

Suspension characterization and electrophoretic deposition of Yttria-stabilized Zirconia nanoparticles on an iron-nickel based superalloy

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ABSTRACT

Yttria-Stabilized Zirconia (YSZ) is the most common material for thermal barrier coatings. Suspensions of 3 mol % YSZ nanoparticles in acetone medium have been prepared in presence of different amounts of iodine as dispersant. Size distribution of particles in the suspensions and zeta potential were measured as a function of dispersant concentration. Adding 1.2 g/l iodine was found to be effective for the dispersion of YSZ nanoparticles in acetone. The stability of YSZ suspension in acetone increased with iodine content increasing until reached 1.2 g/l. Mean diameter of particles and zeta potential of the YSZ suspension in acetone were 912 nm and 2.4 mV respectively, and with addition of 1.2 g/l iodine shifted to 111.6 nm and 50.2 mV respectively. Electrophoretic deposition (EPD) process has been carried out from this suspension at different applied voltages and deposition times. A uniform green coating was obtained at voltage of 6 V and deposition time of 2 min the thickness of the green coating is measured about 25 μm .

1. Introduction

Ceramic coatings are of much interest in electronic and optical instrument, cutting tools, aerospace and other industries due to individual electrical, optical, physical and thermal properties [1]. Thermal barrier coatings are ceramic coatings, which are mostly coated on superalloy substrates and reduce the working temperature of the substrate [2,3]. Yttria-stabilized zirconia (YSZ) has been reported as the most desirable ceramic material for thermal barrier coatings due to the properties such as high thermal expansion coefficient, low thermal conductivity and high thermal shock resistance [4,5].

There are variety of methods to produce ceramic coatings such as chemical vapor deposition (CVD), physical vapor deposition (PVD), sol-gel, ion implantation, thermal spray and electrophoretic deposition (EPD) [6,7]. Electrophoretic deposition is one of the colloidal methods to produce ceramic coatings in the thickness range of 1–50 μm [8]. In comparison with other coating techniques, EPD is very versatile and can be modified easily for a specific application. Recently, EPD is used for fabrication of nanostructure materials such as advanced coatings for electronic applications [9], porous materials [10], nano-scale ceramic membranes [11], ceramics with complex geometric shape [12] and thermal barrier coatings [13].

Electrophoretic deposition contains dispersion of charged powder

particles in a liquid medium, which in presence of electrical field deposited on an electrode with different charge [14]. Preparing stable suspension is essential to obtain suitable coating in this method [15,16]. If the particles are not well-dispersed in the suspension, agglomerates will be deposited on the substrate and form a structure with weak bonding, low density and bad sintering behavior. Also, researches have revealed that dense ceramic coatings can be achieved easily for nano-sized powders than for coarse powders [17,18]. Accordingly, preparing well-dispersed nanoparticles suspension will be suitable for EPD technique. It is obvious that suspension chemistry plays a vital role in suspension stability [14]. Using water as a solvent is limited in EPD due the electrolysis and forming bubbles on the electrode surface. So, organic solvents are used usually in this method [19,20]. EPD of YSZ particles on metallic substrates has been studied in various organic solvents such as acetone, acetylacetone, ethanol, isopropanol, etc. Das et al. [8] have reported that a deposit with uniform and crack-free surface is obtainable in isopropanol medium, however, using acetylacetone as dispersing medium leads to form non-uniform deposits with many cracks and in the case of acetone, many cracks appear on surface of the deposit while drying even at room temperature due to the high evaporation rate of acetone. In another study [21], EPD of YSZ nanoparticles has been investigated in ethanol, acetone and acetylacetone mediums. Accordingly, researchers have

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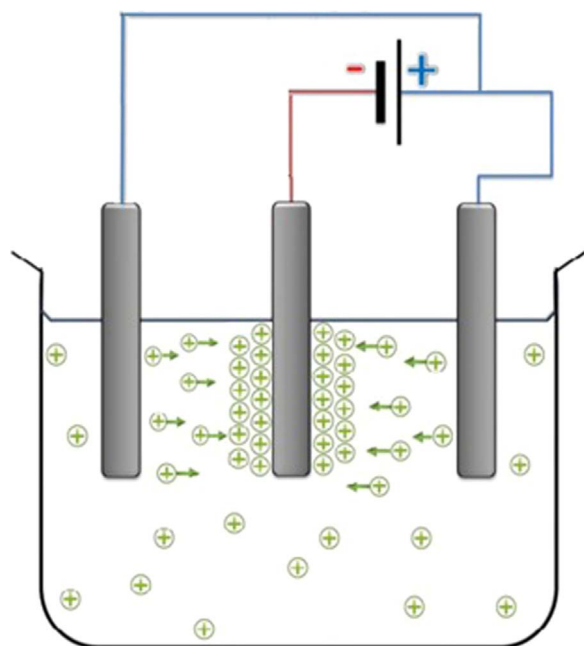


Fig. 1. Schematic illustration of EPD system.

