

Investigation of Structural and Electrical Properties of Al₂O₃/Al Composites Prepared by Aerosol Co-Deposition

Victor Regis ^{1,2}, Matej Šadl ¹, Geoff Brennecka ³, Andraž Bradeško ¹, Urban Tomc ⁴ and Hana Uršič ^{1,2,*}

¹ Electronic Ceramics Department, Jožef Stefan Institute, Jamova Cesta 39, 1000 Ljubljana, Slovenia

² Jožef Stefan International Postgraduate School, Jamova cesta 39, 1000 Ljubljana, Slovenia

³ Colorado School of Mines, 1500 Illinois Ave., Golden, CO 80401, USA

⁴ Laboratory for Refrigeration and District Energy, Faculty of Mechanical Engineering, University of Ljubljana, Aškerceva Cesta 6, 1000 Ljubljana, Slovenia

* Correspondence: hana.ursic@ijs.si

S1: Particle size distribution

To ensure that the composite powder particles were within the optimal range for AD, within 0.2 μm – 5 μm [21], the particle size distribution of all the compositions was measured (Figure S1). Notice the continuous shift from the Al₂O₃ peak at 0.4 μm to the Al peak at 1.5 μm.

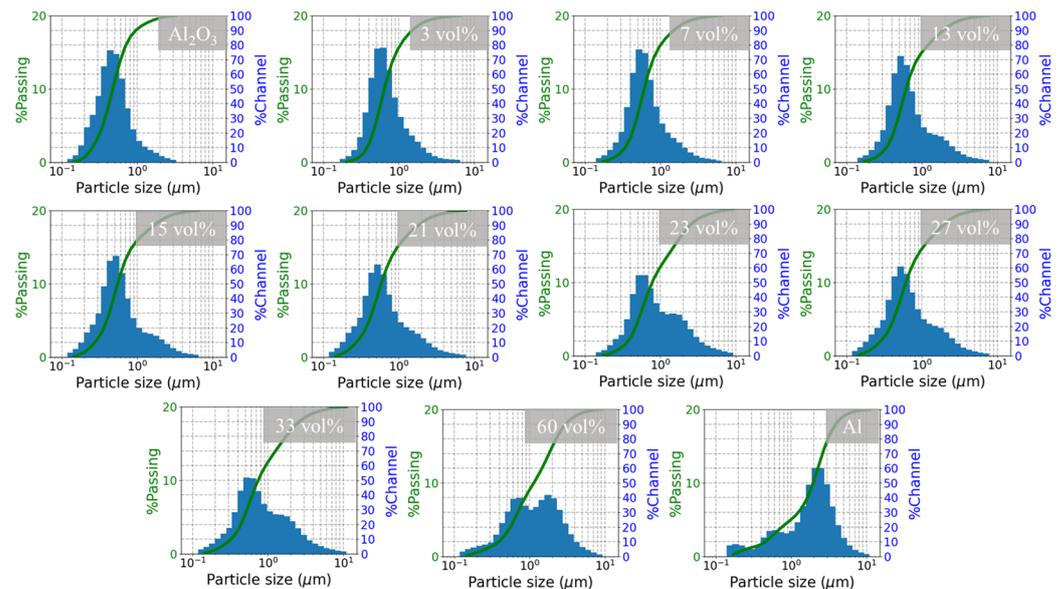


Figure S1: Particle size distribution of all compositions.

S2: X-ray patterns of composite powders

Before the depositions, X-ray patterns of the powders were measured, as shown in Figure S2. Distinctive Al₂O₃ and Al peaks can be observed, with no peak shifts from the peak positions of Al₂O₃ (reference code: 01-071-1123) or Al (reference code: 01-089-2837), indicating no reacting between Al₂O₃ and Al. As expected, with increasing Al content in the compositions, the Al₂O₃ peaks become less intense, whereas Al peaks become more intense.

