

## The Effect of SiC Particles on the Physical Properties of MgO Ceramic Matrix Composites

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### ABSTRACT

The influence of SiC particles on the physical and mechanical properties for MgO/SiC composites was investigated. MgO matrix was reinforced with (2 wt%, 4 wt%, 6 wt% and 8 wt% ) of SiC particles which synthesized using powder technology technique. Five samples of each patch have been prepared and supplied to physical properties (green density (G.D) and bulk density (B.D)) and mechanical properties (hardness and compressive strength) were measured. It was observed that the green density of all samples were decreases with increasing SiC particles content. This due to the lower density of SiC than MgO particles. Prepared samples were sintered at different temperatures (800 °C, 1100 °C, and 1450 °C). The bulk density revealed the unaffected property for samples sintered at 800°C and 1100°C, but it was observed a significant increasing in B.D for samples sintered at higher temperature (1450°C). It has been found that Vickers hardness, compressive strength and diametrical strength values increases with increasing sintering temperature and decreasing with SiC particles content.

The purpose of this study was to confirm the influence of SiC addition on some physical and mechanical properties of MgO matrix.

**Keywords:** MgO/SiC composite, strength, heat treatment, mechanical properties

### INTRODUCTION

MgO matrix is excellent in thermal resistance, durability and electric insulating property but it does not satisfy enough strength sufficiently to be used in a structural material, because it is poor in strength at high temperatures, toughness and thermal shock resistance. MgO and SiC are representatives of oxide and non-oxide ceramics, and are leading candidate materials for many modern-day engineering applications. A critical factor which limits the widespread applications of these materials is a lack of reliability caused by the severe sensitivity to catastrophic, brittle failure. Improvement of fracture strength and toughness of these materials would considerably expand these application ranges. Various toughening methods, i.e. transformation – SiC particle reinforcing was used to improve the mechanical properties of ceramic materials [1]. Dixon Jr., William R., were investigated

the MgO/SiC composite material in which SiC particles with nano-meter order in size are dispersed within MgO matrix. The grains have been prepared by hot-pressing the mixture of fine MgO and SiC powders. It has been found that the addition of SiC particles in the range of 5 volume percent to 50 volume percent to the MgO matrix leads to high strength, high thermal durability and high resistance to thermal shock[2]. M. E. F. Carney, D. W. Readey were studied the oxidation kinetics of SiC particulate-reinforced MgO composites. They have found that the rate of growth of the oxidized layer and the changes in microstructure that occur suggest that Mg<sup>2+</sup> diffusion is the rate-controlling step. To confirm that magnesium diffusion is rate controlling, SiC-reinforced MgO doped with scandium was oxidized under similar conditions. It has been found that Sc<sub>2</sub>O<sub>3</sub>-doping increased the rate of oxidation as expected compared to the

pure reinforced MgO[3]. The level of residual stress in SiC-particle-reinforced MgO composites has been investigated using X-ray diffraction. The significant difference in thermal expansion coefficients between SiC and MgO has resulted in the high residual stress in the composites [4]

### Experimental

The starting materials that have been used for this work were MgO and SiC powders which supplied from BDH chemicals Ltd pool England. Four batches compositions were prepared, it content MgO powder with 2wt%, 4wt%, 6wt% and 8wt% SiC addition with particle size <70 micron. After the desired materials were selected, the amounts have weighed using a sensitive four-digit balance type (Precisa Instruments Ltd.). Batches materials were drying milled in a ball mill during 15 minutes using paddle mixer in order to homogenizing it and then the sieving process have been applied.

The samples have formed by combination of constituents with 5 wt % of distilled water to produce the desired products. The weighted mass (2gm of powder) was subject to uniaxial pressing forced through a steel die to produce a disk samples with 1.5 cm in diameter. It is found that 3 N for 1.5 min press duration is the best load and time to obtain crack free green disk. Samples were dried for 72 hours in air and then at 110 °C for 8 hours in an electric oven. The prepared samples have been sintered at different temperatures (800, 1100 and 1450) °C for 4 h at a heating rate of 10°C/min in an electric furnace.

