

Synthesis of Low Expansion Material for Coating of High Tension Electrical Insulators

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Abstract

Increase in flexural strength of insulators used for supporting high tension electrical cables is investigated here. A low expansion material, Cordierite, is synthesized for its use as a coating for insulators. Cylindrical shaped rods of cordierite were prepared from mixture of alumina, kaolin, talc, silica, potassium feldspar and bauxitic clay in different proportions by ball milling. These rods were slipcast, dried and were sintered at 1350°C and 1400°C. X-ray fluorescence was used for the determination of mineralogical composition of the raw materials. From the XRD analysis of the sintered rods it was concluded that the sample of composition 34.1% Kaolin, 19.94% Alumina, 41.62% Talc and 4.34% Silica, sintered at 1400°C formed the largest amount of cordierite i.e. 80.28% while dilatometry test revealed percentage linear change of 0.168.

Keywords: Flexural Strength, Cordierite, Insulator, Magnesia-Alumina-Silica System

Introduction

A local ceramic company, EMCO, wanted to increase the flexural strength of the insulators, which are produced to support the long lengths of high tension electrical cables. This could be done by increasing the alumina content in the insulator body. However this may increase the sintering temperature and require changes in furnace refractory lining, burner system and other related facilities [1]. This method is expensive. Another possible way to increase the flexural strength of the insulator body is to apply a surface coating of a material with lower coefficient of thermal expansion (CTE) than the insulator body. In this work, the second method to increase the flexural strength of the insulator body was employed using a low expansion material, cordierite.

Cordierite is well known material attributed to its very low thermal expansion, low dielectric constant ($\epsilon = 5-6$), high resistivity ($\rho > 1012\Omega\text{cm}$), elevated thermal and chemical stabilities and excellent thermal shock resistant [2-5].

The most extensive use of cordierite is in honeycomb substrates of adequate mechanical strength and porosity. Millions of substrates are sold annually making cordierite one of the significant ceramic in the world[6].

Cordierite, as a novel material, was synthesized for its use as a coating material. This coating being in compressive state at ambient can substantially increase the strength of the insulator body [7]. This project was designed to synthesize cordierite – containing coatings using domestic raw materials.

Preparation of cordierite can be done by solid state, sol-gel or co-precipitation reactions [8][9]. Slip casting method was used to prepare cordierite rods.

Experimental Procedure

The raw materials were silica, alumina, kaolin, potassium feldspar, talc and bauxitic clay with the composition given in Table I, determined by X-ray fluorescence (from

Table I. Chemical composition of as-received raw material

Constituent Oxide (wt%)	Quartz	Talc	Kaolin	Alumina
SiO ₂	99.47	60	51.84	0.01
Al ₂ O ₃	0.02	3.34	33.48	99.5
MgO	0.04	29.02	0.76	0
CaO	0.06	1.71	2.45	0.025
Na ₂ O	0.07	0.39	0.12	0.3
K ₂ O	0.04	0.05	0.03	0
Fe ₂ O ₃	0.03	0.34	1.25	0.02
TiO ₂	-	-	-	0.007

Table II. Percentage compositions of various batches

Sample name	Kaolin (%)	Alumina (%)	Talc (%)	Silica (%)
Sample 1 ^[10]	34.5	20.6	40.4	4.5
Sample 2	34.1	19.94	41.62	4.34
Sample 3 ^[10]	79	-	21	-
Sample 4	76.09	-	23.91	-

Pakistan Council of Scientific & Industrial Research (PCSIR) laboratories).

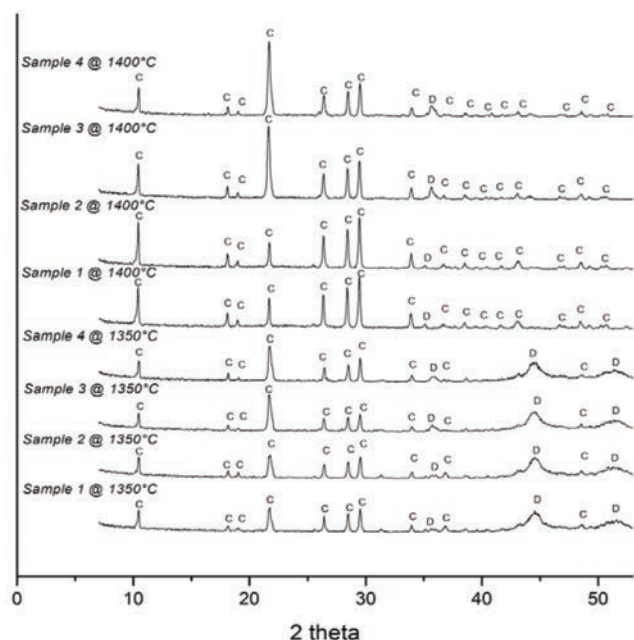


Fig. 1 X-ray diffraction patterns of cordierite specimens after sintering at different temperatures C = Cordierite, D = Dolomite