Citation: Regis, V.; Šadl, M.; Brennecka, G.; Bradeško, A.; Tomc, U.; Uršič, H. Investigation of Structural and Electrical Properties of Al₂O₃/Al Composites Prepared by Aerosol Co-Deposition. *Crystals* **2023**, *13*, 850. <https://doi.org/10.3390/cryst13050850>

Academic Editor: Dah-Shyang Tsai

Received: 24 April 2023

Revised: 12 May 2023

Accepted: 19 May 2023

Published: 21 May 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

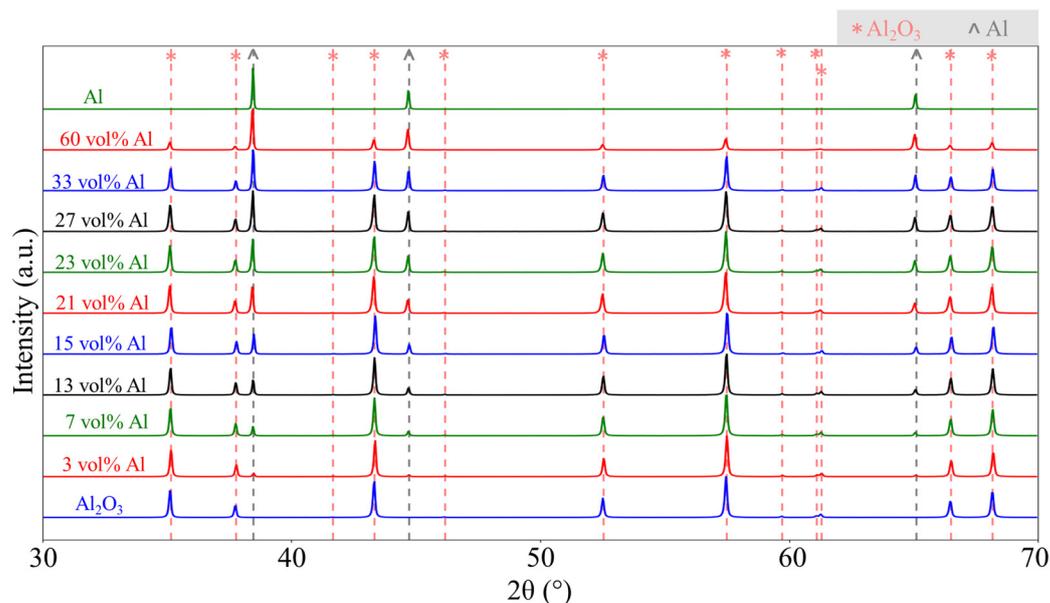


Figure S2. X-ray patterns of the composite powders.

S3: SEM images of composite powders

To analyze the morphology of the precursor powders, the powders were investigated using scanning electron microscopy (Prisma E, Thermo Fisher Scientific, Massachusetts, USA). Prior to the SEM analysis, the powders were deposited on carbon tape and coated with a 10-nanometre-thick carbon layer by carbon evaporation (Bal-Tec Sputter-coater SCD 050, Bal-Tec, Pfäffikon, Switzerland). From the SEM images, it can be seen that the Al particles have a typical mostly spherical shape, while the Al₂O₃ particles are smaller and have irregular shapes. In the composite precursor powders, as expected, the Al particles become increasingly more evident with larger Al vol% (some examples are marked by red arrows until the composition 33 vol% of Al).

