

EVALUATION OF SILICON CARBIDE BRICKS

Alton T. Tabereaux
Reynolds Metals Company
Manufacturing Technology Laboratory
3326 East Second Street
Muscle Shoals, AL 35661 USA

Albrecht Fickel
AnnaWerk Refractory Division
Postach 1144, D-96466
Rodental, Germany

Introduction

The combined experience and knowledge for testing and evaluating silicon carbide (SiC) bricks for their potential application in reduction cell linings are shared in this paper between a SiC brick manufacturer (AnnaWerk) and an aluminum producer (Reynolds Metals Company). Because of the recent introduction of new SiC bond phases and increase in global manufacture of SiC refractories, there is a need to conduct tests of SiC bricks to evaluate their effectiveness as a cathode lining material in reduction cells, but due to their inertness SiC bricks are very difficult to evaluate using standard laboratory refractory tests.

The problem with all laboratory tests trying to evaluate ceramic materials for a special refractory application is their closeness to reality. The laboratory test is supposed to duplicate on a small scale, the thermal-mechanical stresses, as well as, corrosive or abrasive attacks on small sample pieces of the same refractory material of similar geometries, and by that reproducing as far as possible the thermal fluxes, etc. It is also the aim of such tests to supply reliable results on the service potential of a ceramic combination of materials in a shortened test period compared to the rather long actual life time of a furnace or cell lining from 3 to 10 years, and, of course, to be performed at very moderate laboratory test costs. Exaggerations of test conditions compared to real practical application; for example, increased test temperatures, aggressive cryolite chemistries, mechanical loads, etc., try to shorten the test periods, but still provide reliable information and projections on the long term performance of the materials tested. The most important consideration is having a refractory test which provides for quantified judgments and not solely relative classifications of results.

In the first approach of a large refractory evaluation program for the numerous refractory and ceramic materials on the market, classical analysis of the standard properties like chemical and mineralogical composition, bulk density, apparent porosity and information on strength, if possible at elevated temperatures, have to be collected and collated to get a general overview of the materials' character. As with many ceramics, SiC refractories also are liable to undergo changes in their basic properties under the harsh conditions of a metallurgical furnace. When preparing for a test of our candidate materials we have to ask what happens to the refractories, or how they may be influenced or changed in their structural properties as a result of the test conditions and how these "newly formed materials" behave under the still prevailing environmental conditions.

Experimental

Chemical Composition

The bond phase employed in a silicon carbide (SiC) brick will determine to a large extent its chemical and physical properties (1-4). Silicon nitride-bonded SiC bricks have proven to be the best material to date for application in reduction cell sidewall. These bricks have superior resistance to oxidation and abrasion, as well as sufficiently high hot strength. The chemical compositions of commercial SiC bricks with silicon nitride (Si₃N₄), sialon (SiAlON), oxide-silicate and oxynitride bonds are shown in Table I. The majority of the Type 1 silicon nitride-bonded SiC bricks contain 75-78% SiC with 18-25% silicon nitride content in the bond phase. However, Type 2 silicon nitride-bonded SiC bricks contain 85-86% silicon carbide with 13% silicon nitride in the bond phase.

Table I Chemical Composition of Silicon Carbide Bricks
(Vendor Data)

SiC Brick	SiC %	Si ₃ N ₄ %	Sialon %	Si ₂ ON ₂ %	SiO ₂ %	Al ₂ O ₃ %
Si ₃ N ₄ -SiC Type 1						
A	75	23			0.5	-
B	75	23			0.5	0.3
C	75	23			-	-
D	75	25			-	-
E	75	20			-	0.5
F	78	18			2.6	0.9
Si ₃ N ₄ -SiC Type 2						
G	85	13			-	-
H	86	13			0.5	0.3
Sialon-SiC						
I	76		19			
J	73		24			
K	67		20			
Oxide-SiC						
L	89.6				8.5	0.7
M	48.2				1.6	49.9
N	87.9				9.6	1.6
Oxynitride-SiC						
O	85			13	-	-

Newly developed bond phase for SiC bricks, particularly sialon (Si-Al-O-N), are actively being evaluated for application as sidewall lining in cathodes. Sialon-bonded SiC has a higher density, lower porosity and higher hot strength than silicon nitride-bonded SiC bricks. Compared with silicon nitride, sialon has a higher resistance to oxidation, superior inertness to molten metals and resistance to alkalis. As shown in Table I, commercially available sialon bonded SiC bricks contain about 67-76% SiC and 19-24% sialon phase.

Other silicon carbide materials evaluated contained other bonding phase materials including: refractory silicate-bonded SiC, alumina-bonded SiC, clay-refractory silicate-bonded SiC, and oxynitride-bonded (Si₂ON₂) SiC bricks containing 13% oxynitride.

SEM of the Bond Phase of SiC Bricks

Investigations were made with a scanning electron microscope (SEM) using a magnification of approximately 2000 to examine the different characteristics of various types of bonded SiC brick refractories as shown in Figure 1.

SiC, mullite-bond. The upper half is SiC grain with some cristobalite crystals resulting from the production firing; the lower half is strongly oxidized SiC grains covered with a complete layer of cristobalite crystals. Between the two silicon carbide grains is a viscous mullite glassy-phase forming the bond with acicular mullite crystals. Note the surface tension effect of the concave glass portion. Acicular mullite crystals are coming out from this glass bond.

