The Effect of MgO-Y_2O_3 on Al_2O_3-TiC Composites

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Abstract

The effect of the additives, Y_2O_3 and MgO, on the sintering and properties of Al_2O_3-TiC composites was investigated. It is known that MgO is used as additive for improving densification and Y_2O_3 is applied as sintering aid. In this study, the amounts of TiC were varied in the range of 30-47 wt%. The 0.5 wt% MgO and also varied amounts of Y_2O_3 from 0.3 to 1 wt% were added into the composites. The sintering of Al_2O_3-TiC composites was performed in a graphite- heating element furnace at different sintering temperature, 1700 and 1900℃, for 2 hr under an argon atmosphere. The results demonstrated that the properties of the composites sintered at 1700℃ were much better than those sintered at 1900℃. The comparisons on physical properties, mechanical properties and microstructure of composites with and without additives were reported. Comparing with other samples, Al_2O_3-30wt%TiC composites with 0.5wt% MgO and 1 wt%Y_2O_3 exhibited the highest density of approximately 98% of theoretical and flexural strength of 302 MPa.

Keywords : Additives, Al_2O_3-TiC composites, Y_2O_3, MgO

1. Introduction

Al_2O_3-TiC composites have been widely used in various applications, especially as excellent cutting tool because of their attractive properties as high wear resistance, hardness, strength and fracture toughness. Commercial Al_2O_3-TiC ceramics are generally manufactured by the pressureless sintering or hot pressing at temperature in the range of 1600-1800^{o}C [1]. Due to the gas-generating reaction between Al_2O_3 and TiC at high temperature, it introduces pore into the composites that decrease mechanical properties. Thus, highly dense Al_2O_3-TiC composites are difficult to obtain by conventional sintering as pressureless sintering. Hot pressing and hot isostatic pressing are well practical to fabricate dense Al_2O_3-TiC composites to acquire higher mechanical properties. However, these processes are higher cost than pressureless sintering. In order to increase densification of the composites by pressureless sintering is to add an appropriate additive for sintering aid. Some researches reported that the sintering aid, MgO, TiO_2, Y_2O_3, Al, TiH_2 have been adopted in the fabrication of Al_2O_3-TiC composites with high relative density[2-4]. In this present study, the effects of additives, 0.5 wt%MgO and 0.3-1wt%Y_2O_3, on the physical and mechanical properties of Al_2O_3-30wt%TiC and Al_2O_3-47wt%TiC composites sintered at two different temperatures, 1700°C and 1900°C, were investigated.

2. Experimental and Results

The raw materials used for preparing the composites were a calcined Al_2O_3, TiC, MgO, and Y_2O_3 powders. All powders were mixed in proper propositions (Table 1) by ball milling with ethyl alcohol for 24. The slurry was then screened, dried at 100 °C, and then sieved through 100 mesh. The mixed powder was then uniaxially pressed at 7 MPa to form a square-shaped specimen (40×40× 8mm) followed by cold isostatic pressing (CIP) at 300 MPa for 3 min. The square samples with 53-56% theoretical density were obtained. Samples were sintered at 1700 and 1900 ^{o}C for 2 h under an argon atmosphere. Physical, mechanical properties and morphologies of samples were determined.

It was found that the density decreased with the addition of MgO and Y_2O_3 for both samples sintered at 1700^{o}C and 1900^{o}C. The composites with additives sintered at 1700 ^{o}C attained higher density than ones sintered at 1900 ^{o}C. It is evident that the sintered density of the Al_2O_3-30wt%TiC -0.5 wt%MgO- 1 wt%Y_2O_3 composite sintered at 1700 ^{o}C was highest among composites adding additives, almost 98%, and even higher than that of the Al_2O_3-30wt%TiC composite sintered at 1900 ^{o}C (sample A). It is recognized that the appropriate sintering temperature and amount of additives play critical roles in order to improve the mechanical properties. At 1900^{o}C, the mechanical properties except fracture toughness of the MgO-Y_2O_3 doped Al_2O_3-TiC composites are relatively lower than undoped composites for both sintered at 1700 and1900^{o}C. However, it is interesting that the mechanical properties (except for the fracture toughness) of the doped composites sintered at 1700^{o}C are substantially greater than those for doped composites at 1900^{o}C. In addition, the addition of sintering aid, MgO and Y_2O_3, results in some different effects on the properties of composites. The doped -Al_2O_3-30wt%TiC samples obtained better mechanical properties besides fracture toughness than the doped-Al_2O_3-47wt%TiC. Furthermore, the composites with the same amount of dopants behave differently upon sintering temperature. With the increase in the amount of Y_2O_3 from 0.3 to 1 wt%, the flexural strength and hardness of the composites sintered at 1700 °C increase significantly, while the fracture toughness decrease gradually. The contrast results are revealed at 1900°C sintering condition.

