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ISIJ International, February 2016
Morphology evolution and phase interactions of Fe-containing Si3N4 in vacuum high-temperature environment. B. Li, J. Chen, M. Yan, J. Su, J. Sun, Y. Li
To study the substitution of Fe3Si–Si3N4 for refractories in the upper RH refiner, this paper simulated the service condition of RH refining and studied the change of the Fe3Si–Si3N4 in the simulated condition. A Fe3Si–Si3N4 specimen prepared by flash combustion was put in a vacuum sintering furnace with carbon lining, fired at 1 450°C under 80 Pa of vacuum degree for 2 h, and then cooled. The morphological evolution before and after being treated and phase interactions of the Fe3Si–Si3N4 specimen were studied and analyzed thermodynamically and dynamically. The results show that at high temperatures in vacuum, Fe volatilizes from the Fe3Si melt in Fe3Si–Si3N4 and reacts with Si3N4 on the Si3N4 crystal surface, forming new FexSi melt there; then Fe continues to volatilize from the new FexSi melt, causing FexSi alloy particles finer and more uniform in Fe3Si–Si3N4; the hexagonal columnar Si3N4 crystals begin to decompose partially, and become cylindrical with edges and corners disappearing; during prebaking or
operation interval of RH refining, a SiO2 film which has better stability than Si3N4 is developed on the surface of Si3N4 crystals or Fe3Si–Si3N4 bricks, preventing the decomposition of Si3N4 and improving the application feasibility of Fe3Si– Si3N4 in RH refining.

**ISIJ International, January 2016**  
**Curing mechanism of phenolic resin binder for oxide-carbon refractories.** J. Zhang, G. Mei, Z. Xie, S. Zhao  
Phenolic resin has been widely used as the binder of oxide-carbon refractories, and its curing process has a great effect on the bonding strength. In order to optimize the curing process, the curing mechanism, which involved the heat release reaction, weight change and chemical structure evolution, has been investigated in this study. The dehydration-condensation reactions of the curing started at 363 K. Then, the formation and volatilization of water began and accelerated the rate of weight loss of the binder. Meanwhile, these reactions led to the increase of the molecular size of the binder, which might cause the improvement of the binder's bonding strength. As the temperature increased up to 403 K, the exothermic reaction by the dehydration-condensations of the binder increased and the endothermic reaction by the volatilization of free molecules decreased. In the range from 403 K to 523 K, main dehydration-condensation reactions occurred. These reactions let the molecular size of the binder increase obviously and the bonding strength might be improved significantly. Therefore, a slow heating rate was needed. Above 523 K, the curing gradually approached the end and a higher heating rate was needed. Moreover, when the temperature reached 543 K, the curing was completed because the binder almost had the stable chemical structure, constant weight and very small exothermic reaction.

**Ironmaking & Steelmaking, January 2016**  
**Effects of MnO on slag viscosity and wetting behaviour between slag and refractory.** H. Zuo, C. Wang, C. Xu2, J. Zhang, T. Zhang  
As more and more Mn bearing iron ores are used to decrease steel cost and deal with the problem of hearth deposition, slag regime change and hearth refractory erosion in blast furnace become more often. To address these problems, it is urgent to clarify the effects of MnO upon the ironmaking production. Herein, the viscosities of slags with different MnO contents were measured for the first time, and the influence mechanism of MnO was analysed by infrared spectrum. The wetting behaviours between slags with different MnO contents and alumina-carbon refractory were investigated. The results showed that meltability temperature and viscosity decrease simultaneously with the increasing MnO content from 0 to 2.0 wt-%. Infrared spectrum analysis also proved that the existence of Mn2+, Ca2+ and Mg2+ makes the Si–O bonds peak moving towards high frequency and the asymmetry of Si–O bond increasing, leading to the decrease in viscosity decreasing. In addition, the characteristic temperatures for wetting reaction increased by ,408°C with the increasing MnO content from 0 to 3 wt-% (basicity=1.18). The characteristic temperatures decreased by nearly 50°C with the basicity of slag increasing from 1.0 to 1.3 (MnO = 1 wt-%). Therefore, the increasing MnO content in slag accelerates the erosion rate of BF hearth lining and then decreases the campaign life of blast furnace.