SiC, oxide-bond. SiO₂-bond phase is completely covering all SiC grains. Numerous, acicular tridymite crystals have been formed during the production firing. Also typical are the large number of cracks in the bond phase open for oxygen diffusion and/or for further attack on the SiC grain surfaces.

SiC, oxynitride-bond. Silicon oxynitride, Si₂ON₂, is evident adhering to the surface of the SiC grains, formed after reaction firing of SiC-Si metal mixtures in N₂-O₂-atmosphere; not very common any more today. In some cases, nitride bonded SiC in the course of long run oxidation will form silicon oxynitride as an intermediate state before complete transformation from silicon nitride into silicon dioxide, SiO₂.

SiC, silicon nitride bond. Both silicon carbide and silicon nitride bond are evident. A pore filled with β-Si₃N₄-needles forms a bond system between SiC grains for the SiC structure. Dense silicon nitride areas are to be seen in the top position and lower right corner. This type of Si₃N₄ bond is compact and has high strength.

SiC, sialon-bonded. High strength material, as evident from the stepped SiC fractured surface, rather dense bond structure with big, compact sialon crystals to be seen in center and upper left corner.

SiC, β-SiC-bond. Good contact between α-SiC grains (upper left and center right) and β-SiC bond phase (lower half). Bond formations at rather low temperature are indicated; production firing connected with problems of environmental pollution, similar to pitch-bonding in carbon or graphite materials.

SiC with alpha-SiC-bond. Absolute high temperature version of alpha-SiC consisting of +99% SiC. Direct connection of alpha-grains "sinter-and condensation-necks," very strong bond with big pores. Excellent corrosion resistance because of the nearly complete absence of corrosion sensitive intergranular bond phases.

Refractory Hot Strength

Sidewall lining materials must have sufficient strength at high temperatures to provide mechanical stability for supporting the cathode assembly during cell operation.

Conventional HMOR Measurements. The high temperature modulus of rupture (HMOR) of the various phase-bonded SiC bricks was measured according to ASTM Method C 583 to determine the strength of the commercial SiC bricks at the cathode sidewall lining service temperature. Test bars (25.4 mm x 25.4 cm x 228.6 mm) cut from SiC bricks were soaked in the furnace at test temperature for 1 hour in air before breaking them in the 3-point tests.

The results for hot modulus of rupture, as given in Table II for the various SiC based bricks demonstrate a wide range in density and porosity, as well as HMOR measured for the same type of SiC based bricks, but produced by different manufacturers.

Table II HMOR and Physical Properties of Silicon Carbide Bricks

SiC Brick	Modulus of Rupture 927°C MPa	Std. Dev.	Bulk Density* g/cm ³	Apparent Porosity* %
Silicon Nitride-SiC Type 1				
A	40.4	3.7	2.60	15.0
B	44.1	1.8	2.62	15.0
C	45.1	3.3	2.40	22.0
D	42.9	1.5	2.60	16.0
E	50.1	1.6	2.60	17.0
F	<u>36.3</u>	6.1	<u>2.56</u>	<u>15.5</u>
Average	43.2	-	2.56	16.8
Silicon Nitride-SiC Type 2				
G	50.8	4.00	2.65	15.0
H	<u>29.3</u>	3.16	<u>2.60</u>	<u>17.7</u>
Average	40.1	-	2.63	16.4
Sialon-SiC				
I	51.6	2.0	2.65	16.0
J	39.9	2.9	2.64	15.0
K	<u>51.3</u>	3.0	<u>2.65</u>	<u>15.0</u>
Average	47.6	-	2.65	15.3
Oxide-SiC				
L	30.8	5.3	2.57	14.0
M	16.9	2.9	2.78	17.2
N	<u>36.5</u>	5.3	<u>2.58</u>	<u>14.0</u>
Average	28.1	-	2.64	15.1
Oxynitride-SiC				
O	-	-	2.6	15.0

* Vendor Data

Apparently, the modulus of rupture of the various types of SiC bricks is directly related to the mineralogical composition of the bond phase of the SiC bricks. The results obtained for the measured hot strength of various SiC bricks can be summarized:

- The average modulus of rupture for Type 1 silicon nitride-bonded SiC bricks was high, 43.2 ± 3 MPa, with a bulk density of 2.56 g/cm³ and porosity of 16.8%