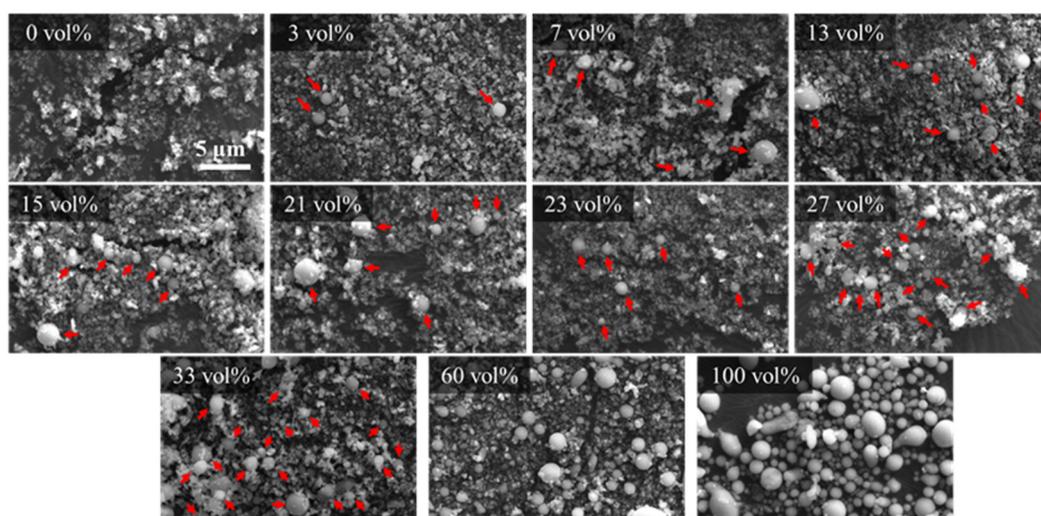


Figure S3. SEM images of the precursor powder of all compositions. The red arrows indicate some of the Al particles within the Al₂O₃ matrix for Al₂O₃-rich compositions. For visual clarity, the Al particles in the 60 vol% composition are not indicated by red arrows because the Al content predominates.

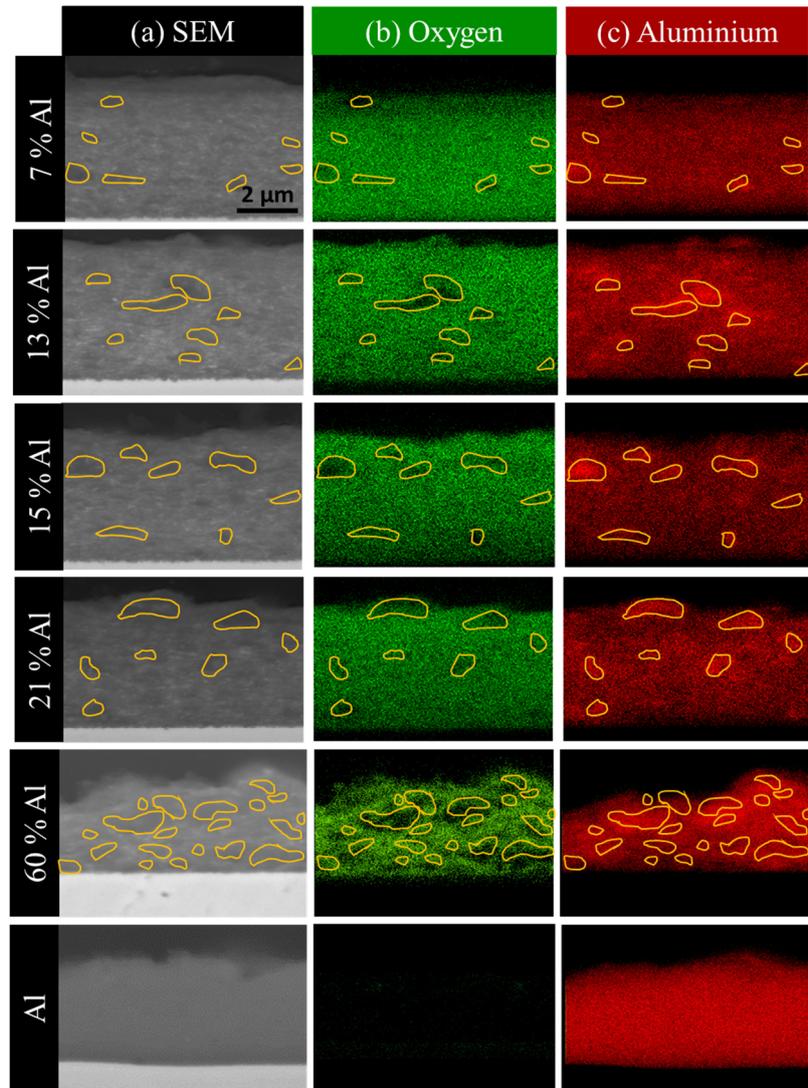
S4: Additional SEM and EDS analyses of the composites

Figure S4. SEM images (a) and EDS mapping of oxygen (b) and aluminium (c) for 7 vol%, 13 vol%, 15 vol%, 21 vol%, 60 vol%, and Al films. The regions highlighted in yellow indicate the aluminium phase within the alumina matrix. Yellow lines are guides to the eye.