The raw materials procured were in the form of lumps, thus they were pulverized into required particle size. For sintering, the raw materials were mixed in predetermined proportions for slip casting, as given in Table II. For each batch, the raw materials were wet ball milled with 40% water. The lining of the mill and the balls were made of flint opal. Sodium silicate was used as a deflocculant. Its amount depends upon the desired viscosity of the slurry. The slurry was poured into a Plaster of Paris mold which was cylindrical in shape to slip cast rods. The length of each rod was approximately 10 cm whereas diameter was approximately 1.25 cm. The obtained rods after drying at 100°C were subjected to sintering at 1350°C and 1400°C in a Sentro Tech Box Furnace (Max Temp 1800°C). Phase analysis of sintered samples was done using Panalytical Diffractometer having a Cu anode with potential of 45kV and current of 40mA. Scanning was carried out at a speed of 5° to 120°/2theta. Wavelength of K α 1 rays were 1.54Å. After obtaining XRD pattern identification of peaks were made using Match! (XRD analysis software) and COD-AMCSD REV 1155 as a reference database. Relative intensities of the peaks and reference database were used to identify the samples. Percentage linear change under thermal stresses was determined by using horizontal Orton Dilatometer DIL

Table III. Amount of Cordierite and Spinel of various sintered samples

Sample No.	Cordierite	Spinel
Sample 1 (1350°C)	73.03	12.89
Sample 2 (1350°C)	67.86	10.27
Sample 3 (1350°C)	76.29	6.4
Sample 4 (1350°C)	70.94	6.86
Sample 1 (1400°C)	81.11	3.11
Sample 2 (1400°C)	80.28	3.33
Sample 3 (1400°C)	76.22	4.9
Sample 4 (1400°C)	74.2	1.18

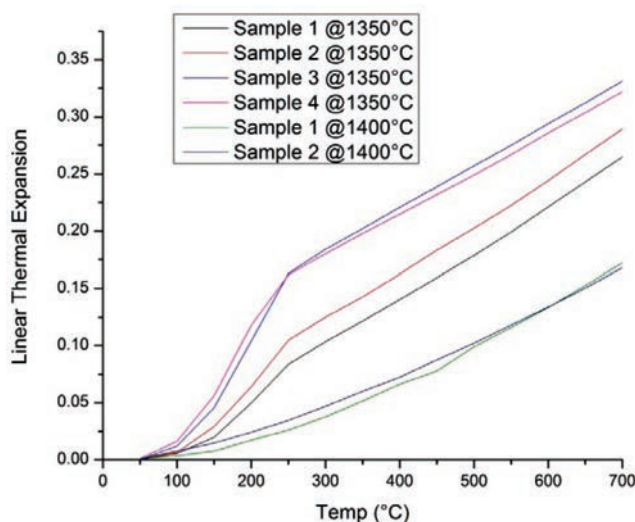


Fig. 2. Graph of Linear Thermal Expansion of the samples

2010 B having sample holder and probe rod made of fused quartz. Properties such as water absorption, bulk density, apparent specific gravity and apparent porosity of the sintered samples were determined using ASTM C 373-88 standard.

Results and Discussions

a. **Sintering.** The specimens were sintered at temperatures 1350°C and 1400°C. Most of specimens fired at the two temperatures didn't show any change in shape however specimens of sample 3 and sample 4 sintered at 1400°C devitrified and deformed to large extent.

b. **X-Ray Diffraction.** Figures 1 shows the diffractograms of sintered samples at 1350°C and 1400°C. As reported elsewhere [10], solid state reaction between precursors containing silica, magnesia and alumina occur at 1300°C which results in the formation of cordierite polymorph. This statement is clearly supported by our XRD result of the sintered samples at 1350°C which showed peaks of cordierite along with traces of unreacted corundum (a crystalline form of alumina) which is undesired. Diffractograms of samples sintered at 1400°C reveal the reaction of remaining corundum resulting in total crystallinity of cordierite and only minute traces of impurities left.

