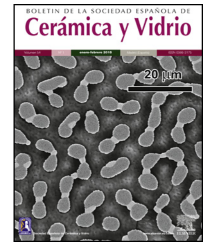
BOLETÍN DE LA SOCIEDAD ESPAÑOLA DE CERÁMICA Y VIDRIO xxx (2017) xxx–xxx

ELSEVIER

BOLETIN DE LA SOCIEDAD ESPAÑOLA DE
Cerámica y Vidrio
www.elsevier.es/bsecv



Q1 Review

Preparation and characterization of clay bonded high strength silica refractory by utilizing agriculture waste

Q2 *Aman Bhardwaj, S.K.S. Hossain, Manas R. Majhi* *

Q3 *Department of Ceramic Engineering, Indian Institute of Technology (BHU), Varanasi, India*

ARTICLE INFO

Article history:
Received 8 January 2017
Accepted 4 April 2017
Available online xxx

Keywords:
Rice husk ash
Amorphous silica
SiO_2
Refractory grog
Waste utilization

ABSTRACT

Clay bonded silica refractory was prepared by utilizing agriculture waste called rice husk ash (RHA) and refractory grog. Various samples were prepared with different compositions based upon partial replacement of quartz by RHA. Rectangular samples were prepared by following semi dry process prior to pressing in a uniaxial hydraulic press and sintering at a temperature of 1200 °C in air atmosphere. Various physical, mechanical and thermal characterizations were done like X-ray diffraction (XRD), scanning electron microscope (SEM), apparent porosity (AP), bulk density (BD), cold crushing strength (CCS), refractoriness and thermal conductivity measurement. The sample utilizing 30% of RHA was considered most optimum composition which produced cold crushing strength of 38 MPa and thermal conductivity of 2.08 W/m K at 800 °C with a considerable good refractoriness. Enhancement in the mechanical as well as thermal properties may be considered as attributed to the amorphous silica which has reacted more easily and efficiently with other material surrounding giving rise to the densification and produced stable crystalline phase to the refractory material. These promising characteristics suggests that the RHA may lead to be used as a potential material for the preparation of clay bonded high strength silica refractories.

Preparación y caracterización de sílice refractaria de alta resistencia unida a arcilla utilizando residuos agrícolas

Palabras clave:
Ceniza de cascarilla de arroz
Sílice amorfa
SiO_2
Grog refractario
Utilización de residuos

RESUMEN

Se preparó sílice refractaria unida a arcilla con residuos agrícolas conocidos como ceniza de cascarilla de arroz (*rice husk ash* [RHA]) y grog refractario. Se prepararon varias muestras con diferentes composiciones basadas en la sustitución parcial de cuarzo por RHA. Las muestras rectangulares se prepararon siguiendo un proceso semiseco antes de prensarlas en una prensa hidráulica uniaxial y sinterizarlas a una temperatura de 1.200 °C en atmósfera de aire. Se realizaron diversas caracterizaciones físicas, mecánicas y térmicas, como la

* *Corresponding author.*
E-mail address: mrmajhi.cer@iitbhu.ac.in (M.R. Majhi).

http://dx.doi.org/10.1016/j.bsecv.2017.04.002
0366-3175/

difracción de rayos X, el microscopio electrónico de barrido, la porosidad aparente, la densidad aparente, la resistencia al aplastamiento en frío, la refractariedad y la conductividad térmica. La muestra que utiliza el 30% de RHA se consideró la composición más óptima que produjo una resistencia al aplastamiento en frío de 38 MPa y una conductividad térmica de 2,08 W/m-K a 800 °C con una refractariedad considerablemente buena. La mejora tanto de las propiedades mecánicas como de las térmicas puede atribuirse a la sílice amorfa que reaccionó más fácil y eficazmente a otro material circundante, lo que produjo la densificación y una fase cristalina estable al material refractario. Estas características prometedoras sugieren que la RHA puede justificar que se use como material potencial en la preparación de sílices refractarias de alta resistencia unidas a arcilla.

