Materials Letters 210 (2018) 182–185

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/mlblue

Morphology-controlled synthesis of α-alumina microplatelets through an additive-assisted molten salt reaction

Minmin Zhang [a], Yunfei Chang [a,b,*], Nuerxida Pulati [b], Shantao Zhang [c], Yuan Sun [a], Jie Wu [a], Yingchun Liu [a], Bin Yang [a,*], Wenwu Cao [a,d]

[a] Condensed Matter Science and Technology Institute and Department of Physics, Harbin Institute of Technology, Harbin 150080, China
[b] Department of Materials Science and Engineering, The Pennsylvania State University, University Park, PA 16802, USA
[c] National Laboratory of Solid State Microstructures, Nanjing University, Nanjing 210093, China
[d] Materials Research Institute, The Pennsylvania State University, University Park, PA 16802, USA

ARTICLE INFO

Article history:
Received 24 June 2017
Received in revised form 24 August 2017
Accepted 2 September 2017
Available online 7 September 2017

Keywords:
Molten salt synthesis
Additive
Morphology
X-ray techniques
Crystal growth

ABSTRACT

Highly dispersed α-Al_2O_3 microplatelets of various sizes and aspect ratios were prepared by additive-assisted molten salt synthesis. The effects of SiO_2 and SiO_2 + CaO additions on phase formation and morphology development of α-Al_2O_3 particles were investigated. Introducing additives are very effective in controlling α-Al_2O_3 morphology. SiO_2 additive significantly enhances shape anisotropy of α-Al_2O_3 platelets, where a particle aspect ratio ~23.8 was achieved, about 2.7–6.0 times higher than those of the platelets prepared without additives. When using SiO_2 + CaO mixture, low concentration additive facilitates the growth of large platelets (~9.8 μm), while increasing its content dramatically reduces the platelet size to ~3.7 μm. These findings provide a new insight for the design and synthesis of novel advanced anisotropic microcrystals with improved quality.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

α-Al_2O_3 platelets have attracted extensive attention recently due to their unique mechanical, electrical, thermal and chemical properties. Because of the special two-dimensional structure, they are widely used as reinforcements in composites to enhance mechanical properties [1–3], as templates for fabricating textured ceramics with anisotropic properties [4,5], and as fillers to plastics for thermal conductivity improvement [6] etc. Since the applications of α-Al_2O_3 particles strongly depend on their morphologies [1–7], controlling morphological characteristics of α-Al_2O_3 are essential.

Molten salt synthesis (MSS) is a very important method to fabricate anisotropic microcrystals [8,9]. Different from solid-state reaction, the unconstrained growth environment in molten salt (s) facilitates formation of less/non-aggregated platelets according to α-Al_2O_3 crystal structure. Among the factors [9–13] that affect the morphology of α-Al_2O_3 particles, introducing additives play a positive role in controlling crystalline growth habits in molten salt(s). As the well-known additives, PO_4^{3-} and Ti^{4+} are very helpful to modify the morphology of α-Al_2O_3 platelets [10,13]. Unfortunately, these additives either substantially reduce aspect ratio or remarkably broaden size distribution range of the products [10,13], which are not beneficial to significantly improve structural/functional properties of α-Al_2O_3 applications.

SiO_2-containing additives (either SiO_2 or SiO_2 + CaO) favor anisotropic grain growth inside alumina ceramics through forming liquid phase(s) at grain boundaries [4,14]. This merit makes them to be promising morphological modifiers for α-Al_2O_3 particles during MSS. However, the effects of SiO_2 and CaO additives on crystallization behavior and morphology characteristics of α-Al_2O_3 particles have been rarely studied. In this work, we report our achievements on the above-mentioned issues.

2. Experimental procedures

Equiaxed γ-Al_2O_3 particles (~60 nm) were used as the precursor, and SiO_2 (~15 nm) and $CaCO_3$ (≤100 nm) were used to provide SiO_2 and CaO + SiO_2 (1:1, molar ratio) additives during MSS. For salt effect study, γ-Al_2O_3 was mixed with Na_2SO_4 or Na_2SO_4 + K_2SO_4 mixture (1:1, molar ratio) at different molar ratios. For additive effect study, different amounts of SiO_2 and SiO_2 + $CaCO_3$ were added to γ-Al_2O_3 + Na_2SO_4 + K_2SO_4 mixture (1:1:1, molar ratio).