Quantitative interpretation of the diffraction patterns was done by reference intensity ratio method integrated in the software. Table III shows the amount of cordierite and spinel in the samples produced after sintering at respective temperatures

c. **Dilatometry.** Graph of linear thermal expansion of the specimens is shown in Figure 2. Specimens sintered at 1350°C showed high percentage linear change. This statement can be supported by the fact that less amount of cordierite was produced at lower temperature, as revealed through XRD result. Specimens sintered at 1400°C had a remarkable decrease in percentage linear change as compared to

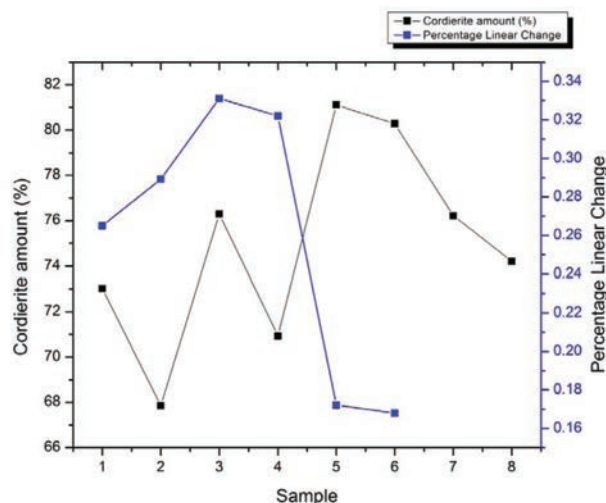


Fig. 3. Variation of linear thermal expansion as a function of cordierite content in the sintered specimen.

other specimens sintered at lower temperatures. Analyzing the X-Ray diffraction results of sample 1 and sample 2 sintered at 1400° suggest that sample 1 have the higher amount of cordierite produced so it should have lower thermal expansion than the other but according to dilatometer results, sample 2 had the lowest thermal expansion. This is because the amount of impurity phases present are less in sample 2 therefore thermal expansion is least. and sample 2 sintered at 1400° suggest that sample 1 have the higher amount of cordierite produced so it should have lower thermal expansion than the other but according to dilatometer results, sample 2 had the lowest thermal expansion. This is because the amount of impurity phases present are less in sample 2 therefore thermal

Table IV. Comparison of cordierite amount with percentage linear change of sintered samples

Sr. #	Samples with sintering temperature	Cordierite amount (%)	Percentage Linear Change
1	Sample 1 (1350°C)	73.03	0.2649
2	Sample 2 (1350°C)	67.86	0.2892
3	Sample 3 (1350°C)	76.29	0.3311
4	Sample 4 (1350°C)	70.94	0.322
5	Sample 1 (1400°C)	81.11	0.1721
6	Sample 2 (1400°C)	80.28	0.168
7	Sample 3 (1400°C)	76.22	-
8	Sample 4 (1400°C)	74.2	-

expansion is least.

Table IV compares the variation of linear thermal expansion of sintered cordierite samples as a function of cordierite content present. The specimens containing large amount of cordierite had shown the least linear thermal expansion owing to the fact that it shows least expansion on the application of heat. Figure 3 summarizes the result by comparing the amount of cordierite present in sintered samples with the thermal expansion produced in terms of a graph.

Conclusions

In this project, cordierite-containing coatings were synthesized by using raw materials which were characterized for their mineralogical and compositional analysis. These coatings were intended for their use as a glaze on electrical porcelain insulators. Cylindrical shaped rods were prepared from mixture of alumina, kaolin, talc, silica, potassium feldspar and bauxitic clay in different proportions by ball milling. These rods were slipcast, dried and were sintered at 1350°C and 1400°C. The furnace was ramped up at 8°C/h and sample rods soaked for one hour at the highest temperature.

From the XRD analysis of the sintered rods it was concluded that the sample of composition 34.1% Kaolin, 19.94% Alumina, 41.62% Talc and 4.34% Silica, sintered at 1400°C formed the largest amount of cordierite and least amount of MgO-Al₂O₃ spinel. X-Ray diffraction of the sintered bodies revealed that amount of spinel formed is higher at lower temperature. Higher temperature sintering is essential to produce high amount of cordierite. However, more than or equal to 1400°C sintering temperature could deform the cordierite bodies since the sintering range of cordierite is very narrow. Care is needed to avoid over sintering.

In addition to the XRD analysis, these results were also confirmed by dilatometric measurements of the sintered rods for thermal expansion to 700°C.

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