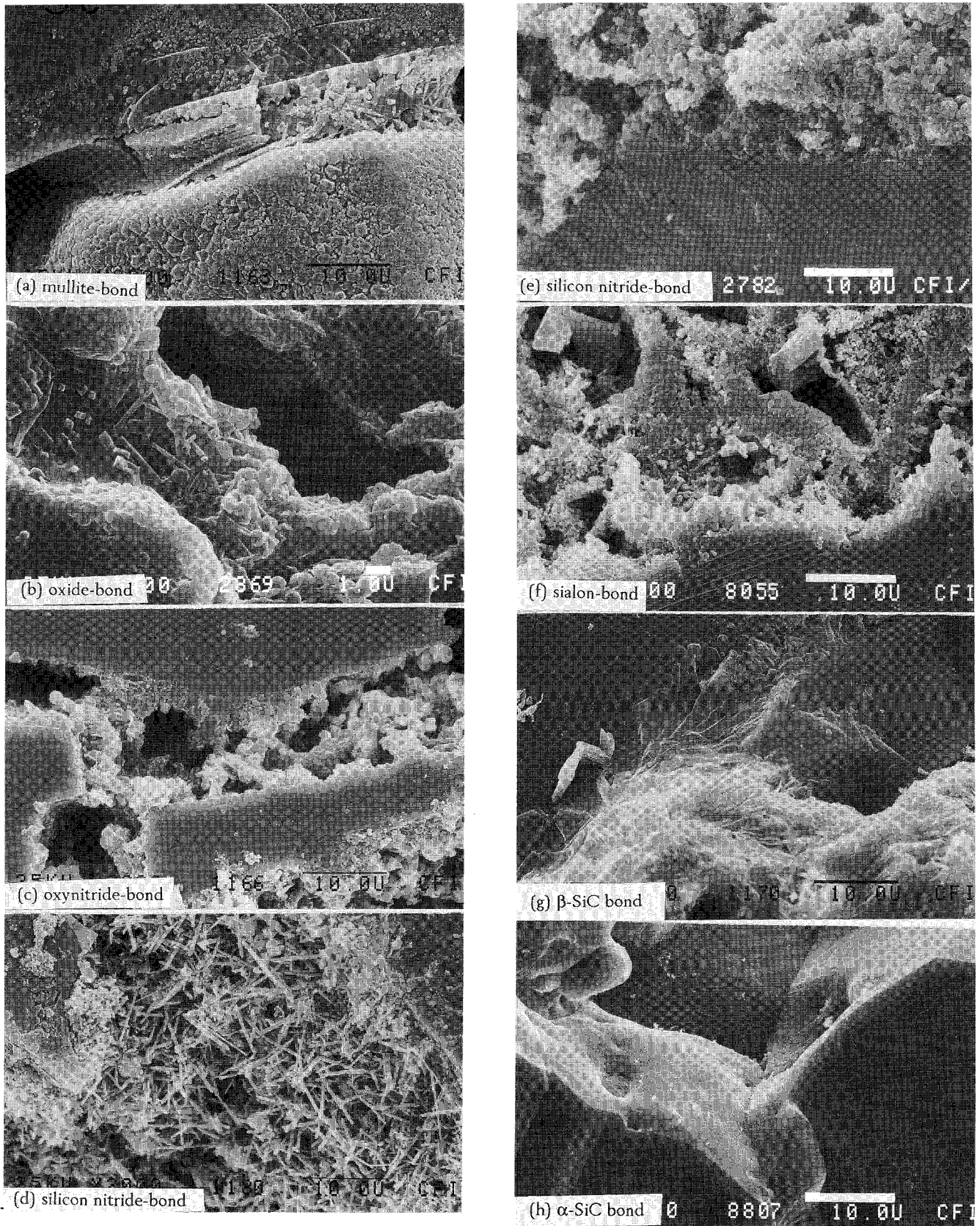


Figure 1. SEM micrographs showing the bonding phase between SiC grains.

