Powder Injection Molding of Alumina Parts Using a Binder System Based in Paraffin Wax and High Density Polyethylene

P. Thomas-Vielma[1,a], A. Cervera[2,b], B. Levenfeld[1,c] and A. Várez[1,d]

[1] Materials Science and Engineering Department. Universidad Carlos III de Madrid.Avda. de la Universidad, 30. 28911 Leganés. SPAIN.
Chemistry and Materials Technologic Institute "Alvaro Alonso Barba"
[2]Euroortodoncia. C/ Aeronáuticas, 18. Polígono Industrial Urtinsa. 28923-Alcorcón
[a]pthomas@ing.uc3m.es, [b]acervera@teleline.es, [c]alvar@ing.uc3m.es

Abstract

In this experimental work, the development of a multicomponent binder system based on high density polyethylene (HDPE) and paraffin wax for Powder Injection Molding of Alumina (Al_2O_3) parts was carried out. The optimum composition of the injection mixture was established through mixing torque measurements and a rheological study. The maximum powder loading was 58 vol%. The miscibility of organic components and the optimum injection temperature was evaluated by thermal characterization of binder and feedstock. The thermal debinding cycle was developed on the basis of thermogravimetrical analysis of the binder. After sintering the densities achieved were closed to 98% of the theoretical one.

Keywords : Alumina, ceramic injection molding, polyethylene

1. Introduction

Ceramic Injection Molding (CIM) is a cost effective technique in high volume production of small, complex, precision parts. The process involves several steps ranging from mixing to sintering [1]. Feedstock preparation for CIM is a crucial step. It involves mixing selected powder and binder in the correct proportion. Very fine powder of tipically less than 20 µm are usually preferred[2] with multi component binder systems comprising by three components: a backbone polymer that provides strength, a filler phase that is easily extracted in the first phase of debinding, and a surfactant serving as a bridge between the binder and powder[1]. The properties of sintering parts depend strongly on the homogeneity of feedstocks[3]. Failure to disperse the powder uniformly or unsuitable rheological properties will cause molding defects such as distorsions, cracks or voids that will lead to non-uniform shrinkage or warping in the sintered parts[2]. The quality of the mechanical strength of a ceramic injection molded part is relevant to the solid loading (55-60 vol.%) of feedstocks[3].

2. Experimental and Results

Alumina powder of commercial purity (Alcoa, CT3000SG) with particle size of 0.8 µm was used in this study. A multicomponent binder system was used to prepare the alumina feedstock (table 1).

Table 1. Characteristics of binders used in this study

Binder	Density (g/cc)	Tm (ºC)
Stearic Acid (SA)	0.94	71.05
High Density Polyethylene (HDPE)	0.96	132.70
Paraffin Wax (PW)	0.91	56.97

Formulations containing powder loading between 50 and 60 vol% of powder were prepared in order to study the effect of solid loads on torque and rheological behavior. Mixing was performed in a Haake Rheocord machine. Table 2 illustrates the composition of the feedstocks used in this study.

Table 2. Feedstock compositions.

Powder Loading (Vol.%)	By weight (%)				
	Al_2O_3	HDPE	PW	SA	Label
50	80.64	9.93	8.66	0.78	A50
55	83.58	8.41	7.34	0.66	A55
58	85.19	7.59	6.62	0.59	A58
60	86.20	7.07	6.17	0.55	A60

The elimination of the polymeric part was carried out by inmersion of the parts in n-heptane at 60 ºC followed by thermal heating. The thermal cycle was designed on the basis of a thermogravimetrical analysis. The total debinding time was 19 hours. The pieces were sintered during 2 hours at different temperatures (1500, 1550, 1600 and 1650ºC).

Figure 1 shows torque *vs*. time of processed feedstocks with different powder loads. Higher powder loading resulted in a higher torque level at the end of the mixing process, when the steady stage was achieved.

