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(RESEARCH ARTICLE)

Effects of alumina slag (Valoxy) and rice husk ash as substitute resources on mechanical properties of mullite based ceramics

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Abstract

In this study, mullite-based ceramics were prepared by substituting alumina slag (valoxy) and rice husk ash (RHA) for commercially pure alumina and quartz, respectively. Five body compositions containing 5, 10, 15, and 20% valoxy: RHA were created. At 75MPa load, the formulated bodies were thoroughly mixed homogeneously and uniaxially compacted to produce cylindrical shaped samples 30 mm diameter and 50 mm high. After compacting the samples, they were sintered in a muffle furnace at 1200 °C at a rate of 10 °C/min for 2 hours before being allowed to cool to room temperature before offloading. Mechanical properties such as microhardness and compressive strength was conducted on the samples to determine the effects the substitute materials have over the formulated mullite ceramics. The results showed maximum hardness (16 GPa) and compressive strength (56.76 GPa) was observed for samples containing 2.5 % valoxy: 2.5 % RHA respectively while decline in hardness and compressive strength was observed for the remaining compositions. Thus, indicating that the use of these wastes materials is only beneficial at lower percent inclusion.

Keywords: Mullite based ceramics; Rice husk ash; Yaloxy; Alumina; Quartz

1. Introduction

Mullite (3Al2O3.2SiO2) is the only stable intermediate phase in the alumina-silica binary system at normal atmospheric pressure, and it is found mostly in ceramics [1]. Mullite has a high relevance in both traditional and advanced ceramics due to its inherently favourable properties when subjected to high temperatures. High thermal stability, low expansion coefficient, high melting point, creep resistance, good mechanical strength, low dielectric constant, and corrosion resistance are among these properties [2]. Mullite's diverse set of exceptional properties makes it an increasingly attractive material for structural advanced materials, chemical, electrical, optical, and advanced ceramics applications [3]. Mullite is a rare mineral, so several precursors and processes have been developed in recent years to synthesize it. These methods include reaction sintering of silica-alumina mixtures [4, 5], thermal decomposition of aluminosilicates, sol-gel technique [5, 6], and co-precipitation. Mullite formation is dependent on the type and nature of precursors used, particle size, an accurate blend of silica and alumina, and temperature, according to previous research [7]. Although mullite has been successfully synthesized using various materials as precursors, its synthesis from clay minerals remains the most cost-effective [8]. Clay minerals (raw kaolinite clays) from various countries [9] have been used in conjunction with alumina bearing materials (as alumina precursors) for the synthesis of mullite, whereas little or no detail work on the formulation of porous mullite using alumina slag (Valoxy) and rice husk ash as resources has been reported. As a result, this study is necessary.

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2. Material and methods

2.1. Material preparation

Materials like alumina and quartz were procure as commercially pure material and therefore do not require further processing while alumina slag (valoxy) was also used in its as-received state as alternative to commercially pure alumina. However, in the case of the rice husk ash, it was obtained from thermal treatment of rice husks at a temperature of 850°C to produce a white powder refer to as rice husk ash .The rice husk ash was sieved using a 75μm sieve. Figures 1 (a – d) show the raw materials used.

