

FABRICATION AND CHARACTERIZATION OF LTCC BASED ON TALK GLASSES

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ABSTRACT

In this work, fabrication of low temperature co-fired (LTCC) with different Talc content is performed. Density and mechanical characterization of the prepared samples has been examined. Three series of low temperature co-fired ceramics have been prepared. The glass part of these composites contains talc to enhance the mechanical properties. The densities, hardness and splitting strength are measured for these series to monitor the effect of composition on their properties. It is shown that the third series (Base3; Flint 25%, talc 35%, Pota ash 8%, Soda ash 12%, and Boric Acid 20%) of the higher talc content shoes the better densities and mechanical properties. The results are explained in terms of better balance of the ceramic-class content that enhances the measured properties.

Keywords: LTCC, Sintering, Fabrication, Mechanical Properties, Glass ceramics.

تصنيع وتوصيف سيراميك الـ (LTCC) ذو اساس زجاج الطلق.

فرهاد محمد عثمان

الخلاصة

في هذا البحث, تم تصنيع السيراميك منخفض حرارة التلبيد بالحرق-المساعد بمحتوى متباين من مادة الطلق, وتم قياس الكثافة والخواص الميكانيكية للعينات المحضرة. تم تحضير مجاميع من السيراميك تحتوي على نسب مختلفة من مادة الطلق في تركيب الجزء الزجاجي للمساهمة في تحسين الخواص الميكانيكية. لمراقبة تأثير التراكيب الكيميائية على الخواص تم قياس الكثافات والصلادة ومقاومة الفصل لهذه المجاميع. بينت النتائج العملية ان المجموعة الثالثة (بتركيب: Base3; Flint 25%, talc 35%, Pota ash 8%, Soda ash 12%, and Boric Acid 20%) ذات المحتوى العالي من مادة الطلق اظهرت كثافة وخواص ميكانيكية جيدة. تم تفسير النتائج على اساس حدوث توازن في المحتوى بين السيراميك والزجاج مما عزز الخواص الميكانيكية

INTRODUCTION

Originally, low temperature co-fired ceramic (LTCC) technology stands for a glass ceramic composite with the intention of sintering temperature lower than 1000°C. This type of composite have three main advantages; the first is that the low sintering temperature allows to fabricate metallic print circuits at temperature ranges below the risk of metal oxidization; the second is the high dielectric constant of these composites that prevents the ‘cross-talk’ between closely spaced ‘wires’ due to dielectric coupling; and the thirds is the relatively simple processing that relies on powder technology and allows production of multilayer substrates Moulson, (2003). LTCC technology is applied in electronic circuits as a cost-effective and competitive substrate technology with nearly arbitrary number of layers. The multilayer ceramic stack will be fired (sintered) in the final manufacturing step Kulke, (2009). The interest in integrated passives derives from LTCC compositions with a sintering temperature no more than 900°C are in great demand in the field of highly integrated electronic components and modules. Most of the ceramics having a high dielectric constant and quality factor require high sintering temperature, while glass-only usually shows a low dielectric constant along with poor mechanical properties. In order to solve this problem, ceramic fillers are usually mixed with glass frits with low melting temperature to make the dielectric system co-firable with metal electrode Kim, (2008). LTCC also can be fabricated with integrated passives and has extendibility in the wiring and interconnection ground rules compared to those used today. LTCC will continue to be used in a variety of applications where it is best at meeting the cost and performance objectives sought by the customer Wessel, (2004). LTCC was primarily used in military and medical applications. The advent and explosion of wireless technology in the mid-1990s brought LTCC into the forefront for many commercial wireless products such as cellular phones and wireless local area network (WLAN). With very high pack aging density Fred, (2007); i.e., a significant packaging size reduction may be achieved by embedding passive materials within electronic LTCC modules Barth, (2009). Finally, LTCC technology did not dedicated only for dielectric applications. This technology finds widespread application where the need is for lower temperature maturing for ceramics with good physical and mechanical properties Saad, (2009). In this work, several compositions of glasses were produced. The starting materials for glass compositions includes Talc ($3\text{MgO}\cdot\text{SiO}_2\cdot\text{H}_2\text{O}$) that is known to help produce less porous bodies at lower firing temperatures and better mechanical properties. These glasses are used with burned kaolin to produce LTCC ceramics. The results for density, hardness and splitting (Brazilian) mechanical tests will be the guide for selecting the best samples ASTM, (2006).