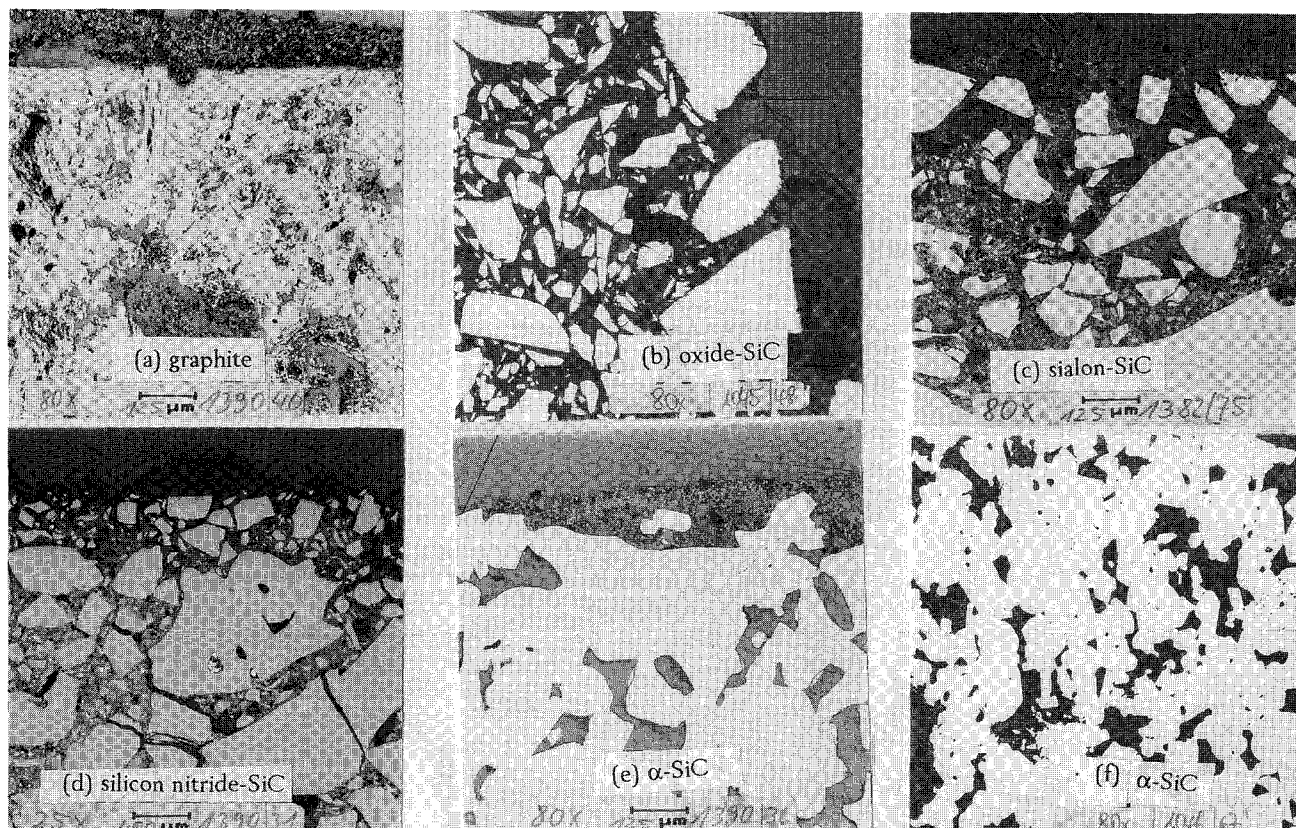


Figure 2. Optical micrographs showing cryolite corroded SiC refractories.

- The modulus of rupture of one of the Type 2 Silicon nitride-bonded SiC bricks was low, 29.3 MPa.
- The modulus of rupture of two sialon-bonded SiC bricks was higher than silicon nitride bonded SiC bricks.
- The HMOR of the oxide and mullite bonded-SiC bricks is significantly lower than nitride SiC bricks, average 28.1 ± 5 MPa.

HMOR of Corroded SiC

The HMOR of flux corroded and untreated SiC samples (140x20x15mm) was measured in 3-point bending tests. One group of bars was tested in their original condition, i.e., as supplied state. The HMOR results were compared with that measured for a second group of SiC samples which had been subjected to corrosion tests. The test had been originally derived for refractories evaluation in blast furnace applications and adapted to the corrosive situations of aluminum electrolysis conditions. In the test, SiC bars are embedded in a steel box in a mixture of coke, Na₂CO₃ and NaF formed in a weight ratio of 3:1:0.1. The box is covered by a steel lid with a double rim filled with SiC mortar to prevent atmospheric gas exchange during the test period. The box containing the SiC samples is then placed in an electric chamber furnace heated to 960°C and allowed to soak for 10 hours. After cooling the SiC bars are leached in hot water to take out the soluble components from the ceramic structure, (with pH control of the wash water), cleaned, if necessary, with a hand brush to remove adhering particles, dried and then tested for their residual HMOR. The results measured for the two groups of SiC bars under these conditions is described in the following table.

Table III Comparison of HMOR of Cryolite Corroded SiC Materials and Untreated SiC Materials

	HMOR at 1000°C		Change
	Original	Corroded	
Graphite	14	15	0
SiC oxide bond	32	*	*
SiC sialon bond	60	25	35
SiC Si ₃ N ₄ bond	44	20	24
SiC α-bond	75	44	31

* destroyed

The modulus of rupture for all cryolite corroded SiC refractories decreased by half (≈ 30 MPa) of their original value. The relative action shown for graphite gives an overly optimistic view in relation to reality. No oxidative and abrasive effects are included in this test; poorer results are anticipated for graphite under practical conditions found in reduction cells. Light microscopic investigations of materials in the corroded state show clearly in Figure 2 the difference in penetration and corrosive attack with the five various refractories including: graphite, silicon nitride bonded SiC, alpha bonded SiC, sialon bonded SiC and oxide bonded SiC. After the initial corrosion reactions, silica forms a protective layer on the carbide slowing the reactions (6).

Graphite. Little corrosive attack was found in most areas, however, quite a large number of pits and grooves were evident in the graphite due to the melt eroding the material.

Oxide-Bonded SiC (Alumina and Silica). The SiC samples were completely destroyed during the corrosion test; there is no recognizable surface contour of the sample.

Sialon-Bonded SiC. Some reaction is shown of the SiC material at its reaction surface with parts of the sialon bond being attacked, but with no really deep penetration; unusual needle-like reaction crystals protrude from the reaction front.

Silicon Nitride-Bonded SiC. The SiC material appears to be less infiltrated and attacked with a clear reaction line between slag and refractory.

α-Bonded SiC. The SiC material is near its original state; there is a little infiltration of the rather crude portions of alpha bonded SiC.

Oxidation Resistance

Oxygen attack may occur on the refractory sidewall lining, as practice and autopsy show, even at the comparative low temperatures found in the cathode lining of reduction cells. Intensive measurements on the oxidation behavior of various shaped and unshaped cathode lining materials, such as: mortars, carbonaceous ramming, carbon and graphite blocks and SiC bricks, proved the strong liability of the carbon-graphite group materials compared to SiC refractories.

There is evidence of a noticeable dependence for oxidation of the cathode lining material on:

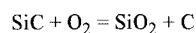
- a) total porosity,
- b) pore size distribution and,
- c) specific (internal) surface area measured by nitrogen adsorption surface area (BET-method).

This internal surface is the area attacked by aggressive gases and vapors, mainly destroying bond structures and negatively affecting mechanical properties of the refractories and changing their chemical and mineralogical compositions. With carbon and graphite materials, we find that these oxidative effects begin below 550°C, while with SiC bricks these attacks will not be noted until well above the 950-1000°C temperature range.