Vickers microhardness tester with a load of 9.8 N and loading period of 40 second was used to obtain the hardness properties for composite samples. The indentation impressions were subject at four positions in addition to the center of each samples and the average has calculate. Equation (1) has supplied to calculate Vickers hardness. The applied stress of compression or tension is given by the expression, Stress =F/A, where F is the applied force in N, and A is the cross-section area. A stress resisting a compression force which is referred to as a Compressive strength [5,6]. An equation (2) was used to calculate the compressive strength. PHYWE test machine (model 1757793, Japan) has

been used in its compression mode. The crosshead speed has been fixed to 0.07mm/sec. Diameters and thicknesses for each sample have been measured and the force at fracture point was observed. The splitting strength was calculating using eq (3).

$$V.H.N. = \frac{2P \sin(\alpha / 2)}{l_{av}^2} = \frac{1854.4P}{l_{av}^2} \left[ \frac{kgf}{mm^2} \right] \dots\dots\dots(1)$$

$$\sigma_c = F/A \dots\dots\dots(2)$$

$$\sigma_D = \frac{2F}{\pi Dt} \dots\dots\dots(3)$$

Where: 1.854 is a constant

F = load (Kgf)

$l_{av}$  = average of indentation diameter (mm)  
 =(l<sub>1</sub>+l<sub>2</sub>)/2

$\sigma_D$  is the splitting tensile strength in Pascal (Pa)

D and t are the cylinder diameter (m) and thickness (m).

### Results and Discussion

Fig (1) gives the variation of green density (G.D.) in (gm/cm<sup>3</sup>) for all prepared ceramic composites versus SiC content. It can be seen that samples content 2wt% of SiC have the highest value of green density. The increases of SiC addition leads to decreasing in G.D, till it reach the lowest value (1.5 gm/cm<sup>3</sup>) for the sample content 8wt% SiC. The behavior that obtained for green density was very reasonable because SiC have lower density than the MgO oxide. This means that the increasing of SiC content leads to gradual decreasing in green density [7, 8].

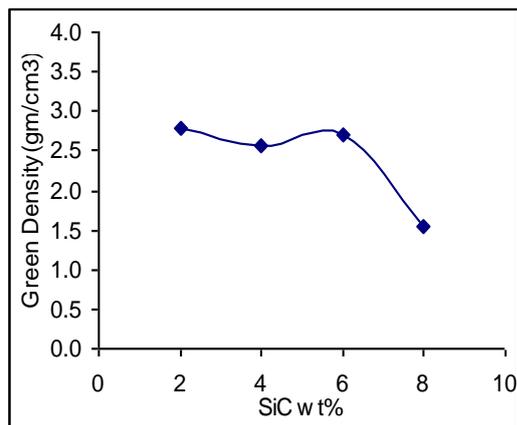


Fig (1) The variation of green density versus wt% SiC.

Fig (2) shows the bulk density (B.D.) of prepared samples content different percentages of SiC which sintered at different temperature (800, 1100 and 1450) °C. It can be observed that the B.D. have a small influence by the first and second sintering temperature (800 and 1100)°C. In spite of pure SiC and MgO have a theoretical density 3.1 (gm/cm<sup>3</sup>)[9] and 3.58 (gm/cm<sup>3</sup>)[7] respectively, an interesting phenomenon has been observed for the samples that sintered at 1450°C; these samples revealed higher values of B.D. (6~6.5 gm/cm<sup>3</sup>) over all the range of SiC content. This can be explained by the formation of new phases having higher density than the original content. Notation the bulk density for samples sintered at 1450°C have higher value than that obtained from CiDRA® Precision Services, LLC production (3.48 gm/cm<sup>3</sup>)[10].

The influence of sintering temperature on the samples components was shown in fig (3). It can be seen that the B.D. increases with increasing of SiC content and sintering temperature.

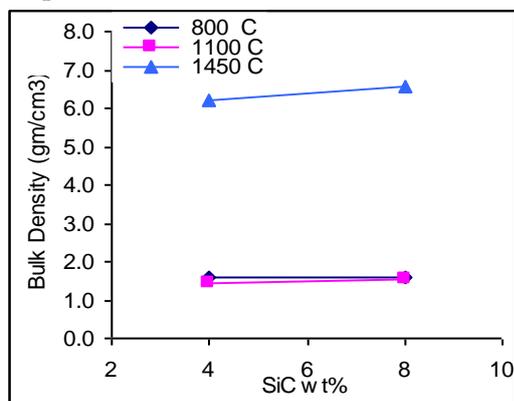


Fig (2): The variation of bulk density versus wt% SiC.

