Laboratory Evaluations of Ceramic Sidelining Materials

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Abstract

Silicon-nitride bonded SiC sidelining materials are today the state of the art in modern prebake aluminium cells. SINTEF started in early1990's procedures for performing relevant test methods and quality evaluations of the different commercial materials available on the market. The test methods developed include both chemical and physical properties. Since then a high number of materials have been evaluated and tested on regular basis. New tests and analysis have been included in the test program to investigate and to understand the degradation mechanism in more detail. Lately we have trials with using computed tomography (CT) as a tool to investigate microstructures, pores and cracks inside the materials. A special test method for chemical resistance is developed and used to measure the degradation in the same chemical conditions as in industrial cells. In this special test cell some materials have also been tested in oxygen atmosphere to investigate the degradation of ceramic materials, for instance with using inert anode technology. In the paper overall test results will be shown and examples on good and bad quality materials will be given.

Keywords: Aluminium electrolysis cells, sidelining materials, tests, analysis, degradation.

1. Background

When the aluminium industry started to increase the amperage to produce more metal and hence increase the productivity, new cell designs were needed. One important part of the new cell designs was reduced sidelining thickness to be able to use anodes with larger dimensions. Therefore, the traditional carbon-based sidelining materials were replaced by ceramic sidelining materials based on SiC. It was found that the best lining with acceptable cost was silicon nitride bonded SiC.

SINTEF started in the middle of the 1990's together with the Norwegian aluminium industry to investigate the performance of SiC, and also to establish tests and analyses in laboratory scale to be able to rank the different materials on the market. The test program is divided into physical and chemical properties. The main challenge was to develop a chemical resistance test with chemical conditions as close as possible to those prevailing in industrial cells. The test set-up was established in 1997. From that year on, we have performed several tests of different commercial materials and in this paper, we will summarize the main findings. The method was published for the first time in 1999 [1] and results from our work have been published regularly [2 - 6].

We do know from industrial autopsies that degradation occurs during the lifetime of the cells. The degradation mechanism and some properties of used sidelining materials are reported earlier [7 - 9]. In some cases, severe degradation has been observed at the level above the bath, as shown in Figure 1 and Figure 2, also after short time of operation. The reason is bad quality sidelining materials as explained later in the paper.

Figure 1. Example on severe degradation due to bad quality sidelining material. Plant A.

Figure 2. Example of severe degradation due to bad quality sidelining material. Plant B.

2. Production Routes of Nitride Bonded SiC

A typical production route for nitride bonded silicon carbide is shown in Figure 3. The raw materials are silicon carbide grains and elementary silicon mixed together with an organic binder, which is pressed to a green block with desired dimensions. 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 (silicon nitride). The finished product then consists of SiC (typically 72 - 80 wt%) bonded by a phase of Si_3N_4 (20 - 28 wt%). The dimensions of the blocks vary according to the type of cell and cell design. Normally, the thickness is from 60 to 100 mm.

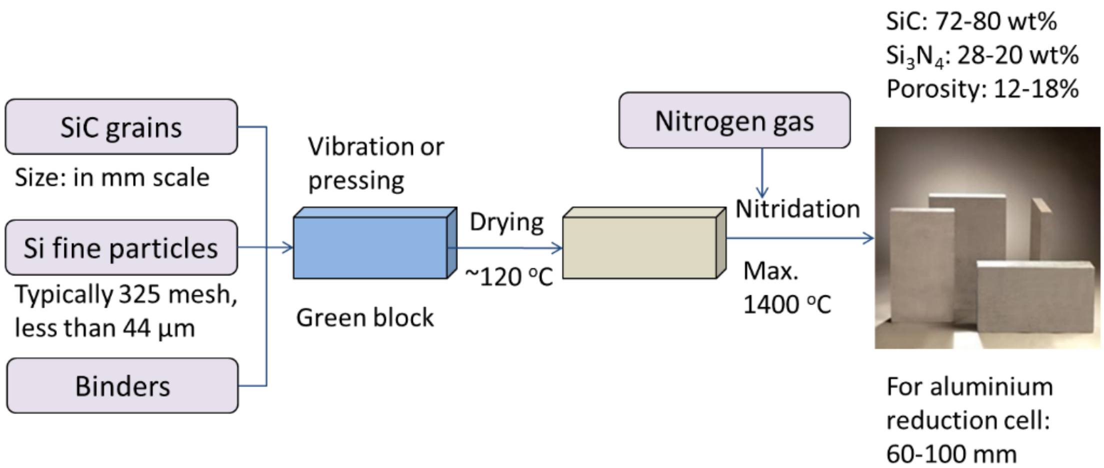

Figure 3. Schematic production route of nitride bonded SiC.

Degradation will occur mainly in periods with unstable sideledge. Hence, the best protection will be stable operation conditions and a stable sideledge that protect the materials.

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