft-contacted electromagnetic continuous casting, several kinds of high frequency Amplitude-Modulated Magnetic Field (AMMF), that is, rectangle, triangle and sine wave AMMF, were adopted in this experimental research. The magnetic field flux in the mould and the intermittent contacting distance were measured. The experiments of Mould Oscillation-Less Electromagnetic Continuous Casting (MOLECC) of tin under the three wave kinds of AMMF were carried out. It is shown that: (1) During the MOLECC process under the rectangle, triangle and sine wave AMMF, when the modulated wave frequency is a little lower than the intrinsic frequency of the experimental system the intermittent contacting distance is the greatest, the mould flux lubrication is the best, the continuous casting withdrawing resistance is the least and the surface quality of billets is the best. (2) Among the three kinds of AMMF, sine wave is the best in deducing the withdrawing resistance and improving the billets surface quality.

(cf. *ISIJ Int.*, **44** (2004), 1842)

#### **In situ synthesis of TiB<sub>2</sub> particulate locally reinforced steel matrix composite by the self-propagating high-temperature synthesis reaction of Al-Fe-Ti-B system during casting**

Q.C. JIANG *et al.*

*In-situ* TiB<sub>2</sub> particulate locally reinforced steel matrix composites were successfully fabricated by the self-propagating high-temperature synthesis (SHS) reaction of 10Al-20Fe-Ti-B and 40Al-20Fe-Ti-B systems, respectively, in the molten high chromium alloy steel during casting. Microstructure analysis of the composite showed that the interface bonding between the matrix and locally reinforced region is very good and the locally reinforced region consists of three different regions, *i.e.* the Fe-rich region, the fine dispersion of TiB<sub>2</sub> particulates region and the larger TiB<sub>2</sub> particulates region. The wear test showed that the wear resistance of the locally reinforced regions of the composites is higher than that of the steel matrix.

(cf. *ISIJ Int.*, **44** (2004), 1847)

#### **Chemical and Physical Analysis**

##### **Determination of arsenic and tin in steels by the automated extraction system with a recycled solvent and an improved gravity phase separation column**

T. TANIAI *et al.*

An automated on-line solvent extraction system has been developed for the determination of arsenic or tin in steel by electrothermal atomic absorption spectrometry (ET-AAS). It is based on the formation of AsI<sub>3</sub> and SnI<sub>4</sub> in concentrated hydrochloric acid and sulfuric acid media, respectively. They are extracted into benzene and back extracted into water and 0.25 mol dm<sup>-3</sup> sulfuric acid, respectively. An improved gravity phase separator was developed for the recycling of organic solvent used in the automated on-line solvent extraction system. Using the proposed system, arsenic or tin contained in the acid dissolved steel sample solution was automatically

extracted and back-extracted. Then, the back-extracted solutions were used for the determination of arsenic or tin by ET-AAS. In the determination of arsenic, 800 mg dm<sup>-3</sup> of cobalt solution had to be used as the matrix modifier to exclude the effect of coexisting substances such as iodide ion. In the determination of tin, 1 000 mg dm<sup>-3</sup> of palladium solution had to be used in the same manner. By this method, a detection limit of As and Sn was 0.2 µg As in the 0.1 g Fe and 0.1 µg Sn in the 0.05 g Fe.

(cf. *ISIJ Int.*, **44** (2004), 1852)

##### **Characterisation of inclusions in clean steels via laser ablation-ICP mass spectrometry**

C. DUBUISSON *et al.*

A new method for detection and assessment of inclusions in clean steels based on laser ablation and ICP mass spectrometry has been developed. Samples were subjected to UV laser ablation (Nd Yag) and ion intensities of elements of interest were monitored on a time-resolved basis. Lasers exhibiting both gaussian and flat-top intensity beam distributions were used. Analytical response for inclusion and matrix elements as a function of laser ablation parameters was studied and procedures were developed for rapid inclusion characterisation and elemental mapping. Main inclusion types identified in clean steels were Mn-S, Mg-Al and Mg-Al-Ca-Ti-Si. Results indicate the considerable analytical potential for the laser ablation technique in a production environment.