The phase analysis revealed only Al_2O_3 and TiC phase. The stronger peaks of TiC phase were observed at 1700 °C compared to 1900 °C which reflectd the superior density and mechanical properties except fracture toughness of the composites sintered at 1700 °C. The composites with MgO and Y_2O_3 (sample C-F) additives revealed less densified structure as compared to ones without addives. In addition, the products sintered at 1700°C (sample C,D,E,F-2) revealed dense microstructures with smaller grain sizes, while the porous microstructures were observed in the specimens sintered at 1900 °C (sample C,D,E,F-1). Most of the pores appear to be associated with the TiC particles and clusters. In this study, it was found that the Al_2O_3-30wt%TiC doped with MgO and Y_2O_3 in a proper amount, as 0.5 and 1 wt%, and sintered at 1700 °C (sample D-2), has the highest density, hardness, and flexural strength of 4.067 g/cm^3, 14.43 GPa, and 302 MPa, and obtained the highest dense structure.

3. Summary

The addition of MgO and Y_2O_3 in small amounts reduced the sintering temperature, enhanced the densification and provided good mechanical properties of Al_2O_3-30wt%TiC composites. The 0.5wt%MgO-1wt%Y_2O_3 as additives of Al_2O_3-30wt%TiC sintered at 1700 °C would probably be the appropriate amounts to suppress the gas-generating reaction. Under processing conditions employed in this study, the near-full densification with a lower sintering temperature was achieved in the Al_2O_3-30wt%TiC-0.5wt%MgO-1wt% Y_2O_3 composites.

4. References

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Table 1. The compositions of the composites

Process	Sample	composition (Al_2O_3:TiC)	MgO (%wt)	Y_2O_3 (%wt)	Sample	composition (Al_2O_3:TiC)	MgO (%wt)	Y_2O_3 (%wt)
CIP, 1900°C	A	70:30	-	-	B	53:47	-	-
CIP, 1900°C	C-1	70:30	0.5	0.3	E-1	53:47	0.5	0.3
	D-1	70:30	0.5	1	F-1	53:47	0.5	1
CIP, 1700°C	C-2	70:30	0.5	0.3	E-2	53:47	0.5	0.3
	D-2	70:30	0.5	1	F-2	53:47	0.5	1

Table 2. Physical and mechanical properties of sintered Al_2O_3-TiC composites.

Sample	Bulk density (g/cm^3)	Relative density (%)	Apparent porosity (%)	Water absoption (%)	Young's modulus (GPa)	H_v (GPa)	Flexural strength (MPa)	Fracture Toughness (MPa m $^{1/2}$)
A	3.980	95.66	0.658	0.165	356	15.78	290	4.69
B	4.242	98.19	0.342	0.080	380	19.52	399	3.45
C-1	3.763	90.46	2.960	0.784	279	7.23	144	7.39
D-1	3.724	89.52	3.690	0.988	259	6.12	128	7.60
E-1	3.708	85.84	12.620	3.394	222	5.28	128	8.61
F-1	3.686	85.33	10.791	2.919	211	5.36	112	7.37
C-2	3.846	92.46	7.231	1.875	300	11.02	260	4.75
D-2	4.067	97.76	0.401	0.098	352	14.43	302	3.98
E-2	3.733	86.42	13.247	3.539	253	8.15	230	5.87
F-2	3.950	91.43	7.960	2.010	292	10.70	263	4.77
Commercial	4.200	-	-	-	-	19.57	-	-