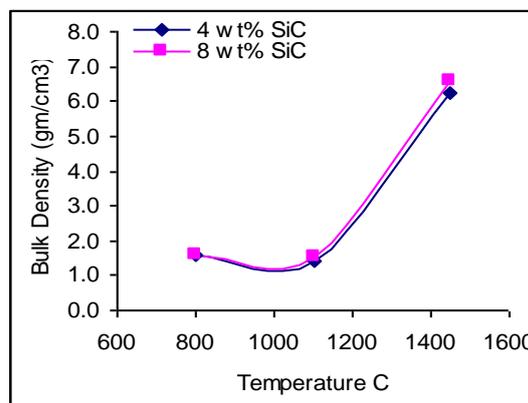


Fig (3): Variation of bulk density versus sintering temperature.

The variation of Vickers hardness versus SiC content has shown in fig (4). The lowest values of V.H. were obtained for samples sintered at 800°C and 1100°C. The increases of SiC addition lead to decreasing in V.H. values. The larger differences for V.H. with respect to SiC powder has shown at 1450°C. Sample that have 4wt% SiC has the highest value of V.H. than the sample content 8wt% SiC at the same temperature. Silicon carbide is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice this produces a very hard and strong material [11]. In spite of the increasing of SiC content must lead to increase the hardness property of material, but in this situation, the inverse behavior has been observed. The reason of this is not exactly understood, but it could be explained by the significant difference in thermal expansion coefficient between SiC and MgO which leads to high stress in the SiC/MgO composites [4]. Indeed, the influence of residual stress is more pronounced at higher sintering temperature [12]. Samples content 4wt% SiC have higher hardness values than that content 8wt% of SiC, this can be attributed to the lower influence of thermal expansion between the component. The variation of V.H. versus temperature has shown in fig (5).

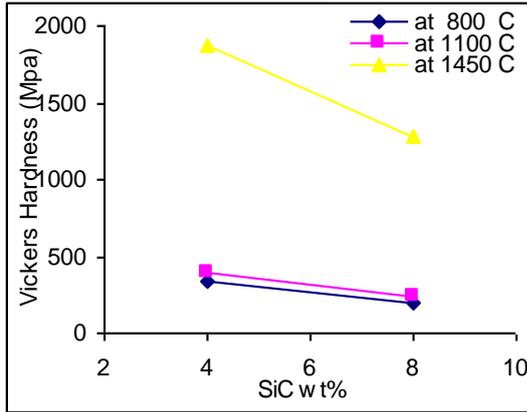


Fig (4): The variation of V.H. Vs SiC wt%

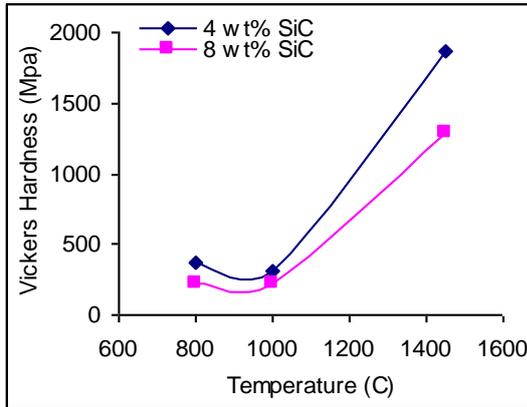


Fig (5) The variation of V.H. Vs sintering temperature.

The influence of addition SiC on the compressive strength has shown in fig (6). Generally, compressive test shows the same behavior that illustrated in Vickers test. Samples that sintered at 800°C and 1100°C revealed slightly effected in compressive property with increasing SiC content.

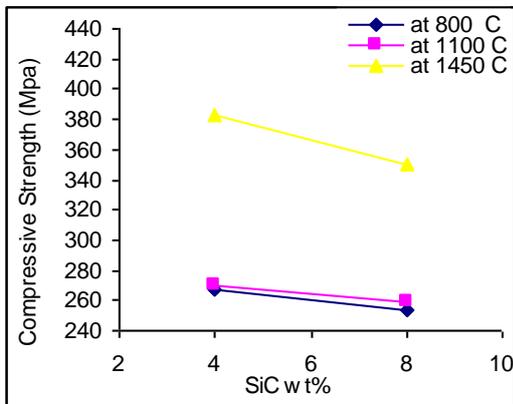


Fig (6) The variation of compressive strength Vs SiC wt%

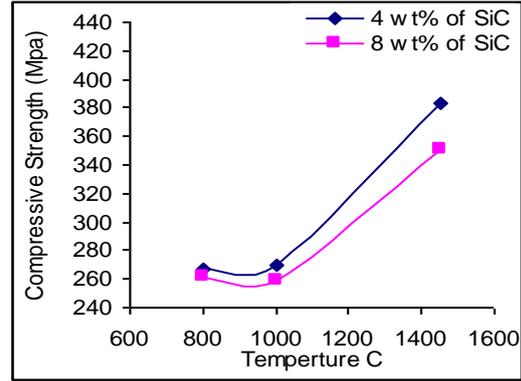


Fig (7) The variation of compressive strength Vs sintering temperature.

