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Review article

Recent advances in silica-alumina refractory: A review

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ABSTRACT

In this article, the elaboration and the characterization of silica-alumina refractory have been reviewed. Refractory oxides encompass a broad range of unary, binary, and ternary ceramic compounds that can be used in structural, insulating, and other applications. This paper provides a historical perspective on the elaboration and the use of silica-alumina refractory, reviews applications for refractory oxides, describes typical processing routes, overviews fundamental structure–property relations, and summarizes the properties of these materials.

Contents

1. Introduction

Refractory materials can be divided into several classes based on: chemical composition (acid, basic and special), method of implementation (shaped and unshaped), method of manufacture (fused and sintered), and porosity content (porous and dense). These materials are supposed to be resistant to heat and are exposed to different degrees of mechanical stress and strain, corrosion from liquids and gases, and mechanical abrasion at high temperature [1–8]. Different types of refractory materials can be synthesized according to the nature of the raw materials and the process used. The application fields of refractory are multiple and depend on the properties of each type. In fact, the performance of a refractory (good resistance to heat and thermal shock) is directly related to texture and richness of the mineral refractories, such as mullite, corundum, periclase, doloma, spinel and alumina [9,10].

Refractories are mostly used in basic metal industries. In the steel-making process by the basic oxygen furnace (BOF), the molten iron from the blast furnace is purified from the impurities including C, S, P, Mn, etc., by blowing oxygen [11]. The major characteristic requirement of these refractories is resistance to molten slag

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(basic) and to the high temperature generated in the process. In the aluminum industry, the refractory property requirements are quite different from that of steel making. Although the temperature of aluminum refining and alloying process is much lower than for steel, it has the unique problem of penetration in the refractories. Hence, the refractory should be designed so that it has a nonwetting characteristic to molten aluminum [2]. In hydrocarbon industries, the refractories suffer from a high rate of abrasion due to the flow of high-velocity particles at a continuous rate. Hence, the refractory properties should be such that it should be capable of resisting the abrasion [11]. In the glass-making process, the refractories are in constant contact with the molten glass, and this poses different kinds of requirements for the refractory. Since glass in the molten state is quite fluid and tends to go through the refractory pores, the most needed characteristic should be nonporous refractories, and hence fused refractories are used in molten glass contact areas [1,6,8].

The silica-alumina refractories are materials which are increasingly demanded and whose manufacturing involves necessarily the synthesis of mullite. They have the attributes of being relatively inexpensive compared to other bricks (special carbon refractories, zircon, zirconia, fused-cast refractory). In addition, silica-alumina refractory can be used in several applications: coating of laboratory furnaces, refractory supports, thermal insulating, industrial ceramics and pottery, chemical producers, pulp and paper, food production-related industries and anything involving heat and/or hot products. This review is intended to provide a large overview of the current status of this type of refractories and to provide a summary of recent information concerning the elaboration and the characterization of mullite refractories.

2. Materials

Aluminosilicate refractories are manufactured using refractory clays, sillimanite minerals, bauxite, and mixtures of alumina and silica sand. They will refer, somewhat arbitrarily, to common crystalline compounds with melting temperatures of at least 1500 °C [2]. The major categories of traditional refractories are fire clays, high alumina, and silica. The choice of material for traditional refractory applications, as with advanced material applications, was and is based on balancing cost and performance lifetime. The ultimate use temperatures and the applications for some common refractories are summarized in Table 1 [12].

The fireclay subgroup is that having alumina content of between 25% and 45%. Because of their ease of fabrication, resistance to chemical attack, and low cost, fireclay bricks are still widely used as refractory materials. Kaolin clay, basic raw materials for the elaboration of silica-alumina refractory, is resulting from hydrothermal alteration of alkali granite. This alteration caused the kaolinization of alkali-feldspar of the granitic rock and gives an aluminous friable material (Fig. 1), rich in kaolin clay with an appreciable quantity of quartz, flakes of muscovite, and chloritized biotite. Chemically, this clay is mainly composed of alumina (29%) and silica (57%) [109].

Mullite refractory can also be produced from sillimanite minerals (Al_2SiO_5). They are the three anhydrous aluminosilicates: andalusite, kyanite, and sillimanite. Their ideal composition is 62.92 wt% alumina and 37.08 wt% silica [12]. However, in natural states involving significant impurities, the alumina content is usually less than 60 wt% (57.06% for Moroccan andalusite [106]). The andalusites are in the form of pink strips and whose size can reach up to 7 cm in length (Fig. 2). As the sillimanite minerals are geologically formed at high pressures (indicator mineral of metamorphism), they decompose when heated to elevated

Fig. 1. Career exploitation of kaolin clay of Oulmes (Moroccan Central Massif).

Fig. 2. Macroscopic sample of andalusite crystals in the region of Sidi-Bou-Othman (Morocco).

Table 1
Compositions, ultimate use temperatures, and applications for some common silica-alumina refractory materials from [12].

Class	Material	Phases	Used temp. (°C)	Applications
Fire clay	Low heat duty	Mullite, glass, quartz	Up to 1500	Kiln linings
	High heat duty	Mullite, glass		Crucibles
High alumina	Kyanite	α-Al_2O_3, mullite, glass	Up to 1800	Metal handling
				Lab ware
Silica	Silica	Tridymite cristobalite	1650	Glass tanks crowns