

The aim of the present study was to develop an amorphous-nanocrystalline aluminum phosphate coating by the simple and low-cost sol-gel process to increase the working temperature or extend the longevity of metal parts. In this regard, aluminum phosphate precursor solution was synthesized by sol-gel process and applied on stainless steel 304 substrate by dip coating technique. The micro structure of the coating material was studied by transition electron microscopy (TEM). Thermal analysis and study of amorphous to crystalline transformation were investigated by thermal-gravimetric and differential scanning calorimetry (TG-DSC). Molecular spectroscopy of the synthesized powder was studied by Raman spectroscopy. Fourier transform infrared spectroscopy (FTIR) was used to identify differences between non-stoichiometric amorphous aluminum phosphate bonding with that of stoichiometric crystalline one. Topography and roughness of coated and un-coated surfaces were investigated by atomic force microscopy (AFM). The oxidation resistance of the coatings was evaluated in an electrical furnace at 1100°C for 100 h in air with weight measurements performed at regular ten-hour intervals. Phase composition analysis of the coatings before and after cyclic oxidation process was performed by X-ray diffractometer (XRD). The surface and cross section morphology of the coatings before and after oxidation test were observed using scanning electron microscopy (SEM) analysis equipped with energy dispersive spectroscopy of characteristic X-rays (EDS). Thermal analysis of the coating material showed that the onset temperature of the amorphous to crystalline transformation with 1°C.min⁻¹ heating rate was around 100°C. The presence of graphitic and amorphous carbon (I_D:I_G=0.95) in the coating material structure was confirmed by Raman spectroscopy. Based on the FTIR results, the amorphous aluminum phosphate owned Al-O-Al bonding besides Al-O-P groups caused by excess aluminum content present in the precursor solution. XRD patterns of the synthesized powder confirmed the amorphous structure of aluminum phosphate after drying at 100°C for 2h and after annealing at 500°C for 10 min and the amorphous-nanocrystalline structure after annealing at 1100°C for 1h. These structures were further confirmed by TEM observations. According to SEM images a uniform, continuous and crack-free coating was achieved. Surface roughness of the coating was around 1.0 nm according to the AFM images. Weight change measurements after 100 h oxidation test revealed that the trace of weight gain against oxidation time for both coated and un-coated substrates were parabola in nature and the range of the weight change of the bare substrate was about 3 times greater than that of the coated one, namely 4 mg.cm⁻² for coated substrate and 12 mg.cm⁻² for the bare one. Also, formation of spinel oxides on the coated surface and hematite on the un-coated surface were dominant after oxidation test indicating the superior oxidation resistance of the coating. According to cross sectional studies the approximate thickness of the coating was around 300 nm which was capable to protect the substrate against oxidation up to 1100°C. In general, the results showed that the applied

amorphous aluminum phosphate coating could provide surface protection of metals/alloys against degradation at elevated temperatures over 1000°C.