* Corresponding authors at: Condensed Matter Science and Technology Institute and Department of Physics, Harbin Institute of Technology, Harbin 150080, China (Y. Chang).
E-mail addresses: changyunfei@hit.edu.cn (Y. Chang), binyang@hit.edu.cn (B. Yang).

http://dx.doi.org/10.1016/j.matlet.2017.09.025
0167-577X/© 2017 Elsevier B.V. All rights reserved.

All powder mixtures were ball-milled in ethanol for 24 h. After drying, they were heated at 5 °C/min to 1100–1200 °C and held for 1–4 h. The final products were washed and separated with hot deionized water several times to remove the salt(s) and residual additive(s). Crystalline phase was determined by X-ray diffraction (XRD, D/max 2400, Rigaku Corporation, Tokyo, Japan). Morphological features were observed by field-emission scanning electron microscopy (FE-SEM, HELIOS NanoLab 600i, FEI Corporation, OR, USA).

3. Results and discussion

Fig. 1 shows SEM micrographs of Al_2O_3 particles synthesized (a) without salts and with (b) Na_2SO_4 or (c, d) $Na_2SO_4 + K_2SO_4$ salt(s). Spherical particles with an average diameter (d) ~0.2 μm were obtained without salts at 1100 °C. According to the XRD analysis, they are mainly of γ-Al_2O_3 phase. Adding Na_2SO_4 and $Na_2SO_4 + K_2SO_4$ salts accelerated α-Al_2O_3 phase formation, producing pure α-Al_2O_3 at 1100 °C. Well-dispersed hexagonal platelets with d ~3.2 μm and diameter/thickness aspect ratio (d/t) ~6.2 (Fig. 1e) were obtained from γ-$Al_2O_3 + 3Na_2SO_4$. Mixture γ-$Al_2O_3 + Na_2SO_4 + K_2SO_4$ yielded larger platelets with d ~5.7 μm and d/t ~8.7. Doubling $Na_2SO_4 + K_2SO_4$ amount leads to slight decreases of both d and d/t. For the oriented platelets synthesized from γ-$Al_2O_3 + Na_2SO_4 + K_2SO_4$, the XRD pattern (Fig. 1f) is dominated by 0006 and 00012 peaks, confirming that their basal faces are of {0 0 0 l} planes.

Fig. 2 presents XRD patterns of Al_2O_3 particles synthesized with (a) x wt% SiO_2 and (b) x wt% $SiO_2 + y$ wt% CaO (1:1, molar ratio) additives. For the particles formed with SiO_2 and heated at 1150 °C, pure α-Al_2O_3 was achieved at $x = 0$ and 0.15, but γ-Al_2O_3 and α-Al_2O_3 coexisted at $x = 0.30$ and 0.50. Transformation of γ-Al_2O_3 to α-Al_2O_3 completed at 1200 °C for $x = 0.30$ and 0.50, suggesting that more SiO_2 retards α-Al_2O_3 phase transition and crystallization. For the particles synthesized with $CaO + SiO_2$ and heated at 1150 °C, γ-Al_2O_3 and α-Al_2O_3 coexisted at $x = 0.155$ and