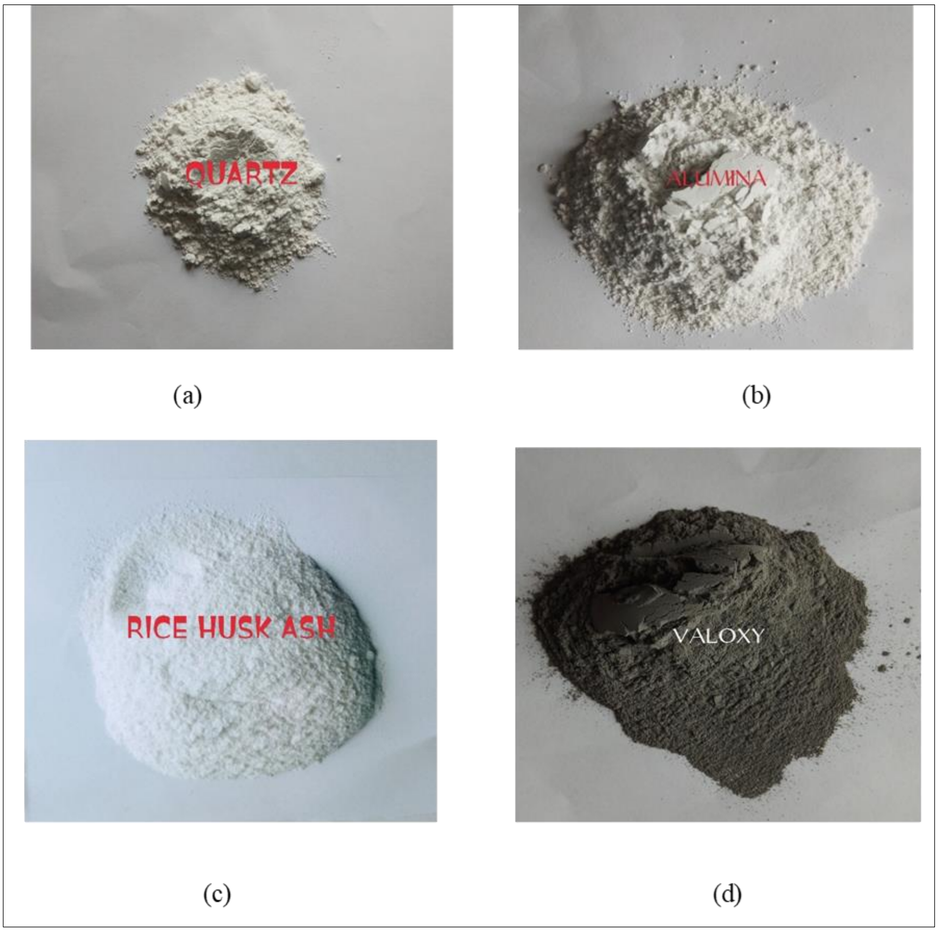

Figure 1 (a) Quartz (b) Alumina (c) Rice husk ash (d) Valoxy

2.2. Body formulation

Table 1 indicates the batch formulation of the prepared mullite ceramics consisting of varying additions of alumina slag (Valoxy) and rice husk ash (RHA).

Table 1 Formulation of the samples weighed in percent (%)

Samples	Alumina (Al2O3)	Quartz (SiO2)	Alumina slag (Valoxy)	Rice husk ash (RHA)
M 1	72	28	-	-
M 2	67	23	5	5
M 3	62	18	10	10
M 4	57	13	15	15
M 5	52	8	20	20

2.3. Sample Preparation

Five compositions as indicated in Table 1 were formulated by proper mixing of all the materials with the addition of organic binder. The properly mixed samples were then cold pressed using a uniaxial powder pressing machine at a pressure of 75MPa to obtain cylindrical sample of 3mm diameter and 50mm high. The compacted sample was then placed in an electrically powered muffle furnace and subjected to sintering process at temperature of 1200°C for a soaking period of two hours at a rate of 10°C/min. The sintered samples were then allow to cool to room temperature before offloading from the muffle furnace. Selected samples from each composition was then analyzed using Vickers' micro-hardness tester and Universal Testing Machine to determine the effects of the wastes incorporation on both hardness and compressive strength of the developed mullite ceramics. Both the hardness and compressive strength was conducted in duplicate from which the average value was obtained.

3. Results and Discussion

3.1. Micro-hardness Evaluation

The result of the micro hardness evaluation carried out using Vicker's hardness machine is shown in Table 2. It can be observed that sample M1 which represent the control experiment has an average hardness of 15.63GPa which corresponds with the literature value of hardness (13-15GPa) for mullite ceramics .It is also observed that samples M2 containing 5 wt. % valoxy: 5 wt. % RHA possessed the highest hardness value of 16.0 GPa. However a drastic decrease in hardness was observed for M3, M4 and M5 respectively. This drastic decrease in hardness value was observed might be attributed to low hardness value of valoxy and rice husk ash when compared with theoretical high hardness of alumina (15GPa) and quartz (~13 GPa) they are replacing respectively. It can therefore be inferred from the trend of hardness result that the inclusion of 2.5 wt. % valoxy: 2.5 wt. % RHA as substitute to pure alumina and quartz respectively is beneficial for preparation of mullite based ceramics.

Table 2 Vicker's micro-hardness values (GPa)

Sample	Reading 1 (GPa)	Reading 2 (GPa)	Average (GPa)
M1	15.64	15.62	15.63
M2	16.00	16.00	16.00
M3	13.75	13.91	13.83
M4	13.40	13.52	13.46
M5	12.28	12.40	12.34

3.2. Compressive Strength Evaluation

The result of the compressive strength evaluation conducted using universal testing machine can be seen in Table 3 .It can be observed from the Table 3 that sample M1 which is the control sample containing no valoxy and RHA possessed the highest compressive strength of average value 68.6 MPa. However, drastic drop in compressive strength is observed for samples M2, M3, M4 and M5 containing 10, 20, 30 and 40 wt. % valoxy: RHA respectively. This trend observed is also similar to what is obtained under hardness measurement. The drastic drop might be as a result of low hardness value obtained for the samples which is due to the low hardness of valoxy and rice husk ash (RHA) as obtained in literature.

Table 3 Compressive strength values (GPa)

Sample	Reading 1 (GPa)	Reading 2 (GPa)	Average (GPa)
M1	70.70	66.53	68.62
M2	56.91	56.62	56.76
M3	56.06	56.14	56.10
M4	56.06	56.06	56.06
M5	56.10	56.06	56.08

4. Conclusion

This work has successfully dealt with preparation of mullite based ceramics using alumina slag (valoxy) and rice husk ash (RHA) as alternative materials to pure alumina and quartz. Properties such as micro hardness and compressive strength are evaluated to determine the mechanical behaviour of the developed mullite ceramics. However, the following conclusions can be drawn within limit if these work.

- Both valoxy and rice husk ash (RHA) can serve as alternative materials to pure alumina and quartz in the preparation of mullite based ceramics.
- Maximum hardness of 16 GPa observed for sample M2 indicate that 5 wt. % valoxy: 5 wt. % RHA is beneficial for the developed waste incorporated mullite based ceramics.

The drastic drop observed for hardness and compressive strength across the samples might be attributed to low hardness (theoretical value) of valoxy and RHA powder as compared with pure alumina and quartz they are substituting respectively.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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