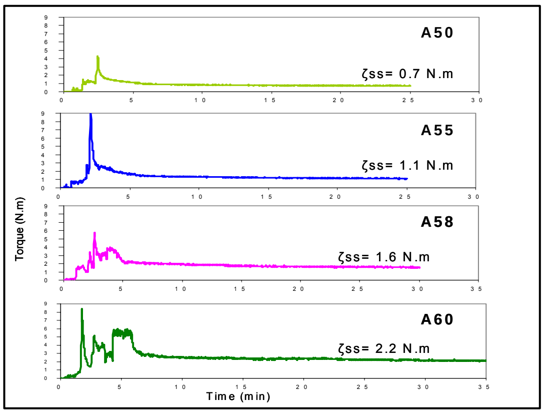

Fig. 1. Mixing behavior for different volumetric powder loading.

Figure 2 shows the viscosity vs. shear rate curve for feedstocks A50, A55, A58, A60 at injection temperature. Viscosity of all feedstocks decreases as the shear rate increases, according with a pseudoplastic behaviour. This behaviour is the most suitable for injection moulding purpose. As it was expected, viscosity increases with the powder loading. Feedstock A60 exhibited the highest torque and viscosity; however the homogenity of the mixture was not suitable. Formulations A50 and A55 showed adequate rheological behavior but their lower solid content could be a problem for the quality of the mechanical strength of the injection molded part[4]. For this reason Feedstock A58 was selected as the most suitable mixture.

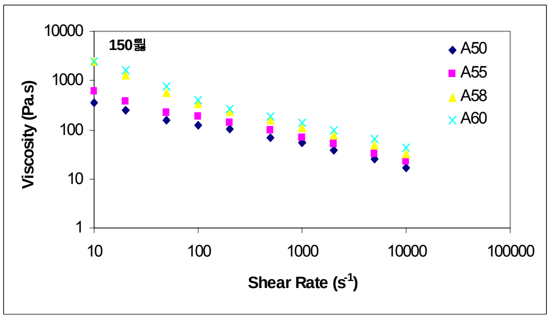

Fig. 2. Viscosity *vs*. shear rate graphs of feedstocks.

Figure 3 shows density *vs*. sintering temperature. Sintering temperatures higher than 1600ºC do not have an important effect in density. For this reason, this temperature was chosen for sintering at diferents times.

Figure 4 shows the evolution of the microstructure with the sintering time for samples sintered at 1600ºC, where a grain growth with sintering time is detected.

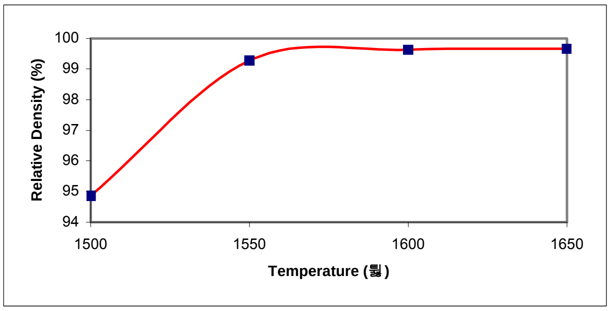

Fig. 3. Relative density *vs*. sintering temperature.

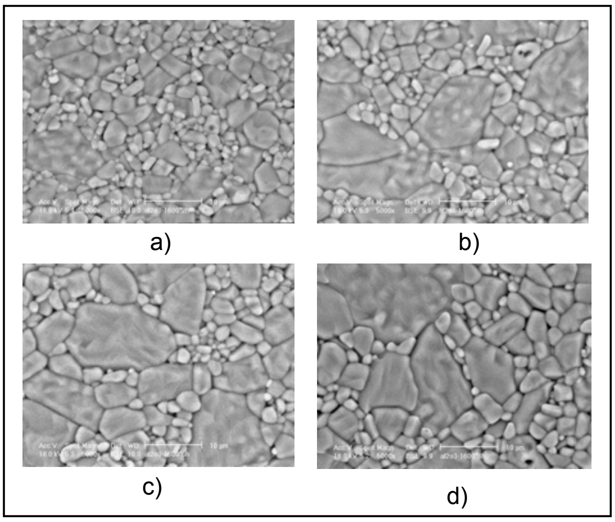

Fig. 4. SEM micrographs of Al_2O_3 sintered at 1600ºC during: a) 2h, b) 4h, c) 6h, d) 8h.

3. Summary

Alumina feedstock with a multicomponent binder system based on HDPE was developed with a maximum powder loading of 58%. The total time of the debynding cycle was 19 h. After sintering parts showed densities close to 99%.

4. References

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