**Materials Research Innovations S10, December 2015**  
**Synthesis process and production properties of forsterite-based refractory from iron ore tailings.** J. Li, Q. Wang, H. Xu  
Forsterite-based refractories were prepared using iron ore tailings as some of its starting raw materials in the study. Forsterite's synthesis process was also examined at the same time. The crystallization behaviour of synthesised forsterite samples was investigated
using differential scanning calorimetry (DSC), X-ray diffraction (XRD) and Scanning Electronic Microscopy (SEM). According to the DSC analysis, the forsterite synthesis experiments were carried out at different temperature of 1423, 1473, 1593, 1673 and 1723 K. The formation temperature of forsterite was determined. A forsterite-based light insulate brick preparation experiment was carried out at 1723 K for 6 hours. The XRD analysis results show that the major phase of the synthesised forsterite-based refractory was primarily forsterite along with Mg-Ferro spinal, and smaller amounts of MgO (periclase). The properties of the synthesised forsterite-based refractory compared well with the value of the industrial forsterite-based refractory. The result indicated interesting potential for iron ore tailings to produce useful materials.

Simulation and experiment of specimen size on the effect of laser scribing width and depth of Al2O3 ceramics. K. Huang, S. Wang, L. Tang
Laser scribing is one of important process in the fields of hard, brittle materials such as silicon and ceramics, films and glasses. To obtain high precision and quality, people should consider all influential factors of laser scribing such as laser scribing parameters and the geometries of specimen size. In this paper, the effect of specimen size on laser scribing width and depth of Al2O3 ceramics was simulated and verified by using ANSYS software and Diode Pumped Solid State laser scribing, respectively. The calculated results and the experimental results all proved that the specimen size had important effect on laser scribing width and depth due to the heat accumulation effect during the laser scribing.

METEC & 2nd ESTAD, June 2015
Tap hole free opening optimization in the EAF through monitorized grain size distribution control of the EBT filler sand. Laboratory testing & industrial application. E. Somolinos, E. Ruisanchez, C. Escudero, J. Martinez
In this paper we will discuss the process of the grain size customization of the EBT filler sand in relationship to the technical characteristics of the furnace and its tap hole. By customizing the grain size distribution, the glassy area formed on the top of the tap hole varies and supports differently the metallurgical pressure of the molten steel providing increased free opening speeds. Taylor made sand improves therefore the free opening rate, reduces the tap to tap time and increases the lifespan of the tap hole.

RHI Bulletin, January 2015
Excellence in inert gas control systems for the steel industry. R. Ehrengruber
Steelmakers are continually improving their process technology to meet market requirements in terms of both steel quality and price. At first glance it can appear that the application of inert gas has a minor impact on overall costs across the entire steel production process, and therefore it is normally a topic where little focus is placed. However, steelmaking requires inert gas introduction at some of the most critical process steps. While it is established that sufficient inert gas benefits the process, too much can degrade the product. If improper purging systems are installed, not only significant amounts of alloying elements are wasted, but process time and energy are lost since the steel has to be downgraded when specifications are not met. It is also costly to reproduce downgraded steel and considerable logistic effort is incurred, especially at the continuous caster. Therefore, accurate and reliable inert gas control is essential. This article describes the holistic approach RHI and INTERSTOP offer regarding this area and the new designs of their inert gas control systems used in basic oxygen furnaces, electric arc furnaces, ladles, and at the continuous casting machine.

China´s Refractories, April/June 2014
Production and running status of China’s refractories and main downstream Industries in 2013. Xu Dianli
In 2013, China’s refractories output was 29.283 million tons increasing by 3.88% YOY; in which the outputs of dense shaped refractory products, insulating refractory products, monolithic refractories were 17.307 million tons increasing by 5.93% YOY, 557.3 thousand tons decreasing by 2.67% YOY and 11.418 million tons increasing by 1.24% YOY, respectively. The outputs of the main varieties are shown in Fig. 1.