The loss of carbon block material due to oxidation in many reduction cells leads to:

- loss of contact between lining and the cathode steel shell-cradle system,
- buildup of thermal barriers,
- the heat flux towards the outside is interrupted,
- the hot face temperature will increase,
- melting of the frozen cryolite ledge at the hot face,
- and enhancement the corrosive reactions by new liquid-solid reactions.

There is also another difference between the two groups of cathode lining materials; the oxidation products of carbon based lining materials are gases, CO₂ and CO, while with SiC-refractories solid oxidation products are solids (i.e., cristobalite (SiO₂) from SiC and oxynitride, mullite, etc., from nitrides and sialon) which are left behind from the oxidation of SiC bricks.



The solid oxide-based products, however, are much more sensitive towards corrosive attack by cryolite or alkaline vapors than the virgin, unaffected refractories.

Due to the inherent oxidation resistance capabilities of different types of SiC bricks rather complicated laboratory tests have to be performed in addition to obtaining all of the other necessary basic refractory information. Then differentiation of oxidation of various types of SiC materials by means of rather detailed and sophisticated tests may be obtained, as synergetic surface area, mineral or chemical composition, bulk density, crystal size, etc., become noticeable.

The oxidation of four different silicon nitride bonded SiC refractories was evaluated in humid air for 100 hours at 1000°C and 1300°C. For comparative purposes, alpha-SiC refractory was also included. It can easily be seen that even with nearly identical chemical, as well as, mineralogical composition and total porosity, widespread differences in such important parameters as the oxidation rate may be found, as show in Figure 3.

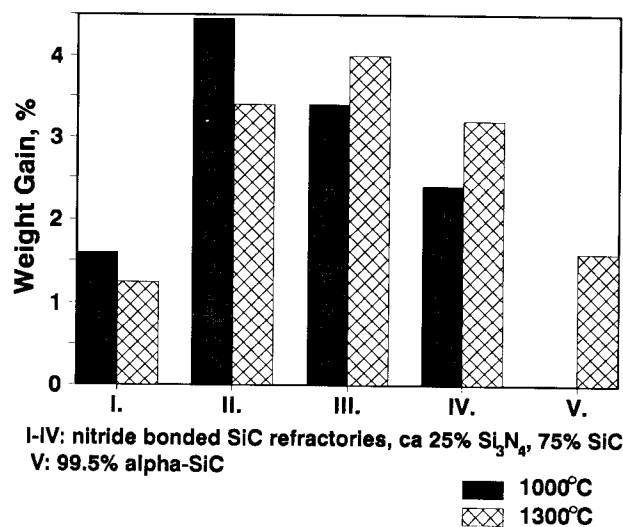


Figure 3: Oxidation of silicon nitride and α-SiC refractories in air for 100 hours.

The effect of porosity, pore size distribution, and specific surface area may clearly be seen in figure 4 in which nitride bonded SiC, recrystallized alpha-SiC and pore free dense SiC have been oxidized in a thermobalance at 1250°C and 1400°C. Three general effects may be seen from this test series: the influences of time, temperature and porosity or specific surface area.

- The absolute range of oxidation increases with increasing temperature.
- Nitride bonded SiC and recrystallized α-SiC are similar in porosity; the latter, however, having much coarser individual pores and much lower specific surface area
 - the initial oxidation (absolute value) of silicon nitride bonded SiC is much higher compared with α-SiC,
 - the oxidation rate begins to slow and approaches zero after a period 5-hours.

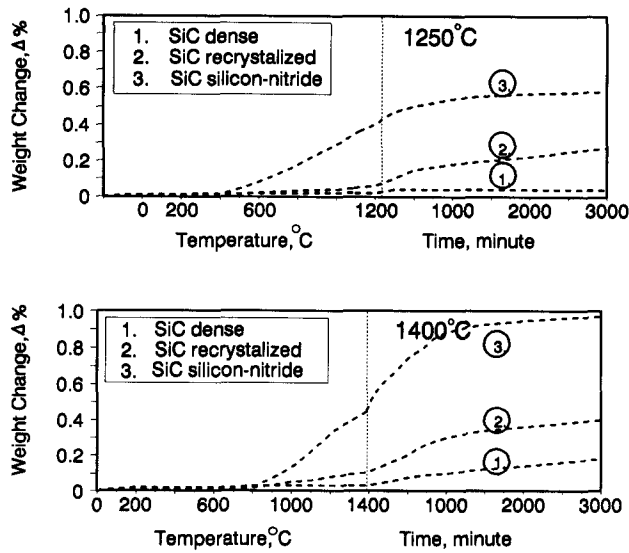


Figure 4: Oxidation of silicon nitride and α -SiC refractories at 1250 and 1400°C.

The oxidation resistance behavior of SiC and Si_3N_4 is due to the formation of protective oxidation films rather than to the inherent oxidation resistance of the underlying materials. The silicon in the materials react with oxygen to form a layer of SiO_2 , which limits the access of oxygen to the carbide or nitride. Silicon nitride-SiC can be described as having a "self-sealing-effect," as shown in SEM micrographs in Figures 5-a and 5-b. A layer of silicon oxynitride is formed between the layer of SiO_2 and Si_3N_4 providing superior oxidation resistance (6).

