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Toughening Effect and Oxidation Behavior of $MoSi_2$-ZrO_2 Composites

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Objective

In this study, the influence of particle size and volume percentage of unstabilized ZrO2-addition on toughening effect in MoSi2-matrix composites were investigated. And, the negative effect of ZrO2-addition on oxidation resistance of the composites was also observed. The aim of this study is to understand the both of positive and negative effects of ZrO2-addition on the composites for reaching a comprehensive results.

Materials and Preparation

- The commercial Kanthal powder (KT-MoSi2) with average size of 2.2 µm in diameter was applied for preparing the composites.
- The Five different USZ- ZrO2-particle sizes between 0.74–5.6µm and 10- 30 vol.% of <1 µm particles were used to prepare the testing materials.
- Composites were produced by two different powder metallurgical processes, including pressure-less sintering (PLS) at 1650°C in H2 for 1 hour and hot-press sintering (HPS) at 1600°C in Ar under 52 MPa for 2 hours.

Testing

1. The hardness and fracture toughness were determined by using Vicker´s indentation technique. And the fracture toughness was calculated by Anstis´equation.
2. The specimens were exposed in air under a temperature of 1400°C for 100 hours.
3. Backscattering electron images of SEM; EDS and XRD methods were applied for the analytical analysis.

Table2. Marks of the MoSi2 – 20vol.% ZrO_2 composites

Mark of sample	starting powder	sintering process
PLS – 1	KT-$MoSi_2$ + SF-Extra	Pressure-less sintered
PLS – 2	KT-$MoSi_2$ + DK-1	as above
PLS – 3	KT-$MoSi_2$ + SF-premium	as above
PLS – 4	KT-$MoSi_2$ + DK-2	as above
PLS – 5	KT-$MoSi_2$ + DK-3	as above
PLS – 6	KT-$MoSi_2$	as above

Table 5. Sintered density, room temperature hardness and toughness of five different ZrO_2-content composites prepared by PLS + HIP processes

Specimen	Sintered density (g/cm^3)	RT-Hardness (Hv, GPa)	RT-toughness ($MPam^{1/2}$)
HIP-1	6.31 (100%)	9.76 ± 0.20	4.50 ± 0.35
HIP-2	6.34 (100%)	9.64 ± 0.22	6.40 ± 0.35
HIP-3	6.17 (99.5%)	9.13 ± 0.25	5.65 ± 0.54
HIP-4	6.16 (99.5%)	8.96 ± 0.15	6.13 ± 0.41
HIP-5	6.16 (99.5%)	9.00 ± 0.20	5.79 ± 0.24

Table3. Marks; compositions of KT-$MoSi_2$ + C208-ZrO_2 composites prepared by PLS + HIP processes

Mark of sample	Starting powder (vol. %)	Sintering process
HIP-1	90 vol. %KT-$MoSi_2$ + 10 vol. % C208	Hot Isostatic Press
HIP-2	85 vol. %KT-$MoSi_2$ + 15 vol. % C208	as above
HIP-3	80 vol. %KT-$MoSi_2$ + 20 vol. % C208	as above
HIP-4	75 vol. %KT-$MoSi_2$ + 25 vol. % C208	as above
HIP-5	70 vol. %KT-$MoSi_2$ + 30 vol. % C208	as above

Conclusions

1. The particles of less than 1 µm usually generated the better results on sintered density, RT-hardness and RT-toughness of the composites, compared with the bigger particles.
2. The composites containing 15–25 vol.% USZ-particles showed a better toughening effect, compared to the composites having less or more particles.
3. External pressure of sintering process assisted the composites for a higher hardness, but slightly improved sintered density and toughness only. It means that the PLS process could be a practical and economical method for producing $MOSi_2$-ZrO_2 composites in industry.
4. A deteriorated oxidation resistance of $MoSi_2$-ZrO_2 composite compared to its monolithic counterpart is due to the formation of the porous oxide layer of $ZrSiO_4$+SiO_2 mixture and a retarded Si diffusion.
5. Therefore, an alloying addition for further forming a protective oxide layer is necessary on developing this type of composites.

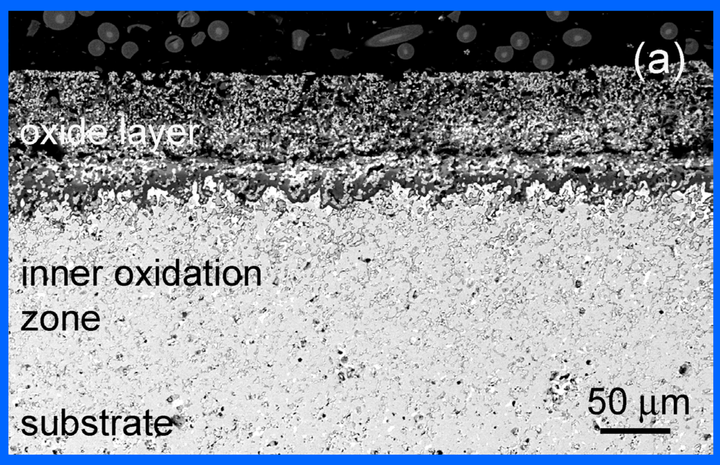

Fig.1 (a) shows the typical microstructures in the oxidized composite and monolithic specimens. The oxidized composite is characterized with a thick oxide layer and an inner oxidation zone with thickness of 110 µm and 200 µm respectively.

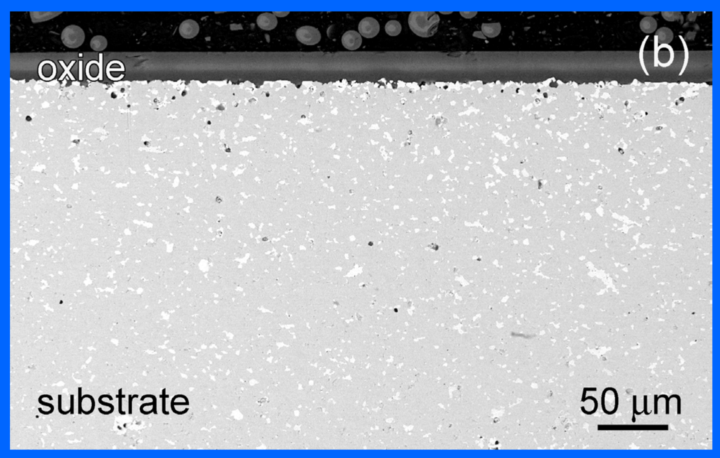

Fig.1 (b) the monolithic $MoSi_2$exhibits an excellent oxidation resistance due to a protective silica scale with an average thickness 25 µm, which is under one fourth of that in the composite counterpart. No inner oxidation occurs in the sub-interface region.

Table1. The starting powders of ZrO_2 used for preparing $MoSi_2$ – 20vol.% ZrO_2 composites

Commercial mark	SF-Extra	DK-1	SF-Premium	DK-2	DK-3
Average size (µm)	0.74	0.87	0.96	2.13	5.65

Table4. Sintered density, room temperature hardness and toughness of $MoSi_2$ – 20vol.%ZrO_2 composites by PLS process

Specimen	Sintered density (g/cm^3)	RT-Hardness (Hv, GPa)	RT-toughness ($MPam^{1/2}$)
PLS-1	6.07 (98%)	7.82	5.79
PLS-2	6.13 (99%)	7.80	6.89
PLS-3	6.08 (98%)	7.48	5.63
PLS-4	6.02 (97%)	6.97	4.61
PLS-5	5.89 (95%)	6.01	4.06
PLS-6	6.07 (97%)	9.19	3.09

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