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Fabrication of aluminum nitride coatings by electrophoretic deposition: Effect of particle size on deposition and drying behavior

H. Abdoli [a], M. Zarabian [b], P. Alizadeh [a,*], S.K. Sadrnezhaad [b]

[a] Department of Materials Science and Engineering, Tarbiat Modares University, P.O. Box 14115-143, Tehran, Iran
[b] Department of Materials Science and Engineering, Sharif University of Technology, P.O. Box 11365-9466, Azadi Avenue, Tehran 14588, Iran

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Abstract

Electrophoretic technique was used to deposit micro- and nano-sized aluminum nitride coatings on stainless steel surfaces by using a well-dispersed stable suspension produced by addition of AlN powder plus a small amount of iodine to ethanol. Parabolic regime governed the deposition. Electrophoretic deposition for 240 s at 100 V resulted in formation of a uniformly dense film on the top, but a porous inhomogeneous layer at the bottom. This was attributed to fast deposition of coarse particles and/or agglomerates at large electric fields. After drying, micro-sized particles led to a uniform crack-free interface while nano-particles resulted in fragmented non-cohesive layers. Weight loss measurements revealed higher drying rates for micro-layer as compared to nano-cover. This seemed owing to the larger pore sizes and lower specific surfaces of the former. Stress inducement by lateral drying of small capillaries led to crack initiation from the edges and its propagation across the surfaces. This resulted in fragmentation of the samples due to their delamination. Effect of deposition rate on particles packability was also investigated.
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Keywords: A. Drying; Electrophoretic deposition; Microstructure; Kinetics

1. Introduction

Electrophoretic deposition (EPD) is a rapid developing technology capable of producing ceramic coatings [1,2], functionally graded materials [3,4], thin and thick layers [5,6], porous materials [7] and nanoparticle deposits [8]. Various materials including alumina [9,10], zirconia [11,12], hydroxyapatite [13] and carbon nanotube [14] have previously been deposited by this technique. EPD has received increasing attention because of simplicity, low cost, applicability to different materials, possibility of using complicated substrates and capability of scale-up to large production rates [15,16].

EPD comprises two steps [15]: (i) charged colloidal suspended particles are forced to migrate towards an electrode under the applied electric field and (ii) the particles depositing on the working electrode form a coherent dense layer. These processes follow drying and densification by sintering or curing. Although many efforts have been devoted to understand this process, there are still many parameters that must be worked on to control the formation of the EPD layers.

Two types of parameters are to be considered to control the morphology and microstructure of the electrophoretically deposited layer [17–19]: (i) physical factors comprising of the applied voltage, deposition time, suspension concentration and substrate specifications and (ii) chemical parameters including zeta potential, liquid-phase dielectric constant, raw-materials morphology and their particle size plus conductivity, viscosity and stability of the suspension. Kinetic equations have previously been developed to predict the effect of the influential parameters on the rate of deposition [20,21].

Packing behavior of the colloidal particles is influenced by particle size, particle concentration, interaction between particles and rheological properties of the mixture. Packing compactness affects shrinkage, density and microstructure of the consolidated ceramic objects [22]. A uniform green density has substantial effect on controlling the sintering contraction and microstructural flaws which may cause in-use component fail [23]. It is commonly accepted that ceramic compacts having high green density and small uniform pores can most effectively be densified by sintering [24,25].

* Corresponding author. Tel.: +98 21 8288 4399; fax: +98 21 8288 3381.
E-mail addresses: habdoli@alum.sharif.edu (H. Abdoli), p-alizadeh@modares.ac.ir (P. Alizadeh).

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