



Exploring composites based on PPO blend as ablative thermal protection systems – Part II: The role of equiaxial fillers

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ABSTRACT

Similarly to the activity described in Part I, the PPO-based composites were studied in view of their pre-screening as potential candidates in innovative ablative shields. In this case equiaxial, oxide and non-oxide powders, precisely magnesium aluminate spinel, aluminum hydroxide (boehmite), δ - and α -alumina, silicon carbide, silicon nitride and molybdenum disilicide, were used as fillers. Nanometric and micrometric α -alumina and silicon carbide powders were exploited to investigate the effect of the particle size. The alumina-based composites presented the most promising behavior. On the other hand, molybdenum disilicide implied a significant decrease in thermal stability and combustion time.

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1. Introduction

Generally, polymer nanocomposites are prepared by using inorganic layered fillers, due to their small particle sizes and intercalation properties [1]. For this reason, in Part I, two clays and a layered silicate, sepiolite, were investigated as fillers in the PPO composites as alternative materials for ablative thermal protection systems (TPSS).

Recently, different kinds of fillers, such as boron nitride, aluminum nitride, silicon nitride [2,3], alumina, silicon carbide [4], silica, and diamond, have been studied to improve the thermal behavior (for instance, in terms of thermal stability, thermal conductivity [2,4]) of polymer composites.

Non-oxide silicon-based ceramics have already been used for aerospace applications (for example, as thermal heat shields for space vehicles) [5]. Moreover, these materials undergo oxidation phenomena at high temperature yielding silica [5,6], that could stabilize the char and form a protective layer on the composite surface [7]. On this ground, the non-oxide fillers silicon carbide, silicon nitride and molybdenum disilicide [8] were selected for this preliminary study.

As well as silica-based ceramics, aluminas have also been widely employed for thermal protection applications [9]. Among the different alumina phases (α , η , χ , δ , κ , θ , γ , ρ Al_2O_3), alpha-alumina is the thermodynamically stable phase, while the others are metastable and undergo transformation during heating [10]. In order to evaluate the influence of the nature of the ceramic phase, but also of the related transformation, both δ and α -alumina were selected. An aluminum hydroxide (boehmite, γ - $\text{Al}(\text{OH})_3$) was

also exploited as filler, since it undergoes dehydroxylation and then several phase transformations during heating [11,12]. Finally, the widely used, refractory spinel (MgAl_2O_4) was investigated, also considering its chemical similarity to hydrotalcite (aluminum magnesium layered double hydroxide), already studied in Part I.

2. Experimental

2.1. Materials

2.1.1. Polymeric matrix

The PPO/PS matrix is the grade Noryl® 914 (produced by GE Plastics), and its properties were already described in Part I of this paper.

2.1.2. Inorganic fillers

Several quasi-spherical oxide and non-oxide ceramic particles were investigated as fillers: magnesium aluminate spinel, aluminum oxyhydroxide (boehmite), two alumina (precisely, a stable and a metastable phase, α - Al_2O_3 and δ - Al_2O_3), silicon carbide, silicon nitride and molybdenum disilicide. For both α -alumina and silicon carbide, two commercial powders having different particle size distribution, were selected to evaluate the size effect.

The main features of the above-mentioned inorganic fillers are shown in Table 1, together with their designation.

In Fig. 1 the particle size distribution of the as-received powders are collected: the nanometric powders, in particular, δ , n α and n SC, are affected by a severe agglomeration, as generally occurs [13]. On the other hand, the particle size distributions of μ α , μ SC and N powders presented a mean diameter of about 1 μm , whereas in the case of M filler the distribution was centered at about 3 μm .

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Table 1
Summary of the fillers and their designation.

Filler	Designation	Chemical nature	Density (g/cm ³)	Average crystallite (nm)
Spinel by Nanocerox	SP	MgAl ₂ O ₄	3.58	30
Disperal® 40 by SASOL	B	γ-AlOOH	3.03	300
Nanotek® by Nanophase Technology	δ	δ-Al ₂ O ₃	3.60	45
TM-DAR® Taimicron by Taimei Chemicals Co.	n α	α-Al ₂ O ₃	3.96	150
Aluminum oxide by Alfa Aesar	μ α	α-Al ₂ O ₃	3.96	n.a.
Nano beta-silicon carbide by Marketech	n SC	SiC	3.10	30
Alpha-silicon carbide Grade UF-10 by H.C. Starck	μ SC	SiC	3.10	700
Alpha-silicon nitride Grade M 11 by H.C. Starck	N	Si ₃ N ₄	3.29	600
Molybdenum disilicide Grade C by H.C. Starck	M	MoSi ₂	6.29	2500