The diametrical strength for samples content 4wt% and 8wt% of SiC at different temperature has illustrated in fig (8). It can be seen that the increase of sintering temperature leads to increasing diametrical strength for all product samples, however, the increase becomes too high for samples sintered at 1450°C. Samples that have higher amount of SiC give the lower diametrical strength values [4].

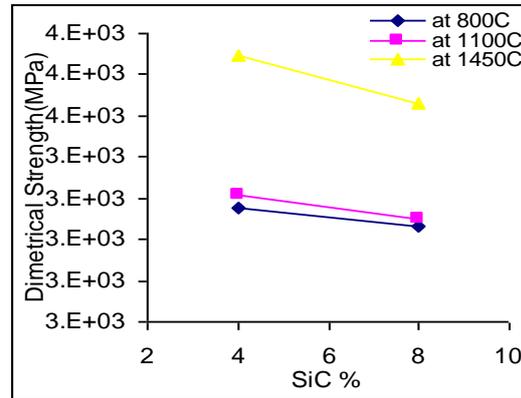


Fig (8) The variation of brazilin test Vs SiC wt%

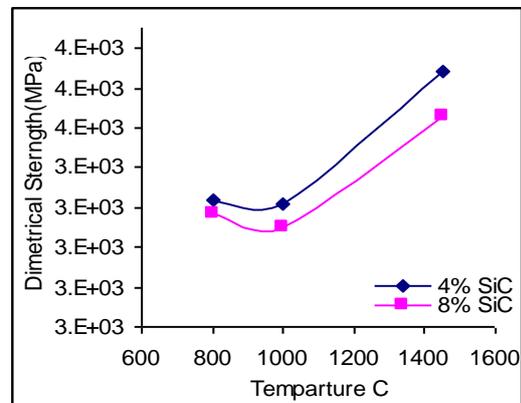


Fig (9): The variation of brazilin test Vs sintering temperature.

## CONCLUSION

1-the green density has reduce with increased SiC content. This is due to lower density of SiC than the MgO.

2-Samples that sintered at 800 and 1100 reveled gradually increased in B.D. and tha significant increasing were obtained at a higher sintering temperature.

3-The microhardness for test samples increases with increasing temperature and decreasing with the SiC content. This maybe due to the difference in thermal expansion between SiC and MgO.

4-The other mechanical properties, Compressive and diametrical strength, had given the same demeanor as the hardness property, which means, it can be explained as the same principle of thermal expansion.

5-All the mechanical property that have been measured reveled extremely high values at higher sintering temperature, this can be attributed to the formation of new harder phases than the other phases that created at a lower temperature.

6-The best values of hardness and compressive properties have attachment at 2wt% of SiC and the best value for diametrical strength was related at 8wt% of SiC.

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## تأثير دقائق كاربيد السليكون على الخصائص الفيزيائية لمتراكب ذات الأساس السيراميكي لأوكسيد المغنيسيوم

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### الخلاصة

تم دراسة تأثير إضافة دقائق كاربيد السليكون على الخواص الفيزيائية والميكانيكية لمتراكب اوكسيد المغنيسيوم/كاربيد السليكون وبنسب مئوية مضافة من كاربيد السليكون هي 2%، 4%، 6%، 8% والتي تم تصنيعها بطريقة تكنولوجيا المساحيق. تم تحضير العينات وقياس الخصائص الفيزيائية (الكثافة قبل الحرق والكثافة الحجمية) والخصائص الميكانيكية (الصلادة ومتانة الانضغاط). لقد تم ملاحظة أن الكثافة الطرية لكل العينات تقل بازدياد دقائق كاربيد السليكون المضافة وهذا نتيجة انخفاض كثافة كاربيد السليكون مقرنة باوكسيد المغنيسيوم. أظهرت الكثافة الحجمية عدم تأثرها بالعينات الملبدة بدرجات الحرارة 800م، 1000م وتأثرها الواضح بدرجة التليد 1450م. لوحظ أيضا أن صلادة فيكرز ومتانة الانضغاط والمتانة القطرية تزداد بازدياد درجة حرارة التليد وتقل بازدياد كمية الدقائق المضافة.  
الغرض من البحث هو لتوضيح تأثير إضافة دقائق كاربيد السليكون على الخواص الفيزيائية والميكانيكية لقالب اوكسيد المغنيسيوم.