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Particle size effect of $LiAlSiO_4$ on the thermal expansion of SiC porous materials

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This paper reports the effect of the particle size of $LiAlSiO_4$ on the thermal expansion and Young's modulus of low thermal expansion (LTE) coefficient of porous materials using silicon carbide (SiC), vitrified bonding material (VBM) and lithium aluminum silicate ($LiAlSiO_4$) at 850 ºC. According to the XRD results, there is no reaction between the raw materials during the sintering process. SEM analysis revealed the presence of an internal porous structure with a pore size less than 4 micrometers. It was found that decreasing the particle size of $LiAlSiO_4$ by almost 4 times reduces the porosity, keeping a low thermal expansion coefficient, but the Young's modulus increases 50%.

Key words: $LiAlSiO_4$, Low Thermal Expansion (LTE), SiC, Porous Materials.

Introduction

SiC porous materials have attracted attention because of their wide range of applications, such as in electronics, exchange filters, vacuum devices, etc [1-3]. In previous investigations, in our laboratory, the fabrication of SiC porous materials was carried out by mixing a positive with a negative thermal expansion material [4, 5]. In both cases, $LiAlSiO_4$ was used as the negative thermal expansion material to control the thermal expansion. Due to its negative thermal expansion, $LiAlSiO_4$ has been used for several years to tailor the thermal expansion of dense materials [6]. Although very low thermal expansion porous materials were obtained because $LiAlSiO_4$ has a negative thermal expansion, the presence of $LiAlSiO_4$ affects considerably the Young's modulus. In this study, the fabrication of SiC porous materials was carried out using $LiAlSiO_4$ with two different particle sizes; the particle size of $LiAlSiO_4$ was modified by a ball milling technique.

Results concerning the effect of the particle size of $LiAlSiO_4$ on the thermal expansion, porosity and Young's modulus values are discussed here. X-ray diffraction (XRD) and scanning electron microscopy (SEM) analysis are also reported.

Experimental

Porous ceramic materials were prepared in the same way as has been reported previously for the fabrication of a porous material containing SiC [4]. The porous material had volume proportion 40%, 20% and 40%, raw material, VBM and pores, respectively [7]. Samples were prepared by mixing SiC (10 g), VBM (5 g), and $LiAlSiO_4$ (7.5 g), previously, $LiAlSiO_4$ was synthesized by a solid state method at 1200 ºC for 12 hours. After the synthesis the particle size of $LiAlSiO_4$ was 18 micrometers, then a portion of this material was placed into a homemade ball mill to reduce its particle size, after 12 hours the particle size was 4 micrometers. Bars of SiC-VBM-$LiAlSiO_4$ were pressed uniaxially at 6 MPa for 1 minute; the size was 70 mm in length and 20 mm of width. Finally samples were heated at a heating rate of 100 K/h and held at 850 ºC for 1 hour.

Structural characterization was carried out by XRD and SEM analyses, while porosity, Young's modulus and thermal

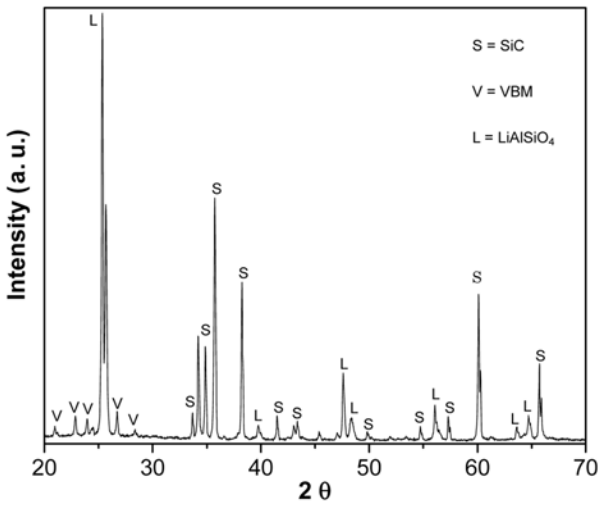

Fig. 1. XRD patterns of a porous material prepared at 850 ºC with SiC-VBM-$LiAlSiO_4$.

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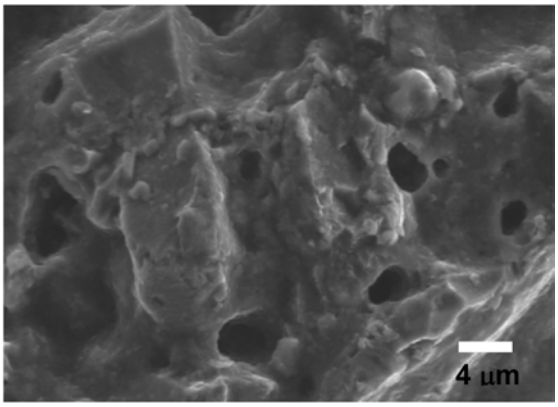

Fig. 2. Micrograph of a porous material of SiC-VBM-$LiAlSiO_4$ sintered at 850 °C.

expansion coefficient were measured by the Archimedes method, resonant frequency and dilatometry, respectively.