S5: Quantitative analysis of the Al vol% within the Al₂O₃ matrix

Using a combination of SEM images and EDS mappings, the Al volume fraction in the thick films was estimated and compared to the nominal Al volume fraction in the powder mixtures (see Figure S5). The estimated Al volume fraction in the thick films was defined as the ratio between the sum of the surface areas of the Al particles and the total cross-sectional area of the thick film in a SEM / EDS image. The procedure was performed on three different areas (three SEM/EDS images of the thick film cross-section with a magnification of 15000 times), and the compositions 3 vol%, 23 vol%, 27 vol%, and 33 vol% were selected as representative cases. From the estimates, the average experimental Al volume percentage value in the thick films is comparable to the nominal value of the powder mixture before AD, so both quantities can be considered equivalent.

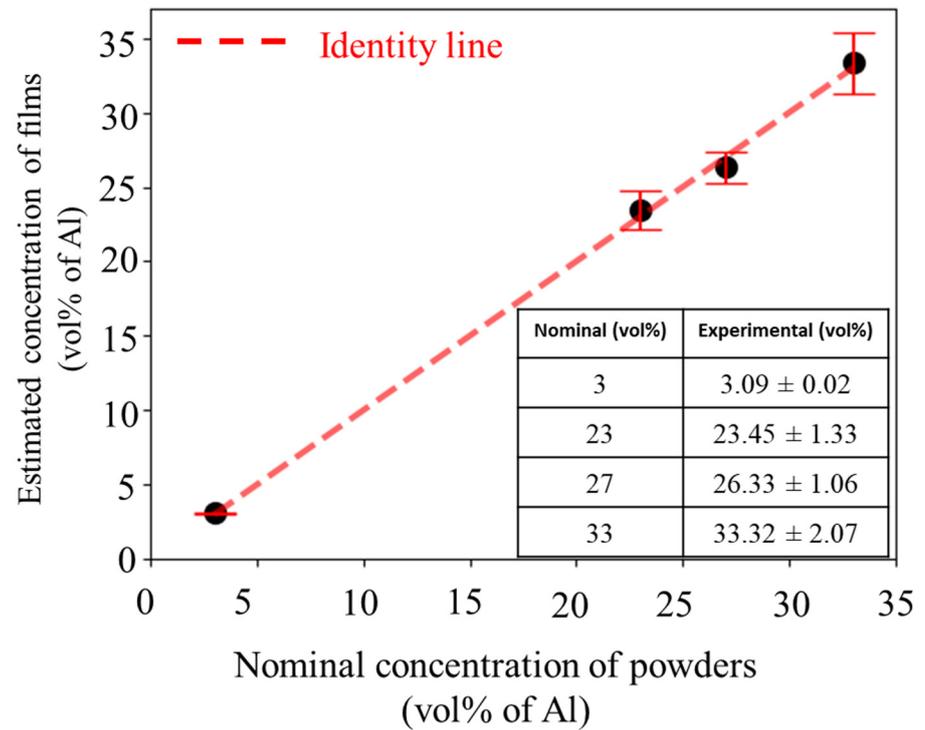


Figure S5. Comparison between the estimated Al volume fraction in the composite films and the nominal Al volume fraction in the powder mixtures prior to AD. The red dashed line represents the ideal case in which both quantities are identically equivalent. The table shows the nominal vol% Al in the powder mixture and mean estimated values of vol% Al in thick films and their respective standard deviations.