By comparison, α -SiC has a smaller total surface area, but has large pores as shown in 5-c which remain open for oxidation attack at a lower level, but at a nearly constant high rate. After the long

furnace test runs, 1-2 micron thick layers of cristobalite covers the SiC crystals located deep inside the ceramic component's structure. Grain boundary layer diffusion still takes place in the cristobalite layer, thus, continuing the detrimental attack by oxygen on the SiC crystals.

Silicon nitride-bonded SiC. Silicon nitride surface is completely covered by a layer of SiO_2 minerals as evident by appearance of the "warty" cristobalite layer on SiC grains.

SiO_2 bonded SiC. The formation of tridymite needles within cristobalite crystals may have resulted from the presence of small amount of alkali contamination. Oxygen-corroded SiC surface is shown at the right side.

α -SiC bonded SiC. Structure exhibits long term oxidation layers, i.e., cristobalite crystals. Open pores in the SiO_2 layer can be noted for oxygen penetration and continued oxidation attack at high temperatures.

Abrasion Resistance

Magnetically caused metal-bath movements may be responsible for abrasive attack along the hot face of the side lining. The formation of a steady state situation with respect to saturation/dissolution and precipitation between refractory and bath will not occur. Corroded surfaces will more easily be abraded. The formation of a frozen ledge along-side the hot face of the SiC is an absolute necessity. Solid-solid ledge-SiC reactions are much slower than liquid-solid bath-SiC reactions will be.

The abrasion resistance of various SiC based bricks and some fireclay bricks was measured at room temperature using a silicon carbide abrading media according to ASTM Method C 704. Results are given in Table IV. The test measures the volume of refractory material abraded from a flat surface at a right angle to a nozzle from which SiC grit is blasted by air at 448 kPa (65 psi). The differences in the measured abrasion values for the silicon carbide bricks and fireclay bricks provide a relative comparison of the bonding phase

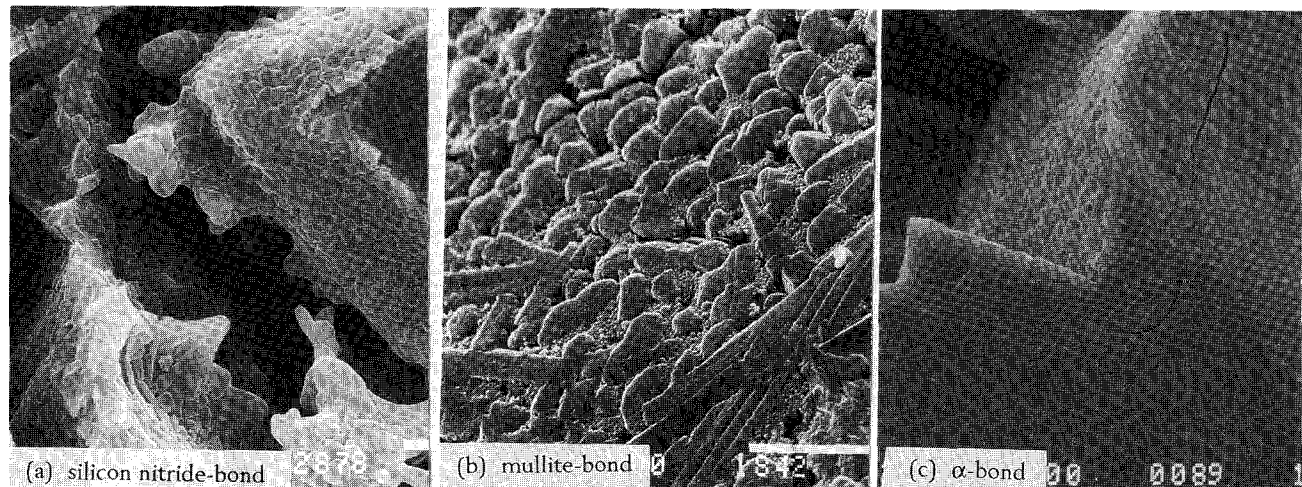


Figure 5. SEM micrographs showing the oxidation of SiC refractories.

properties. Abrasion resistance of these refractory materials provides an indication of their suitability for service in abrasive or erosive environments.

The abrasion resistance values measured for various SiC based bricks and fireclay bricks are shown in Table IV. These values demonstrate the following trends when correlated with the bricks chemical composition and physical properties:

- The abrasion resistance of all types of SiC bricks was significantly better than for fireclay bricks, 2-5 cm³ compared with 14 cm³.
- The abrasion resistance of silicon nitride- and sialon-bonded SiC bricks was superior to the oxide bonded SiC bricks
- The abrasion resistance of the sialon-bonded SiC brick was about the same as that measured for the Type 1 silicon nitride-bonded SiC bricks, 2.37 versus 2.47 cm³ average.

Table IV Abrasion Resistance of Silicon Carbide Bricks

SiC Brick	Average	Std. Dev.
Si₃N₄-SiC Type 1		
A	2.58	0.19
B	1.99	0.16
C	2.67	0.11
D		
E	1.55	1.18
F		
Average	2.37	
Si₃N₄-SiC Type 2		
G	2.19	0.11
H	3.64	0.49
Average	2.29	0
Sialon-SiC		
I	1.83	0.10
J	3.04	0.20
K	1.90	0.12
Average	2.26	
Oxide-SiC		
L	5.15	0.45
M	5.69	0.51
N	-	-
Average	5.42	
Oxynitride-SiC		
O	-	-
Fireclay Bricks		
P	8.6	0.6
Q	10.3	0.8
R	24.3	1.4
Average	14.4	

Cryolite Resistance

SiC cathode lining materials have to resist chemical attack by molten liquids, (cryolitic bath, aluminum metal) on their surface and in case of infiltration also inside the brick. Aggressive vapors of

alkaline fluorides may penetrate the refractories pore structure and chemically attack the material.