EXPERIMENTAL PART

Three types of glasses are prepared in this work. Each type differs in their talc content. The difference in talc content is compensated by the flint (a silica quartz ore that contains about 98% SiO_2 and the remainder is kaolin, CaO , Na_2O and K_2O). Pota ash (K_2CO_3), Soda ash (Na_2CO_3) and Boric Acid ($\text{B}_2\text{O}_3\cdot 3\text{H}_2\text{O}$) is also included. Commercial grade (about 98% purity) powder starting materials are utilized to boost the significance of this work. Table (1) shows the weigh percentages of the starting materials for the three types of the glasses Base1, Base2 and Base3. The powders are sieved to below 75 μm via wire-mesh sieve, weighted according to table 1 and mixed with blade mixer. The powder batches are then melted in high-alumina stone-ware porcelain crucibles at 1100°C for 30min. The glass melts are quenched in tap water, dried, crushed and milled with rotating cylinder miller and sieved to pass 50 μm . The produced glass powders are marked as Base1, Base2 and Base3 as mentioned above. The second phase of the preparation procedure begins with firing of Duekhla kaolin powder to 950°C for an hour in an alumina crucible. The resultant fired kaolin passes the 50 μm sieve. The fired kaolin is used to prepare the mixes for LTCC composites as shown in Table (2).

Obviously, the produced glass and the fired kaolin are both lack for plasticity and compressibility needed for powder die forming process. To overcome this obstacle a wet binder is prepared. The binder is composed of 50% water and 50% water glass (Sodium Silicate, density=1.5g/cm³). 1.2 ml of binder is added to each 6g of the powder mix shown in table 2. Thoroughly mixed in a mortar and pressed by punch and die system. The diameter of the punch was 3cm and the applied force was 100 N. The resultant green pellets are then dried in 100°C for one hour followed by 400°C for another hour. Figure (1) shows the dried pellets before sintering. Each pellet is labeled with two numbers. The first (left) number refers to Base1, Base2 and Base3; and the second numbers refers to composition mentioned in Table 2. Then, sintering of the LTCC pellets were carried out in high temperature furnace at 850°C for one hour. In addition, the sintered pellets is subjected to geometrical density measurements utilizing 2-digit millimeter electronic Vernier and 4-digit balance, HR-30N hardness is measured and finally the splitting (Brazilian) mechanical test is measured according to ASTM D3967 standard test [ASTM, 2006]. The Brazilian test is performed utilizing Leyboldheraves (Germany) apparatus at 7.5 kN.

RESULTS AND DISSECTION

It is found the sintering temperature of 850° for one hour is optimum for the LTCC prepared in this work. Increasing the sintering temperature cause the melting of the prepared samples. Figure (2) shows the densities of the sintered sample versus glass content, where the glass was Base1, Base2 and Base3. Each type of used glass led to different behavior. The densities of the sintered samples at the lower glass content (40%) used in this study are close in value. In addition, the densities are increased with the glass content and the maximum densities are recorded at 80% glass content when using either type of glass. The samples that prepared with Base3 glass show higher densities as the glass content increased. These results suggest that better balance of the ceramic-class content that help better stabilization of the microstructure with Base3 glass. Figure (3) shows the hardness test for the same series of the sintered sample. Obviously the series contains Base3 glass show better behavior. That is, the hardness is better with higher glass content for the series with Base3 glass. The other series shows slower increasing of the hardness as the glass content increased. These results show that both the density and hardness increases with higher class content especially for Base3 series. For further inspection of the properties of the prepared LTCC samples the splitting strength is examined. The results of the splitting strength of the prepared samples are shown in figure (4). The observed behavior shows clear enhancement of the splitting strength with the glass content and the Base3 series show the best results. This confirms the above mentioned conclusion that better balance of the ceramic-class content of Base3 series can be the reason for enhancement of density, hardness and splitting strength.

CONCLUSIONS

From the obtained results, the following conclusions can be drawn:

1. The density, hardness and splitting strength is increased with the glass content of the prepared LTCC in this work with glass content of 80% being the optimum.
2. Base3 (Base3; Flint 25%, talc 35%, Pota ash 8%, Soda ash 12%, and Boric Acid 20%) series shows the better properties for density, hardness and splitting strength due to higher talc content in the starting materials.

Table (1): Weight percentages for glass starting materials

Material	Base1	Base2	Base3
% Flint	35	30	25
% Talc	25	30	35
% Pota ash	8	8	8
% Soda ash	12	12	12
% Boric Acid	20	20	20

Table (2): weight percentages for LTCC materials, %Glass stands for Base1, Base2 and Base3 percentages.