Effect of ZnO on oxidation resistance of low carbon MgO-C refractories. Xie Zhaohui, Chen Liugang, Zhai Pengtao, Zhang Yang
Al-containing low carbon MgO-C refractories were prepared using 70% (in mass, the same hereinafter) fused magnesia (63 mm), 24% fused magnesia powder (< 0.074 mm), 3% flake graphite, 3% Al powder and 4% phenolic resin (extra-added) as the basic formulation. Influence of ZnO addition on oxidation resistance of the materials was investigated by adding 1% ZnO to substitute fused magnesia powder. The relationship between in-situ formed spinel and ZnO in the matrix was discussed by comparing apparent porosity, cold crushing strength, and phase evolution of the materials matrix. The oxidation resistances of the two materials were compared by observing the formed dense MgO layer between the decarburized layer and the original layer. The result shows that adding ZnO in MgO-C refractories accelerates the in-situ formation of ZnAl2O4 spinel and the formation of dense MgO layer, thus improves the oxidation resistance of the low carbon MgO-C refractories.

Preparation of single phase Na-X Zeolite from oil shale ash by melting hydrothermal method. Tong Lingxin, Luo Huaming, Zhang Lin, Zhan Huasheng
A single phase Na-X zeolite was synthesized from pretreated oil shale ash by alkaline fusion and hydrothermal treatment. Effects of the NaOH concentration, crystallization time and temperature on the formation of Na-X zeolite were studied in detail. The single phase Na-X zeolite powders can be prepared by alkaline fusion of pretreated oil shale ash at 600 °C for 1 h, and crystallization at 80 °C for 8-10 h with NaOH concentration of 3-3.5 mol L-1. Na-X zeolite appears when decreasing NaOH concentration, crystallization time or temperature, and an unnamed zeolite emerges when prolonging crystallization time or raising crystallization temperature. SEM micrographs suggest that the aggregates of Na-X zeolite particles have perfect dispersity and uniform granular with about 1.5 μm in size, and most of the Na-X zeolite crystals display a regular octahedral structure with the size of about 500 nm. The specific surface area of the powders with single Na-X zeolite phase reaches the maximum value of 488. 163 2 m2 g-1, larger than that of multiple zeolite powders.

Effect of nano-Al2O3 on mechanical properties and microstructure of Si3N4 ceramics. Wang Huifang, Zhang Xijun, Bi Yubao
Si3N4 ceramics were prepared by pressureless sintering at 1650 °C in nitrogen atmosphere using Si3N4 powder as main starting material and adding nano-Al2O3 powder (3%, 6%, 9%, 12%, and 15% in mass, the same hereinafter). The bending strength and fracture toughness (KIC) of the specimens were detected. The microstructure and phase compositions of the specimens were analyzed. The results show that Si3N4 ceramics can be prepared by pressureless sintering when adding 9% - 12% nano-Al2O3 as active reactant, which dissolves in Si3N4, in-situ forming non-oxide SiAlON. The obtained Si3N4 ceramics have the maximum bending strength of 710.86 MPa and KIC of 8.61 MPa m1/2. The excellent properties come from many interwoven structures distributed uniformly in the ceramics matrix, which is composed of big and firm plate-like β-Si3N4, hexagonal SiAlON and sheet Si3N4O.