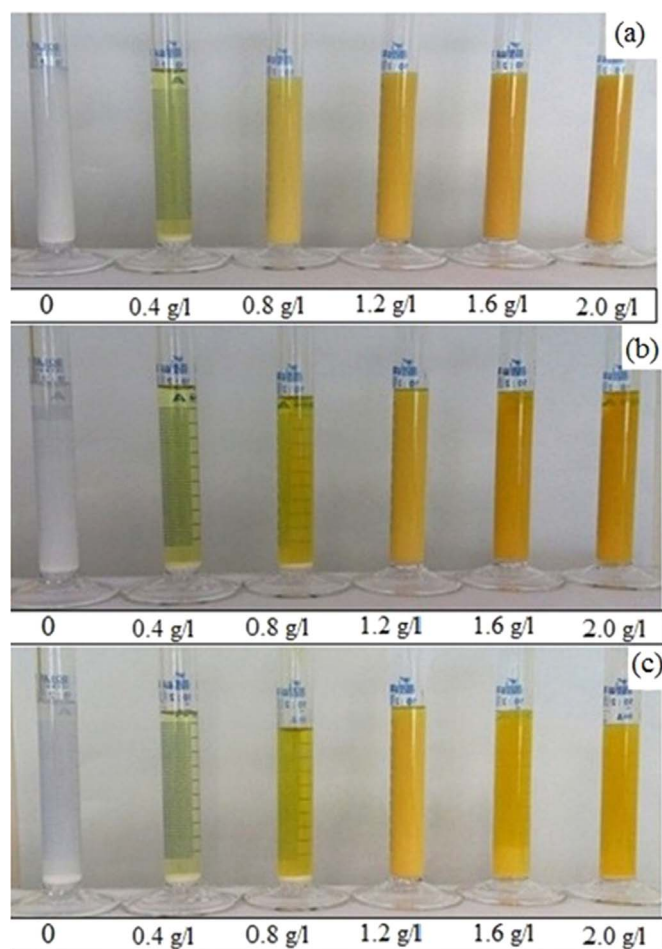


Fig. 2. Photograph of the YSZ suspensions in acetone containing different amounts of iodine after sedimentation for (a) 1 h, (b) 24 h and (c) 72 h.

found that deposit from acetylacetone is uniform and condensed, while deposits from acetone and ethanol are non-uniform and full of cracks. Van der Waals forces between macroscopic particles cause agglomera-

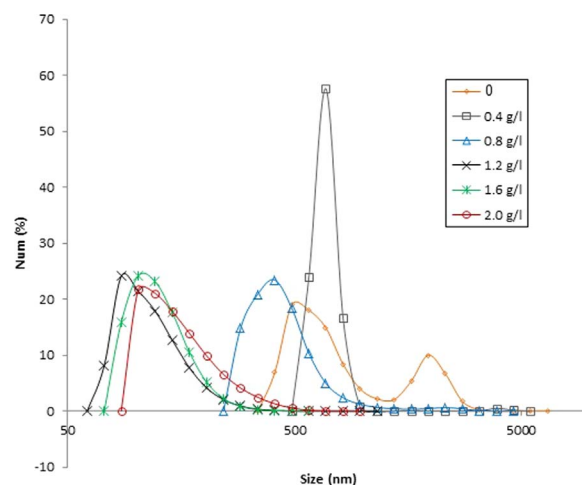


Fig. 3. Size distribution of YSZ nanoparticles in acetone in presence of different amounts of iodine.

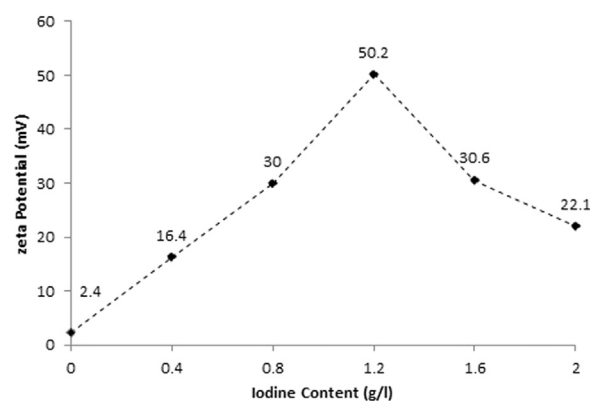


Fig. 4. Zeta potential as a function of iodine content for YSZ suspension in acetone.

tion and sedimentation of the particles. In order to resolve this problem, repulsion force should be produced between the particles. Repulsion force should be able to prevent particles from accumulation together and to increase suspension stability. Generally, there are three ways to produce repulsion between the particles and stabilize the suspension: (1) Electrostatic stabilization, (2) Steric stabilization and (3) Electrosteric stabilization. In first method, the repulsion between the particles is based on electrostatic charges on the particles, however in the second one repulsion is produced by interaction between uncharged polymer chains adsorbed onto the particle surfaces. The third way, which is a combination of electrostatic and steric methods, contains adsorption of charged polymers (polyelectrolytes) onto the particle surfaces [22]. Iodine (I_2) has been used as an electrostatic dispersant in different organic solvents such as acetone [23], acetylacetone [24], isopropanol [25] and mixture of these organic solvents [26]. Iodine dispersing mechanism is based on the formation of H^+ ions in the presence of organic solvents. These H^+ ions absorb on the surfaces of YSZ particles and form positively charged particles [27].

The aim of this research is to investigate the properties of the YSZ (3 mol% Y_2O_3) nanoparticles suspension in acetone in presence of iodine as dispersant and electrophoretic deposition of YSZ coating on an iron-nickel based superalloy substrate.

2. Materials and methods

2.1. Materials

Commercially available Yttria-stabilized zirconia nanopowder (3 mol% Y_2O_3 , Sigma-Aldrich) with spherical geometry, an average

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