

The Effect of SiO₂ and Na₂O Content on the Sintering Behavior of Calcined Specialty Aluminas for the Ceramics Industry

Abstract: The ceramics industry encompasses a wide variety of applications, including advanced ceramics, technical ceramics, honeycomb ceramics, spark plugs, high voltage insulators, wear parts and many more. Calcined alumina is a commonly used raw material in all of these ceramic applications due to its robust mechanical, electrical, thermal and chemical properties. These properties are highly dependent on the physical and chemical characteristics of the alumina itself. Therefore, the focus of this research was to evaluate the role of chemical characteristics on the physical and mechanical properties of four commercially available calcined reactive aluminas. Specifically, this work aims to quantify the effect of the trace impurities SiO₂ and Na₂O, on alumina shrinkage, shrinkage rate, sintered density and flexural strength.

Keywords: calcined alumina, reactive alumina, specialty alumina, ceramics, impurities, sintering

Calcined aluminas for the ceramic industry

Alumina begins as bauxite ore, which is mined and transported to refineries where the purified mineral gibbsite is extracted via the Bayer process [1]. While the vast majority (> 90 %) of the alumina hydrate is calcined for eventual use in the production of aluminum metal, a smaller percentage is used in non-metallurgical applications, such as the production of specialty aluminas. Calcined alumina is one type of specialty alumina, with distinguishing characteristics of predominantly α -phase content, and carefully controlled primary crystal size, morphology, surface area and chemistry. The physical and chemical properties of a given alumina, such as particle size distribution, surface area, green density and trace impurity levels, often dictate performance in a final application. Calcined alumina producers can control physical properties more directly than chemical impurities by altering certain processing conditions, such as temperature and time. Generally, the maximum chemical purity for aluminas processed with Bayer feedstock is less than 99,9 % on an oxide basis. Certainly, production of higher purity alumina products is possible, even to levels greater than 99,999 %, but only through wet chemical processing or the use of high purity aluminum feedstocks [2]. Since most of the impurities are chemically bound in the Bayer crystal, they are not readily available for removal by conventional methods, either prior to or

during the calcination process. More comprehensive summaries of alumina production can be found in the literature and won't be duplicated here [1–3].

Controlling impurities is one of the main challenges for a specialty alumina producer. The most common impurities that are available for control during processing are Na₂O and SiO₂. Though soda control typically refers to a removal process, overall impurity control in specialty alumina processing doesn't explicitly imply removal. Some impurities need to be controlled because of the potential for addition during processing. An example of impurity addition during processing is the increase in SiO₂ content during grinding operations. The content of these impurities, whether removed or added during processing, can impact alumina performance in an end-use ceramic application.

Considering the various calcined and reactive alumina products available in the market, and each with varying impurity levels, ceramic manufacturers are interested in understanding the effects of specific impurities on the performance of a given alumina. Some common application-based reasons for this are:

- Overall purity and/or density requirements for the end-use product
- Need to improve or in some way alter microstructure
- Need to improve or change the physical, mechanical, dielectric or high temperature properties
- Need to improve processing controls, such as shrinkage tolerance

- End-use product is subjected to harsh chemical environments that tend to etch specific impurities.

The direct impact of small impurity differences on performance, and moreover variability, is difficult to quantify. Even with repetitious laboratory testing on multiple samples, conclusions are often still constrained by experimental variance. This can be especially true for ground reactive aluminas.

While some research has focused on understanding the effects of various physical parameters on alumina properties, [4, 5] much has been dedicated to understanding the impact of chemical impurities on sintering kinetics, grain growth and microstructure development. Most of these chemical studies have evaluated high purity systems using specific addition levels of selected impurities, such as SiO₂ [6], TiO₂ [7, 8], Fe₂O₃ [9], MgO [10, 11], and various combinations [12, 13].

Fundamental research using high purity systems does provide a plat-

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