# Experience from Laboratory Testing of Commercial Silicon Bonded Silicon Carbide Materials. Typical Properties and Analyses

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**Abstract**

Silicon nitride bonded silicon carbide is currently the most common type of sidelining material in aluminium electrolysis cells. The material has replaced carbon due to better chemical resistance, better oxidation resistance, and better thermal performance, which opens for increased productivity. Today, many producers offer carbide based sidelining materials, and the users ask for quality evaluations. During the last two decades, SINTEF and partly NTNU have developed test methods and analyses for quality evaluation. The studies have been financed through national research programs as well as by testing of materials from the different suppliers. The work has contributed to improved characterisation and descriptions of the most important material parameters, as well as better understanding of the industrial performance. The present paper describes our findings regarding typical physical and chemical parameters, based on analyses and tests of several hundred samples from suppliers worldwide. The results from some autopsies of industrial cells for studying the degradation mechanisms are included. Based on our findings and experience, a set of up-dated recommendations and useful specifications for suppliers as well as for users has been worked out.

**Keywords:** Aluminium electrolysis cell, sidelining materials, silicon nitride bonded SiC, test and analysis, specifications

## 1. Introduction

SINTEF started the research work regarding Nitride bonded sidelining materials in 1995 financed by the Norwegian Aluminium industry (that time Hydro Al, Elkem Al and Søral) and the Research Council of Norway (RCN). The aim was to establish relevant analysis and test methods to be able to check, and qualify, the commercial materials at the market. The main challenge was to develop a realistic test method in laboratory scale for measuring the chemical resistance to simulate the chemical conditions found in industrial cells. The latest 20 years we also developed analysis of other important parameters for quality checks; physical and mechanical properties, thermal properties and mineral phase analysis. An overview over typical results measured will be presented in this paper.

## 2. Silicon Nitride Bonded SiC

The use of Silicon Nitride bonded SiC refractories as sidelining is today the state of the art in modern high amperage cells. It exists many producers and hence also quality differences on the global market. For the users, it is important to have a stable and reliable quality. It is always also a question what kind of material properties make a good quality and therefore the intention with this paper is to present our main findings based on test work from many suppliers the latest 20 years. Our work and research on this field have regularly been published [1 - 6].

## 2.1. Production Route

A typical production route for Nitride bonded SiC is shown in Figure 1. As raw materials, SiC grains and Si particles are used together with an organic binder. This is pressed to a green block with desired dimension. The green blocks are going through a drying step before entering the nitridation step in furnaces purged with Nitrogen gas to establish the binder phase $Si_3N_4$. The finished products then consist of SiC bonded by a phase of $Si_3N_4$.

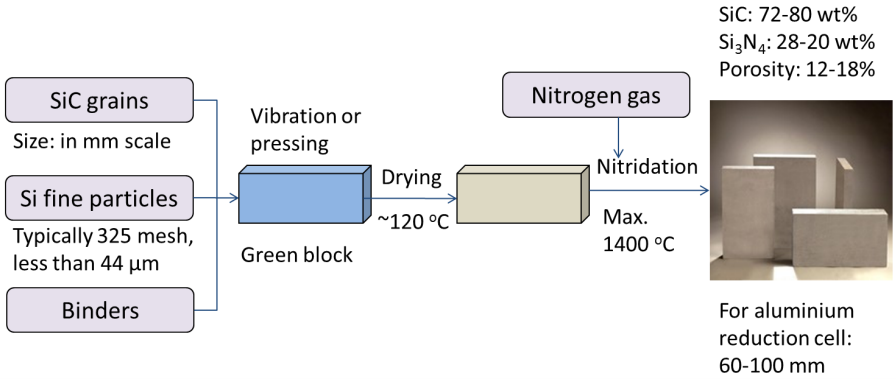


**Figure 1. Schematic production route of Nitride bonded SiC.**

A Si3N4 bonded SiC brick often consists of 72-80 wt% SiC and 20-28 wt% Si3N4 phases. Figure 2 shows the typical microstructure of the composite material, where coarse SiC grains dispersed in fine nitride binder phase.

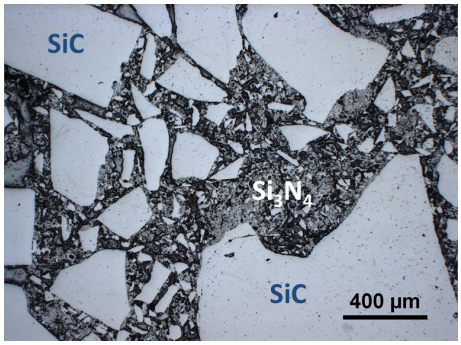


**Figure 2. Optical image of a polished Si3N4 bonded SiC brick surface.**

The $Si_3N_4$ binder phase is formed during the nitridation process and often consists of both an α- and a β- phase. The morphology of α- and β-$Si_3N_4$ phases is shown in Figure 3. The β-$Si_3N_4$ phase is the thermodynamic stable phase and favored by high temperature and presence of liquid Si or FeSi phase, while α-$Si_3N_4$ is formed by gaseous phase reactions and often stabilized by oxygen impurities. The nitridation temperature is not sufficient high to fulfill the complete α- to β-Si3N4 phase transition, so a mixture of α- and β-$Si_3N_4$ is common in this type of composite. The ratio between the two nitride phases varies and is depending on the fabrication conditions including but not limited to particle size of Si powders, temperature, atmosphere composition, impurities in the starting materials and additives [7, 8]. By tuning the fabrication conditions, the α- to β- phase ratio could be to some degree modified.

It should also be mentioned that laboratory tests will give in-put to improvements and more understanding of all parameters involved to optimize the required properties. However, it will always be some uncertainty in analysis and tests also in laboratories with respect to reproducibility and test methods itself.

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