(cf. *ISIJ Int.*, **44** (2004), 1859)

#### **Forming Processing and Thermomechanical Treatment**

##### **Prediction of flow behavior during warm working**

S. SERAJZADEH

In this work, the effects of dynamic strain aging and dynamic recovery on metal flow during warm working are studied. Compression experiments are utilized to assess the flow behavior of a low carbon steel under warm deformation conditions. Then, a two dimensional finite element routine is coupled with dynamic recovery and dynamic strain aging models. In this way, the temperature and the velocity fields are predicted during warm working operations with regard to the effects of dynamic recovery and dynamic strain aging. Warm rolling tests are performed in order to verify the modelling results. Comparison between the predicted and measured roll forces shows reliability of the employed model.

(cf. *ISIJ Int.*, **44** (2004), 1867)

##### **Prediction of interpass softening from the strain hardening rate prior to unloading**

E. I. POLIAK *et al.*

It is shown experimentally that the kinetics of interpass softening, normally described in terms of the strain, strain rate and temperature, can be more conveniently specified as a function of the strain hardening rate, strain rate and temperature prior to unloading. This approach significantly

reduces the number of experiments required to generate sufficient data for modeling purposes. It also eliminates the need to determine the retained strain to predict the softening kinetics in multi-hit deformation and simplifies the extrapolation of laboratory data to the conditions of industrial processing.

(cf. *ISIJ Int.*, **44** (2004), 1874)

#### **Welding and Joining**

##### **Reactive diffusion bonding between commercially pure titanium and 304 stainless steel using nickel interlayer**

S. KUNDU *et al.*

Diffusion bonding was carried out between commercially pure titanium and 304 stainless steel using nickel as interlayer in the temperature range of 800–900°C for 5.4 ks under 3 MPa load in vacuum. The transition joints thus formed were characterized in optical and scanning electron microscopes. TiNi<sub>3</sub>, TiNi and Ti<sub>2</sub>Ni are formed at the Ni-Ti interface whereas, 304 ss-Ni diffusion zone is free from intermetallic compounds at 800 and 850°C processing temperatures. At 900°C, Ni-Ti interface exhibits the presence of  $\alpha$ - $\beta$  Ti discrete islands in the matrix of Ti<sub>2</sub>Ni and the phase mixture of  $\alpha$ -Fe +  $\lambda$  +  $\chi$  occurs at the ss-Ni interface. Nickel is able to inhibit the diffusion of Ti to 304 ss side up to 850°C; however, becomes unable to restrict the migration of Ti to stainless steel at 900°C. Highest bond strength of 80% of that of titanium has been obtained for the diffusion couple processed at 850°C owing to the better coalescence of the mating surfaces and failure takes place from Ni-Ti interface. At higher joining temperature, the formation of Fe-Ti intermetallics reduces the bond strength and failure in tensile loading occurs from ss-Ni interface.

(cf. *ISIJ Int.*, **44** (2004), 1882)

#### **Transformations and Microstructures**

##### **Grain boundary characteristics in grain oriented silicon steel**

T. KUMANO *et al.*

During secondary recrystallization of grain oriented silicon steel, isolated grains are often observed in secondary-recrystallized Goss grains (matrix). In an extraction experiment, the crystallographic relations between each isolated grain and the matrix were investigated. Although the  $\Sigma 9$  grain boundary against Goss orientation is the most frequent in the primary texture, it could not be observed in the relation, but specific grains, which have  $\Sigma 3$  or a high angle misorientation relation, were often observed. As the extraction temperature increased, the frequency of  $\Sigma 3$  decreased and that of GGB (general grain boundary) increased. It was revealed that the  $\Sigma 9$  boundary was mobile,  $\Sigma 3$  was less mobile and GGB was the least mobile. This does not contradict the CSL model but supports it. However, it was not clarified whether this result is caused by grain boundary energy or mobility.