Effect of bauxite aggregate on properties of Al2O3-SiC-C iron trough castables. Wuhan Jianxiu, Fan Haibing, Xue Haitao, Dong Li
Al2O3-SiC-C iron trough castables were prepared using high alumina bauxite clinker GL-90 (> 1 mm) or homogenized bauxite GL-88 to replace the traditional brown corundum
aggregates (> 1 mm) to reduce the cost of iron trough castables. Effects of the two bauxite aggregates on properties of iron trough castables were investigated. The results show that the two kinds of bauxite affect flowability, bulk density, strength and slag corrosion resistance of trough castables differently. Compared with homogenized bauxite, high alumina bauxite clinker is more suitable to substitute brown corundum. The castables prepared from the bauxite clinker have similar performances with those prepared from brown corundum, especially used in medium or small blast furnaces with weak thermal impact and lower temperature hot metal. However, in large blast furnaces with severe thermal impact and high temperature hot metal, the performances of the two castables are significantly different. So it is suggested to use the brown corundum based castables in the front gyral zone of the slag skimmer.

**Development of magnesium aluminate spinel castable for roof of EAF with high molten iron charging ratio.** Chen Yang, Wu Hongping, Zhu Dongdong, Zhang Hang

Specimens of magnesium aluminate spinel castable and calcium aluminate cement bonded bauxite based castable were prepared using special bauxite (particle size ≤8 mm) and sintered magnesia as aggregates, SiO₂ micropowder, α-alumina micropowder and calcium aluminate cement as binders, drying, firing at 1350 °C and 1500 °C for 3 h, respectively. The bulk density, cold modulus of rupture, cold crushing strength, permanent change in dimensions on heating, thermal shock resistance and slag resistance were determined. The results show that compared with calcium aluminate cement bonded bauxite based castable, the magnesium aluminate spinel castable has higher cold crushing strength after drying, better slag resistance but worse thermal shock resistance. Magnesium aluminate spinel based roof of EAF with high molten iron charging ratio has a longer service life.

**Properties and microstructure evolution of Al₂O₃-Si material fired in different atmospheres.** Ma Teng, Liu Xinhong, Zhu Xiaoyan, Ye Fangbao

Al₂O₃-Si composite specimens were prepared using fused corundum, ultra-fine α-Al₂O₃ and Si powders as starting materials and resin as binder. Effects of sintering atmospheres on properties, phase composition and microstructure of specimens after firing at 1500 °C were investigated. The results show that: (1) after firing in oxidizing or weak oxidizing atmosphere, there is some Si in the specimens and some glass phases containing mullite form on specimen surface, the density and strength at room temperature are relatively high, but hot modulus of rupture and thermal shock resistance are relatively poor; (2) after firing in weak reducing or reducing atmosphere, Si reacts completely with CO or N₂ forming whisker-like SiC, granular Si₃N₄O or O’-SiAlON, and the thermo-mechanical properties of specimens are enhanced; (3) after firing in nitrogen atmosphere, Si reacts completely with N₂, CO or C forming whisker-like SiC and columnar β-SiAlON crystals, the hot modulus of rupture and thermal shock resistance of specimens are enhanced noticeably.

**Corrosion resistance mechanism of MgO-CaO refractories to refining slag.** Yu Yanping, Yu Yanwen

Corrosion resistance and penetration resistance of MgO - CaO materials with different CaO contents (22%, 42%, 49%, 53%, in mass) to refining AOD slag or VOD slag were investigated using static crucible technique by visual observation, SEM and XRD. The corrosion resistance and penetration resistance of specimens decrease with the increase of CaO content. This may be caused by the formation of C₃S and C₂S during the reactions between specimens and the slag. The formed C₃S can restrain the further penetration to the matrix. The higher the CaO content, the more the C₃S or C₂S formed, the lower the porosity of the specimens, and the lower the penetration depth and corrosion rate. The corrosion resistance to AOD slag is better than that to VOD slag, because the reaction between AOD slag and the matrix is slighter than that between VOD slag and the matrix.
Progress and developing trend of purging plugs for refining ladle. Zhang Ju, Sun Xiaogai, Jia Quanli, Wu Ran
Damage reasons of purging plugs for refining ladle and research progress on thermal shock resistance of corundum - spinel purging plugs were summarized. Research achievements and application results of non-oxides bonded corundum purging plugs for refining ladle were briefly reviewed. The further research and developing trend of purging plugs was proposed.