Introduction

Silica refractories are generally known as refractory materials consisting more than 93% SiO_2 [1,2]. Silicon dioxide (SiO_2) is most commonly found in nature as quartz which is also considered to be the most conventional source of silica to be used for refractory manufacturing [3]. Silica refractories are typically produced in the form of shaped products (bricks) as well as in bulk powder (castables). Silica refractory bricks possess excellent thermal shock resistance, particularly in certain temperature range. Regardless the reduction in their use in the recent decades; silica refractories are still successful, beneficial or exceptional material for some of the special applications such as glass tank furnace roof constructions, electro steel kilns, coke ovens, blast furnace air heaters and some construction elements in ceramic tunnel kilns and furnaces employed in the fabrication of non-ferrous metals [4–6].

As reported by a study, rice production around the globe reached 661 million tons in 2008 [7]. Around 20% of the rice paddy produces rice husk (RH) during its processing in rice mills and refinement. RH occupies large areas, has a very low nutritious significance and takes very long time to decompose due to which it is not appropriate for composting or manure. Thus it generates disposal problem [8]. To reduce the RH efficiently, one effective method used these days is to use it in the rice mills to generate steam for the parboiling process or as fuel in industries. RH generally contains 70–80% organic matter such as cellulose, lignin etc. and rest 20–30% mineralogical components such as silica, alkalis and trace elements [9–12]. Thus when this RH is burnt, ~25% of its weight is converted into ash during the firing process and is called rice husk ash (RHA). This burnt RHA has different chemical, mineralogical and morphological characteristics depending upon the rice variety, soil chemistry, climatic conditions, and geographic localization of the culture as well as the process acquired during burning conditions of the husk [13]. If the combustion is incomplete, large amount of unburnt carbon is found in the ash while complete combustion results in gray to whitish ash with minimal amount of carbon contamination. This RHA contains around 85–90% of amorphous silica. However, the amorphous silica content depends upon the burning temperature and holding time. Optimum properties can be achieved when husk is burnt at temperatures around 500–700 °C with shorter holding time [14].

In order to utilize this type of waste as silica precursor in ceramics, various studies were accomplished; particularly, in white ware [15], synthesis of colorants [16,17], glaze preparation [18,19] and other ceramics [20,21]. Utilization of RHA in the synthesis of borosilicate [22], cordierite [23], carbosil [24], alumina-silicate [25], and mullite [26,27] are some of the works worth mentioning. Furthermore, this amorphous silica has also been employed in the preparation of various valuable materials such as solar grade silicon [28], magnesium-alumina-silica [29], lithium-aluminum-silica [30], and silicon carbide [31]. Particularly; RHA derived silica refractories have also developed earlier [32,33] but the major objectives of these works were focused upon the application in insulation purpose. On the other hand, effect of incorporation of clay and refractory grogs in a RHA based silica refractory has also not been investigated yet. In this present study, we have prepared clay bonded high strength silica refractory with utilizing agriculture waste-RHA by gradually replacing quartz and studied the effects of this partial replacement with various characterization techniques.

Materials and experimental

Materials and materials characterization

In this work, RHA was collected from rice mills where rice husk is often used as a fuel. Typically in these mills, temperature rises above 500 °C due to which this RHA contains a very negligible amount of volatile matter as well as carbon content. However, to obtain highly pure amorphous silica, this RHA was further heat treated at 600 °C for 2 h to eliminate the possibility of any carbon contamination. The chemical analysis was carried out by using the X-ray fluorescence (XRF) spectrometer according to ASTM C114-00 [34] shown in Table 1. According to XRF results, RHA contains more than 90% of SiO_2, which is almost similar to the amount of SiO_2 present in quartz. So, in this work complete and partial replacement of quartz by RHA was investigated in the preparation of silica refractory. The quartz was purchased by Lobachemie Pvt. Ltd., India having analytical grade quality and used without any further treatment.

Microstructural analysis of RHA heat treated at 600 °C was carried out using a SEM analysis for which results are shown in Fig. 1. It can be observed that the RHA particles possess an