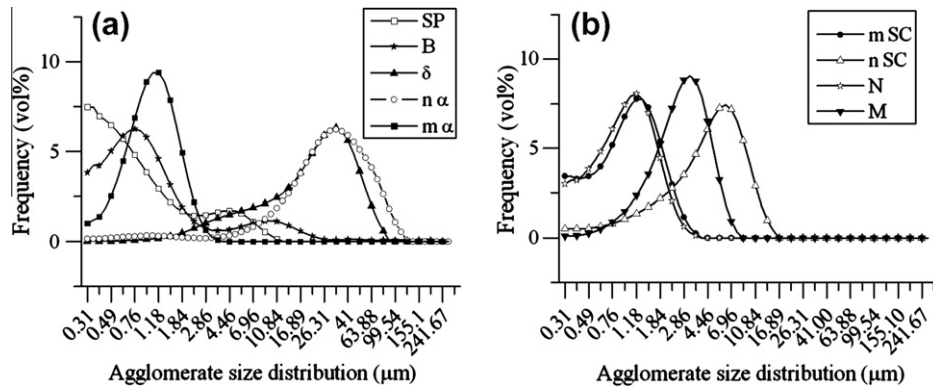


Fig. 1. Agglomerate size distributions of the as-received (a) oxide and (b) non-oxide fillers.

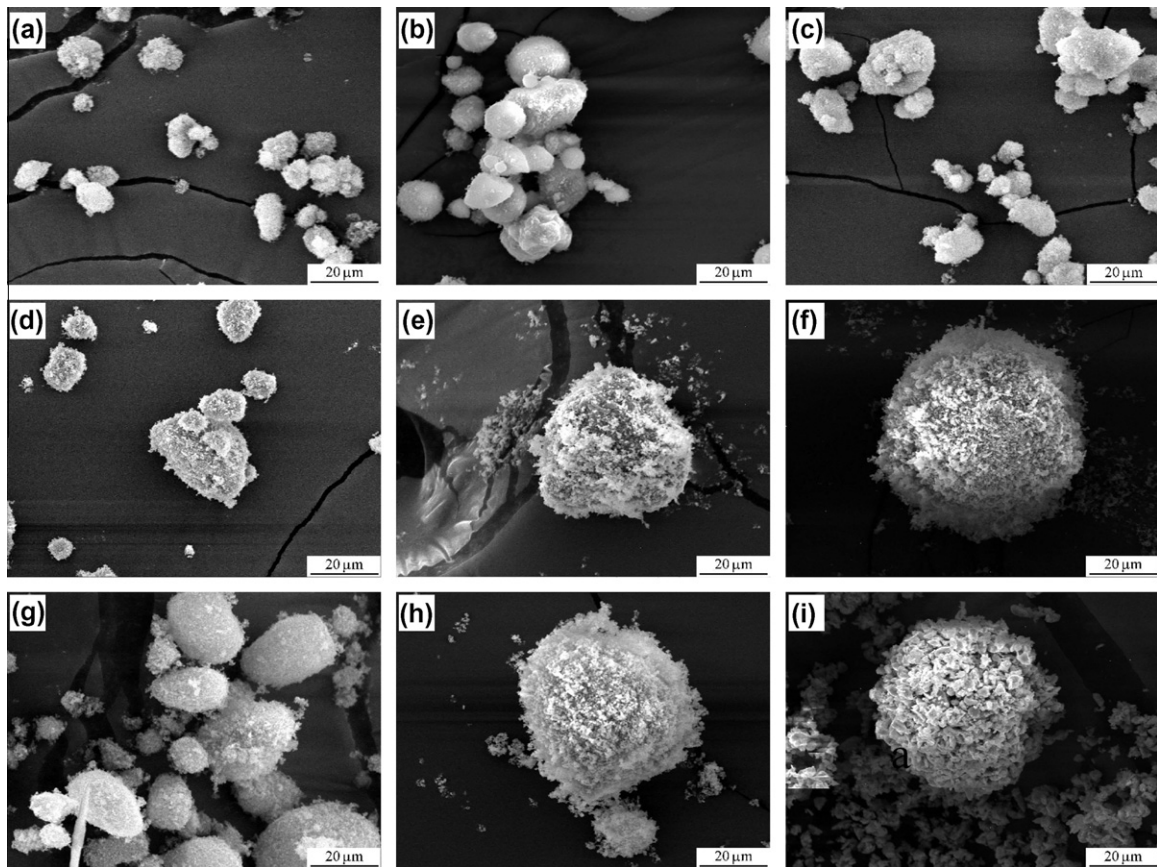


Fig. 2. SEM micrographs of the as-received powders: (a) SP; (b) B; (c) δ; (d) n α; (e) μ α; (f) μ SC; (g) n SC; (h) N and (i) M.

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