Our test results show the differences in sensitivity against chemical attack of either molten bath and alkaline vapors depending on the chemical composition of the SiC bricks. In some way, it seems logical that SiC bricks having constituents such as alumina or silica in their structure weight be attacked by the cryolite, the same reactions taking place in the bricks as in the electrolysis process itself. This is also valid for the case of oxidation and its consequences (see below).

A relative corrosion resistance comparison was obtained for the SiC bricks by using an extended cryolite cup test. In these tests, 40 grams of high ratio cryolite was placed into a 3.81 cm diameter hole drilled into the top surface (11.43 cm x 11.43 cm x 6.35 cm) of SiC brick samples. The SiC test samples were then heated in a furnace at 950°C for a period of 144 hours. After cooling to room temperature, the test samples were cut in half to reveal the cryolite-SiC brick reaction zone. The width and depth of the cryolite-SiC reacted zone on both halves of the SiC bricks was accurately measured using a digital vernier caliper; the overall volume loss was calculated and the percent volume change in the test sample was determined for each SiC brick.

Rating	Volume Loss %
1	0 to 0.9
2	1.0 to 1.9
3	2.0 to 2.9
4	3.0 to 3.9
5	4.0 to 4.9
6	5.0 to 5.9
7	6.0 to 6.9

The cryolite resistance values of various SiC based bricks are given in Table V. The rating index above was used to provide a direct comparison of the cryolite resistance for SiC based bricks.

The above trends are indicated for cryolite resistance for the various commercially available silicon carbide bricks.

- Silicon carbide bricks found to have the best cryolite resistance as indicated by the smallest volume loss and low rating included,
 - silicon nitride-bonded SiC bricks A, B, D, F and G
 - oxynitride-bonded SiC brick O
- Silicon carbide bricks found to have the poorest cryolite resistance, as indicated by the highest volume losses were:
 - oxide bonded SiC bricks L and M
- The silicate-bonded (oxide) SiC brick had the highest abrasion loss and the highest degradation by cryolite in tests.

Cryolite-SiC Wetting Experiment

To get a better understanding about the individual influence of the SiC bond phase materials with cryolite, the wetting of two SiC samples, recrystallized SiC (α -SiC) and reaction bonded silicon nitride (Si₃N₄), with cryolite was investigated using a high temperature microscope. Recrystallized SiC is formed by blending various sizes of SiC grains. The finer SiC particles sublime and are transported to the surface where they condense and cause the large coarse grains to grow together (recrystallization).

Table V Cryolite Resistance of SiC Bricks

SiC Brick	Reacted Volume cm ³	Volume Loss %	Rating
Si₃N₄-SiC Type 1			
A	2.719	0.3	1
B	2.728	0.3	1
C	2.787	2.5	3
D	2.769	1.8	2
E	2.807	3.2	4
F	2.773	2.0	2
Average	2.764	1.6	2
Si₃N₄-SiC Type 2			
G	2.736	0.6	1
H	2.833	4.2	5
Average	2.785	2.4	3
Sialon-SiC			
I	2.833	4.2	5
J	1.565	2.2	3
K	2.831	4.1	5
Average	2.410	3.5	4
Oxide-SiC			
L	2.862	5.2	6
M	2.891	6.3	6
N	2.796	2.8	3
Average	2.850	4.8	5
Oxynitride-SiC			
O	2.744	0.9	1

Pressed cryolite pellets (3 mm dia. x 3 mm height) were placed on top of cylindrical (10 x 10 x 3 mm) samples. The samples were then heated in a high temperature microscope at a rate of 5°C/min. up to a maximum temperature of 960°C. Shadow photographs were taken of the two samples and cryolite at 950 and 960°C as shown in figure 6. From the pictures, it can be seen that a much higher degree of wetting of cryolite occurred with the reaction bonded Si₃N₄ (a & b) than with pure α-SiC (c & d). It is our opinion that the wetting was also accompanied by an infiltration process by cryolite into the Si₃N₄ due to its very fine pore structure and larger capillary effect. Less wetting was found to occur with α-SiC which has a more coarse pore structure.

Conclusions

The hot modulus of rupture, abrasion resistance, oxidation resistance and cryolite resistance were determined for SiC bricks and the results were correlated with the chemical and mineralogical composition of the bricks. In these tests, the application of the silicon nitride-bonded SiC bricks as the principal choice for sidewall lining in reduction cell cathodes was confirmed as they demonstrated the best overall performance, followed closely by sialon-bonded SiC bricks. Oxide-bonded SiC bricks are unsuited for the environment found in aluminum reduction cells.