Results and Discussion

Fig. 1 shows the XRD pattern of a SiC-VBM-$LiAlSiO_4$ sample sintered at 850 °C; the particle size of $LiAlSiO_4$ used in this sample was 18 micrometers. It was observed that peaks corresponding to the raw materials are still present indicating that no reaction occurred between them at this temperature. However it is expected that VBM melts during sintering to act as a bridge between SiC grains.

The SEM micrograph of Fig. 2 shows the presence of VBM wetting and bonding SiC grains. It is possible to observe that its internal structure has pores with a size less than 4 micrometers. The porosity was 50% for the sample containing $LiAlSiO_4$ with a particle size of 18 micrometers, and 42% for the sample containing $LiAlSiO_4$ with a particle size of 4 micrometers.

Fig. 3 shows the Young's modulus values for the SiC porous materials prepared in this study. It is observed that the Young's modulus increased when the particle size of $LiAlSiO_4$ decreased.

According to this result, the Young's modulus value increased 50% when the particle size of $LiAlSiO_4$ decreased by almost four times (22 GPa when $LiAlSiO_4$ is 4 micrometers in size vs 15 GPa when $LiAlSiO_4$ is 18 micrometers in size); Young's modulus values were measured three times in each case.

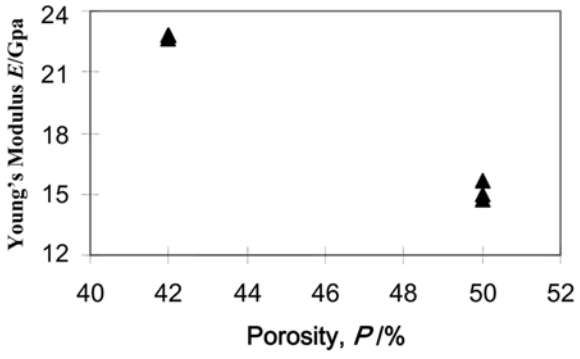

Fig. 3. Young's modulus values for samples containing SiC-VBM-$LiAlSiO_4$ sintered at 850 °C.

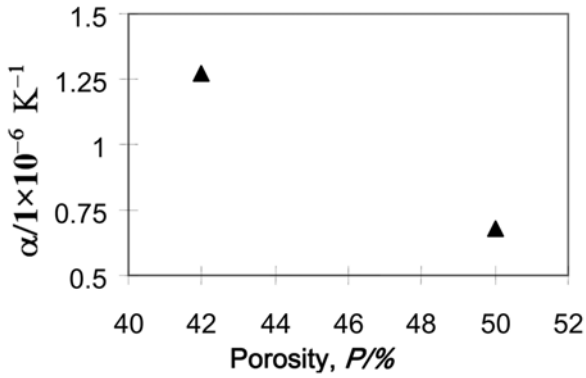

Fig. 4. Thermal expansion behavior for SiC-VBM-$LiAlSiO_4$ porous material sintered at 850 °C.

The behavior of the thermal expansion coefficient obtained for the samples prepared in this study is showed in Fig. 4. It is observed that changes in the particle size of $LiAlSiO_4$ did not affect considerably the thermal expansion coefficient of SiC porous materials. Such a situation is very important because according to this result, through the modification of the particle size of $LiAlSiO_4$ it is possible to keep low thermal expansion coefficient in SiC porous materials and increase their Young's modulus.

Conclusions

By decreasing the particle size of $LiAlSiO_4$ in almost four times it was possible to increase the Young's modulus value of SiC porous material keeping a low thermal expansion coefficient. No reaction between the raw materials during the sintering process of SiC porous material was detected and its internal structure had pores with size less than 4 micrometers. The use of raw materials with a small particle size could be an excellent option to fabricate SiC porous materials with low thermal expansion coefficient and high Young's modulus values.

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References

1. K. Ishizaki, S. Komarneni and M. Nanko in: Porous

Materials. Process Technology and Applications, edited by Kluwer Academic Publishers. The Netherlands (1998).
2. J.C. Zolper and M. Skowronki; MRS Bulletin, Vol. 30, (2005) 273-278.
3. Ruishou Li; PhD Thesis, Max-Planck Institut Für Metallforschung, Stuttgart, Germany (2001).
4. I. Juarez-Ramirez, K. Matsumaru and K. Ishizaki: Journal of the Ceramic Society of Japan 114 (2006) 1111-1114.
5. Isaías Juárez Ramírez, Koji Matsumaru, Kozo Ishizaki and Leticia M. Torres-Martínez; Materials Science Forum: Ecomaterials Processing and Design IX, 569 (2008) 321-324.
6. R. Roy, D.K. Agrawal and H.A. McKinstry in: Ann. Rev. Mater. Sci. 19 (1989) 59-81.
7. S. Okada in: "Development and Applications of Porous Ceramics", CMC, Tokyo (1991) 118-122.