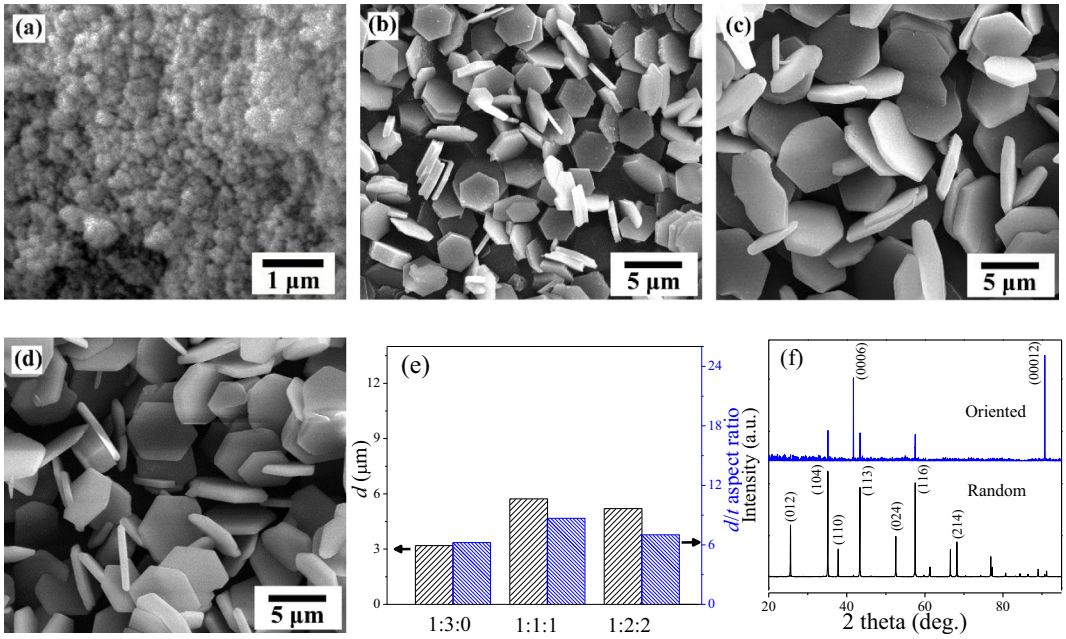

Fig. 1. SEM micrographs of Al_2O_3 particles synthesized with γ-Al_2O_3/Na_2SO_4/K_2SO_4 = (a) 1:0:0, (b) 1:3:0, (c) 1:1:1 and (d) 1:2:2 at 1100 °C, respectively; (e) Average diameter and diameter/thickness aspect ratio of α-Al_2O_3 platelets; (f) XRD patterns of α-Al_2O_3 platelets synthesized from γ-$Al_2O_3 + Na_2SO_4 + K_2SO_4$ mixture: randomly oriented platelets and well-oriented ones aligned by casting these platelets on a glass substrate.

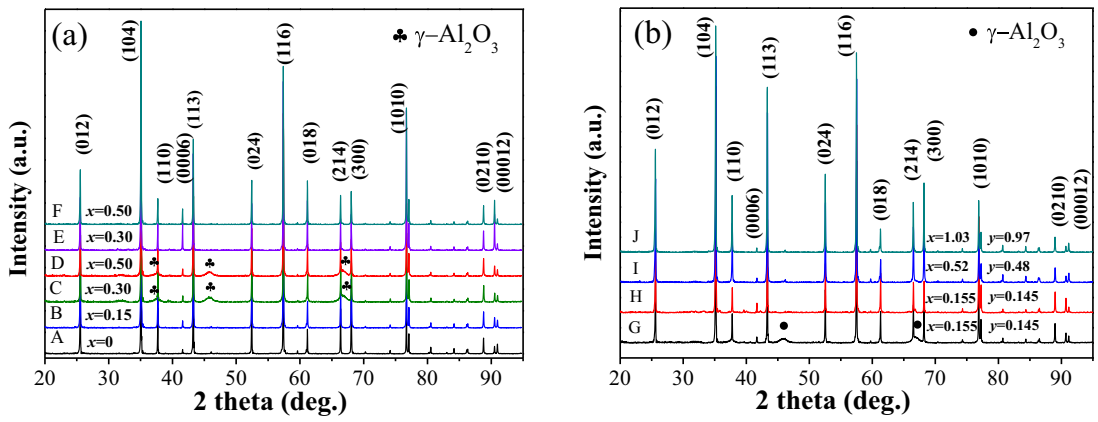

Fig. 2. XRD patterns of Al_2O_3 particles synthesized with (a) x wt% SiO_2 and (b) x wt% $SiO_2 + y$ wt% CaO at 1150 °C (A–D, G, I, and J) or 1200 °C (E, F and H), respectively.

Download English Version:

https://daneshyari.com/en/article/5462626

Download Persian Version:

https://daneshyari.com/article/5462626

Daneshyari.com