- Hot Modulus of Rupture of SiC Bricks:
 - Silicon nitride and sialon-SiC bricks have good hot strength, 40-50 MPa
 - By comparison, oxide-SiC bricks have lower hot strength, 17-56 MPa.
 - HMOR of cryolite corroded SiC refractories decrease by half, ≈ 30 MPa.
- Abrasion Resistance of SiC Bricks:
 - SiC bricks have excellent abrasion resistance in the order, [Sialon-SiC ≈ Si₃N₄-SiC >> Oxide-SiC >>>> Fireclay bricks]

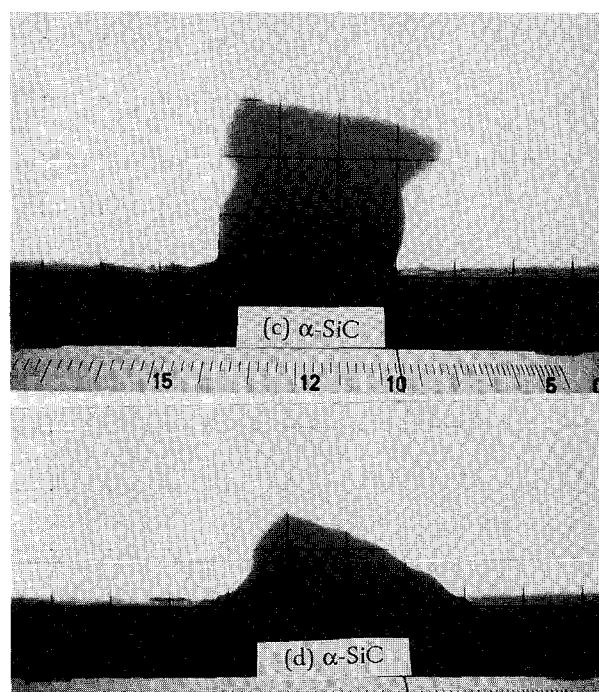
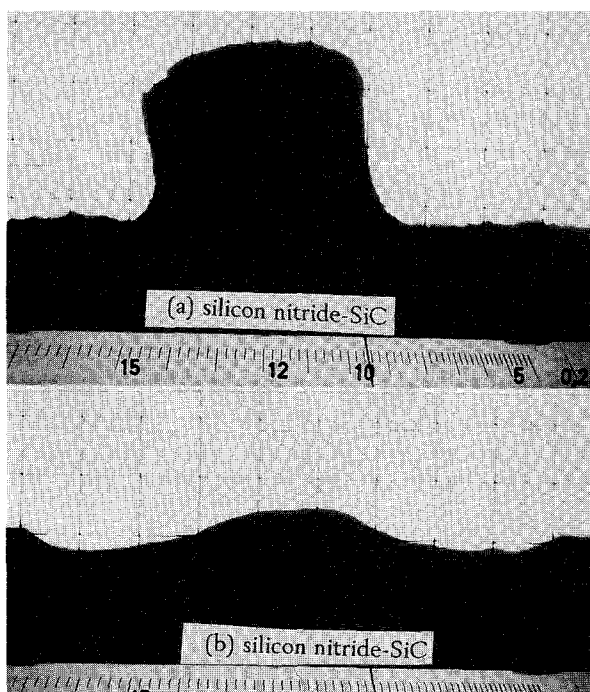


Figure 6. Optical micrographs showing the wetting of SiC refractories by cryolite.

3. Oxidation Resistance of SiC Bricks:
 - Oxidation of SiC bricks results in solid products, such as cristobalite (SiO_2), oxynitride (Si_2ON_2), mullite ($3\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$), etc.
 - Oxidation of Si_3N_4 -SiC is initially higher than α -SiC, but then decreases significantly due to the formation of oxynitride layer, while the oxidation of α -SiC continues unabated due to a larger porous pore diameter.
4. Cryolite Resistance of SiC Bricks:
 - Si_3N_4 and sialon bricks exhibit good resistance with molten cryolite,
[Si_3N_4 -SiC > Sialon-SiC > Oxide-SiC]
 - Si_3N_4 -SiC is wetted by cryolite more than α -SiC

References

1. A. F. Fickel, J. S. Kramss, and P. W. Temme, "Silicon Carbide Refractories for Aluminum Reduction Cell Cathodes," *Light Metals*, 1983 (Warrendale, PA: TMS, 1993), 183-188.
2. A. F. Fickel, H. Friedli, J. S. Kramss and P. W. Temme, "Mutual Effects of Board-Lining Metal and Melt in Aluminum-Electrolysis," *Light Metals*, 1989 (Warrendale, PA: TMS, 1989), 191-194.

3. A. F. Fickel, B. Rolofs, and P. W. Temme, "On the Oxidation Behavior of Some Pot Lining Refractories," *Light Metals*, 1991 (Warrendale, PA: TMS, 1991), 405-412.
4. S. K. Reddy and J. Mukerji, "Silicon Nitride-Silicon Carbide Refractories by Reaction Bonding," *J. Am. Ceram. Soc.*, 5 (1991), 1139.
5. A. T. Tabereaux, "Silicon Carbide Bricks in Aluminum Reduction Cell Cathodes," CIM Conference: Light Metals Processing and Applications, (1993), 149-164.
6. N. S. Jacobson, "Kinetics and Mechanism of Corrosion of SiC by Molten Salts," *J. Am. Ceram. Soc.*, 69 (1986), 74-82.
7. P. Hsu, S. Ip, C. Park and M. J. McNallan, Oxidation of Silicon, Silicon Carbide and Silicon Nitride in Gases Containing Oxygen and Chlorine," *J. Am. Ceram. Soc.*, 76 (1993), 1621-1623.