Sample	% Glass	% fired kaolin
1	40	60
2	50	50
3	60	40
4	70	30
5	80	20



Fig. (1): The compacted and dried pellets are shown, where the bottom row includes Base1 glass, the middle row includes Base2 and the top row includes Base3.

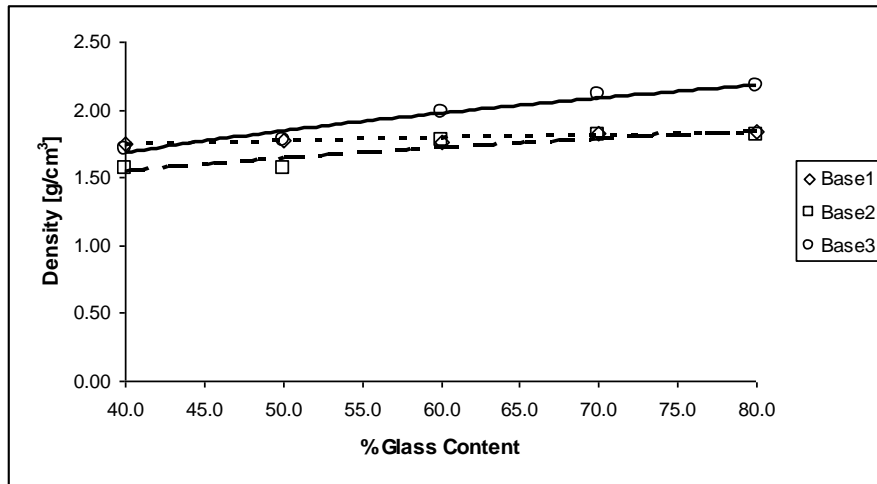


Fig. (2): The sintered densities of the prepared LTCC.

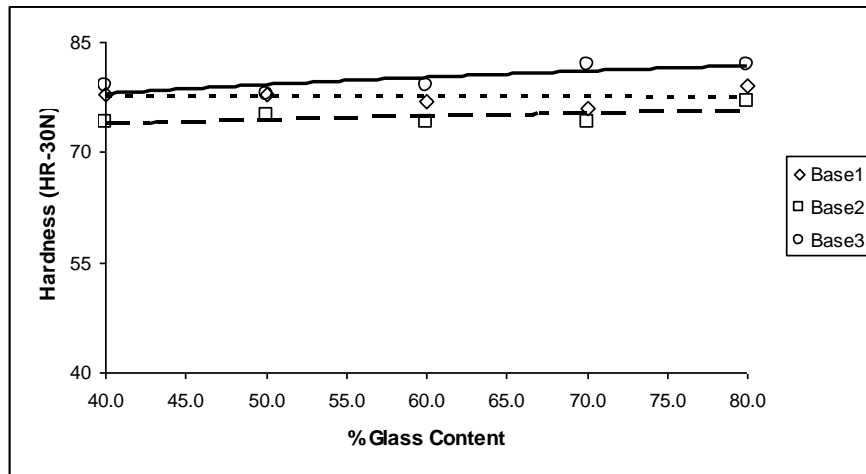


Fig. (3): Measured Hardness of the prepared Ceramics.

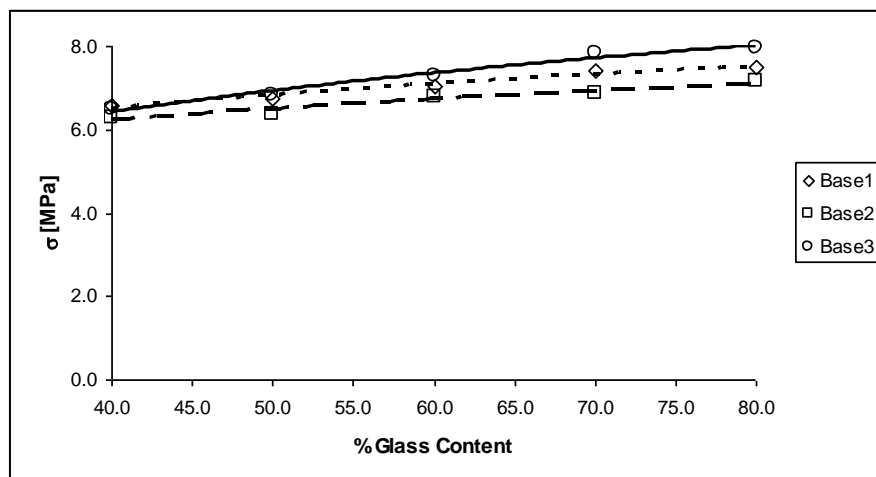


Fig. (4): Splitting Strength of the prepared Ceramics.

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