Amorphous alumina films for tunable multifunctional oxides

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Abstract

A series of chemical vapor deposition (CVD) processes are presented for the deposition of amorphous alumina (a-Al_2O_3) films with tunable characteristics. Aluminum tri-isopropoxide (ATI) or dimethyl aluminum isopropoxide (DMAI) are introduced in the reactor either by vaporization or by direct liquid injection (DLI). All processes provide compact films with typical surface roughness values lower than 2 nm, except the DLI-ATI one which yields films with columnar structure. Very high-field (20 T) solid state 27Al NMR spectroscopy reveals that films processed from vaporized ATI and from DLI-DMAI in temperature ranges 360-600 °C and 150-450 °C, respectively, contain more than 40 at. % of 5-fold coordinated aluminum sites, while the percentage of $^{[6]}$Al remains less than 10 at. %. The utility of such coatings to face various materials challenges is demonstrated through four examples covering different application domains.

1. Films processed from vaporized ATI on 304L stainless steel provide increasing corrosion protection from a 0.1 M NaCl solution at room temperature with increasing thickness up to 500–600 nm, as revealed by polarization curves and electrochemical impedance spectroscopy.
2. SAED-TEM, XRD and XPS reveal that DLI-DMAI films provide pure Ti parts with excellent protection against oxygen ingress up to 600 °C. The oxidation kinetics of the Ti6242S alloy coated with 0.5 µm DLI-DMAI films are 100 to 1000 times lower than the uncoated sample, while the mass gain after 80 cycles between the ambient and 600 °C of such coupons reveal no mass gain and no spallation, to be compared with a mass gain of 0.2 mg/cm^2 for the uncoated sample.
3. Hydrothermal ageing of DLI-ATI films processed on glass vials used in the pharmaceutics industry, simulated by a standard sterilization cycle results in the increase of the root mean squared roughness of the surface of the coatings from ca. 17 to 61 nm and in the increase of the porosity, without affecting the adhesion of the coatings.
4. Finally, it is shown that a-Al_2O_3 based composite coatings containing Ag nanoparticles provide efficient protection from biofouling to optical sensor glass windows immersed in riverine waters, while maintaining satisfactory transparency for the sensor to e operational.