(cf. *ISIJ Int.*, **44** (2004), 1888)

### Cold swaging, recovery and recrystallization of oligocrystalline INCOLOY MA 956—Part I: Deformed state

M.F.HUPALO *et al.*

Oxide dispersion strengthened (ODS) superalloys combine high temperature strength and excellent corrosion and oxidation resistances. INCOLOY MA 956 is an iron-based ODS superalloy containing about 1% (volume) of fine and uniformly dispersed  $Y_2O_3$  particles in a ferritic matrix. In the present work a coarse-grained (oligocrystalline) bar of MA 956 alloy was cold deformed by rotary swaging to reductions in area of 20, 47, 61, and 72%. Microstructural characterization of deformed samples was performed using light optical microscopy (LOM), X-ray diffraction (XRD), electron backscatter diffraction (EBSD), and Vickers microhardness testing. The microstructure in the deformed state was found to be very inhomogeneous. Deformation bands were observed in all grains. The extent of deformation banding varies from grain to grain in terms of morphology and spacing. The deformation substructures were found to be very different in each grain. A sharp  $\langle 110 \rangle$ -fiber texture was developed during plastic deformation becoming more pronounced with increasing strain.

(cf. *ISIJ Int.*, **44** (2004), 1894)

### Cold swaging, recovery and recrystallization of oligocrystalline INCOLOY MA 956—Part II: Annealed State

M.F.HUPALO *et al.*

The combination of a coarse-grained structure (oligocrystalline material), a strong initial texture, and the presence of fine particles make ODS superalloys like INCOLOY MA 956 very interesting materials for recrystallization studies. In the present paper, we have investigated the annealing behavior of the MA 956 alloy deformed by cold swaging to reductions of 20, 47, 61, and 72% followed by annealing at temperatures ranging from 600 to 1450°C. Light optical, scanning, and transmission electron microscopy were used to follow the microstructural changes upon annealing. Orientations of individual grains as well as microtexture were determined by electron backscatter diffraction (EBSD). Recrystallization texture was determined by X-ray diffraction (XRD). The isothermal softening kinetics curves were determined for all samples. Discontinuous recrystallization and extended recovery are responsible for the softening of this alloy. The Johnson-Mehl-Avrami-Kolmogorov (JMAK) model was used to test our experimental data. The Avrami exponents ( $0.26 \leq n \leq 0.48$ ) showed substantially smaller values than those predicted theoretically. This can be attributed to concurrent recovery and to a non-random distribution of recrystallization nuclei.

(cf. *ISIJ Int.*, **44** (2004), 1902)

### Strength-ductility relationship in solution treated and aged $\alpha+\beta$ type Ti-4.5%Al-3%V-2%Fe-2%Mo titanium alloy

H.FUKAI *et al.*

The microstructural variation with solution treat-

ing or aging conditions in SP-700 alloy with Ti-4.5%Al-3%V-2%Fe-2%Mo was investigated, and the effect of the microstructure on strength-ductility balance of this alloy was studied by tensile testing using both the smooth and notched specimens. Solution treating in the  $\alpha+\beta$  region formed a two-phase microstructure consisting of the primary  $\alpha$  and transformed  $\beta$  phases, and the microstructure and hardness of the latter were widely varied by the cooling rate. The microstructures of the transformed  $\beta$  obtained by water quenching were  $\alpha'$ , athermal  $\omega$  and retained  $\beta$  phases, while air cooling formed acicular  $\alpha$  in  $\beta$  matrix and its width became thicker with reduction of cooling rate. Water-quenched and aged alloy exhibited better strength-ductility balance compared with air-cooled and aged one, which appeared to be due to retardation of void formation during straining. Strength after aging in this alloy could be analyzed by a law of mixture, and microhardness and the volume fraction of the transformed  $\beta$  phase were found primarily to control strength. Reduction of hardness difference between the primary  $\alpha$  and transformed  $\beta$  phases by the increase of the oxygen content of this alloy improved ductility-strength balance. Notch tensile strength increased with strengthening due to age-hardening and also the increase of cooling rate after solution treating, and showed a peak value at tensile strength of around 1300 MPa.

(cf. *ISIJ Int.*, **44** (2004), 1911)

### Static and metadynamic recrystallization of interstitial free steels during hot deformation

S.H.ZAHIRI *et al.*

A rapid method was used to identify kinetics of the recrystallization for two IF (Interstitial Free) steels which have different phosphorous and boron contents. The static and metadynamic softening behaviour of the materials for a range of strain rates and temperatures were quantified. The critical strain for initiation of strain independent softening was estimated for the IF steels in respect to the time for 50 percent softening after deformation. The results showed that the strain for the initiation of strain independent softening (often referred to as metadynamic recrystallization) varies with the Zener Hollomon parameter. Classic static recrystallization was observed at strains below the strain independent softening for all processing conditions and the strain rate had a strong effect on the time for strain independent softening. Results also revealed that static and metadynamic recrystallization was delayed owing to the phosphorous and boron alloying elements. Hence, the large strain at above no-recrystallization temperature may be required for the early stage of Finishing Stands Unit (FSU) in hot strip rolling mills to initiate austenite grain refinement of phosphorous and boron added IF steels.

(cf. *ISIJ Int.*, **44** (2004), 1918)

### Reverse transformation in Fe-Ni bicrystals

M.UEDA *et al.*

The effect of grain boundary character on the reverse phase transformation was investigated using Fe-Ni bicrystals containing a  $90^\circ \langle 211 \rangle$  symmetric

tilt or a  $90^\circ \{211\}$  twist boundary, focusing on the transformation temperature during heating, the morphology of reversed austenite and the variant selection. Martensitic transformation behaviour in bicrystals depends strongly on the type of grain boundary. The tilt bicrystals showed a characteristic self-accommodation of martensites across the boundary called cooperative nucleation (C-N) and higher martensite-start temperature ( $M_s$ ). On the other hand, the reverse transformation-start temperature ( $A_s$ ) of bicrystals with the tilt boundary was higher than that of single crystals or bicrystals with the twist boundary. By *in-situ* observation, a retardation of reverse transformation of cooperatively nucleated martensites was confirmed in the vicinity of the tilt boundary on heating. The C-N reduces a local stress field around martensites which helps the reverse transformation. Therefore, the bicrystals with the tilt boundary containing the C-N show higher than the others. Many martensites near the tilt and the twist grain boundary returned to the austenite phase inheriting the initial orientation. However, numerous sub-boundaries were retained near the tilt boundary. The C-N seems responsible for the lack of information about initial orientation of austenite. Thus, the reverse transformation behaviour in bicrystals was also found to depend strongly on the grain boundary character.

(cf. *ISIJ Int.*, **44** (2004), 1924)

### Effect of inhomogeneous deformation on the recrystallization kinetics of deformed metals

H.LUO *et al.*

In this paper, the Johnson-Mehl-Avrami-Kolmogorov equation, modified by Rollett *et al.* (1989) to take the heterogeneity of recrystallization into account, was used to derive analytical equations to calculate the instantaneous and average Avrami exponent during the heterogeneous recrystallization process. The model can explain experimental observations, such as a lower exponent than predicted by the JMAK theory and a decreasing exponent with proceeding recrystallization; moreover, by building up a quantitative relationship between local strain variation and heterogeneity of recrystallization kinetics, it can also describe so-far unexplained observations, such as the range of experimentally observed exponents in recrystallization, and the very small effect of temperature and deformation conditions on the Avrami exponent.

(cf. *ISIJ Int.*, **44** (2004), 1931)

### Control of cementite precipitation in lath martensite by rapid heating and tempering

T.FURUHARA *et al.*

Lath martensite structures, tempered at various temperatures (723–923 K) were studied by changing heating rates (2 K/s to 1000 K/s) to the tempering temperature in an alloy steel for machine structural use (SCM435; Fe-0.35C-0.24Si-0.77Mn-1.05Cr-0.17Mo). Hardness of the rapidly heated (at 100 K/s or 1000 K/s) specimen is larger than that of the slowly heated (at 2 K/s) specimen when tempering temperature and time are the same. Cementite precipitates are formed on high angle boundaries (prior

austenite grain boundary, block and packet boundaries) as well as within laths and at low angle boundaries (lath boundaries) by tempering. TEM observation has revealed that finer cementite is dispersed more uniformly in the rapidly heated specimen than in the slowly heated specimen. It is considered that the temperature where cementite precipitation starts is raised by increasing the heating rate to tempering temperature, resulting in a higher nucleation rate and a finer dispersion of cementite.

(cf. *ISIJ Int.*, **44** (2004), 1937)

### Mechanical Properties

#### Development of high strength hot-rolled sheet steel consisting of ferrite and nanometer-sized carbides

Y.FUNAKAWA *et al.*

A ferritic steel precipitation-strengthened by nanometer-sized carbides was developed to obtain a high strength hot-rolled sheet steel having tensile strength of 780 MPa grade with excellent stretch flange formability.

Manganese in a content of 1.5% and molybde-

num in a content of 0.2% were added to 0.04% carbon Ti-bearing steel in order to lower austenite-ferrite transformation temperature for fine carbides and to retard generating of pearlite and large cementites, respectively. Tensile strength of hot-rolled sheet steel increased with titanium content and it was achieved to 800 MPa in a 0.09% Ti steel. Microstructure of the 0.09%Ti steel was ferrite without pearlite and large cementites. Fine carbides of 3 nm in diameter were observed in rows in the ferrite matrix of the 0.09%Ti steel with transmission electron microscope. The characteristic arrangement of the nanometer-sized carbides indicates that the carbides were formed at austenite-ferrite interfaces during transformation. By energy dispersive X-ray spectroscopy, the carbides were found to contain molybdenum in the same atomic concentration as titanium. Crystal structure of the nanometer-sized carbides was determined to be NaCl-type by X-ray diffractometry. The calculated amount of precipitation-strengthening by the carbides was approximately 300 MPa. This is two or three times higher than that of conventional Ti-bearing high strength hot-rolled sheet steels.

Based on the results obtained in the laboratory in-

vestigation, mill trial was carried out. The developed hot-rolled high strength sheet steel exhibited excellent stretch flange formability.

(cf. *ISIJ Int.*, **44** (2004), 1945)

#### Elastic strains of cementite in a pearlite steel during tensile deformation measured by neutron diffraction

A.KANE *et al.*

Lattice plane strain, *i.e.*, elastic strain, in cementite plates embedded in the ferrite matrix was measured by *in situ* neutron diffraction during tensile deformation for a hypereutectoid pearlite steel. The employment of time-of-flight method and microstructure control enable us to measure the shift of cementite peaks along tensile and transverse directions at the applied stress up to 1.6 GPa. The highest elastic strains of cementite determined was approximately 0.015. Heterogeneous plastic deformation between ferrite and cementite as well as among ferrite blocks are discussed.

(cf. *ISIJ Int.*, **44** (2004), 1952)

### 平成 17 年度 俵・澤村論文賞候補論文の自薦について

「鉄と鋼」Vol.90(2004), No.1~No.12 に掲載された論文、及び「*ISIJ International*」Vol.44(2004), No.1~No.12 に掲載された論文の寄稿者は、「鉄と鋼」掲載の場合は俵論文賞、「*ISIJ International*」の場合は澤村論文賞の候補論文に、自著の論文に限り自ら推薦することができます。

また、平成 15 年度よりニオブに関する優秀論文に与えられるギマラエス賞が設けられました。ニオブに関する論文の寄稿者は上記俵論文賞、澤村論文賞と併せてギマラエス賞にも自薦することができます（ギマラエス賞のみの自薦はできません）。推薦要領は下記の通りです。

1.候補論文推薦締切：2005 年 1 月 6 日（木）必着（締切後は受け付けられません）

2.必要書類：指定推薦用紙 1 通

推薦用紙は鉄鋼協会ホームページ(<http://www.isij.or.jp>)からダウンロードできます。ホームページからダウンロードできない場合は下記宛にご請求下さい。

推薦用紙の  
請求・送付先 (社)日本鉄鋼協会 学会・生産技術部門事務局 編集グループ 内田または林  
〒101-0048 東京都千代田区神田司町 2-2 新倉ビル 2 階  
TEL.03-5209-7013 FAX.03-3257-1110 E-mail: [editol@isij.or.jp](mailto:editol@isij.or.jp)