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Hot corrosion behavior of CoWSi/WSi_2 coating exposed to Na_2SO_4+NaCl salt at 900 °C

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Abstract

In this study, the high temperature hot corrosion behavior of a CoWSi/WSi_2 composite coating was investigated. Hot corrosion studies were performed on CoWSi/WSi_2 coated nickel specimens after exposure to a molten Na_2SO_4+NaCl salt environment at 900 °C under cyclic conditions. Thermogravimetric technique was used to establish the kinetics of corrosion. XRD and SEM/EDS techniques were used to analyze the corrosion products. The oxide scale formed on the coating surface was complex and the hot corrosion resistance of coating may be attributed to the formation of oxides and spinels of silicon, cobalt and tungsten. Also, NaCl accelerated the degeneration of the coating because of producing the volatile $CoCl_2$ and thereby oxygen and sulfur could easily penetrate into the coatings and caused the formation of internal oxide and sulfide.

Keywords: CoWSi/WSi_2 coating; Cyclic hot corrosion; Molten salt

1. Introduction

For high temperature components serving in aero-gas turbine engines, the material must possess both excellent mechanical property and corrosion resistance. However, these two properties are usually incompatible [1]. A common solution is to develop alloys and compounds with optimum mechanical properties, then deposit a protective coating to improve their corrosion resistance [2,3]. It is reported that silicon-containing overlay coatings on nickel- and iron-based alloys improve high temperature oxidation and hot corrosion resistance in the temperature range of 700–1200 °C [4,5]. The most known silicides are based on tungsten disilicide (WSi_2) which are resistant against hot corrosion in gaseous oxidizing media up to 1600–1700 °C [6]. Tungsten disilicide can be regarded as an attractive coating material for protection of alloys used in an oxidative and corrosion atmosphere at high temperatures for its ability to form an adherent and continuous SiO_2 film on its surface [7,8]. Previous studies have reported the general microstructure of the CoWSi–WSi_2 coating by laser cladding. Similarly, the high temperature oxidation behaviors of this coating has also been studied in terms of weight change measurements and oxide scale characterization [9,10], but to the knowledge of the authors, little information is available on hot corrosion behaviors of the multi-phase metal silicides coating. In the present study, CoWSi/WSi_2 composite coatings were fabricated on a substrate of a Ni by laser cladding using CoWSi/WSi_2 nanocomposite powder (fabricated by mechanical alloying) [11] and the hot corrosion behavior was evaluated under cyclic high temperature conditions. Knowledge of the nature of the surface scales formed during hot corrosion is important for evaluating the alloys for their use and degradation characteristics in high-temperature applications.

2. Experimental procedure

CoWSi/WSi_2 composite powder was synthesized by mechanical alloying according to the previous studies [11]

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and were used as the laser cladding precursor materials. Commercial pure electrolyzed nickel plates, 60 mm × 25 mm × 0 mm in size, were selected as the substrate material. The powders were placed on Ni surface samples with a powder-bed thickness of approximately 1 mm. Laser cladding was conducted on Nd:YAG pulsed laser materials processing system equipped with a 4-axis computer numerical controlled (CNC) machine under Argon shielding environment. After experimenting with different sets of processing parameters, the best laser cladding parameters were selected: laser power of 0.45 kW, an impulse width of 5.0 ms, a frequency of 30 Hz, a beam diameter of 1.8 mm, a defocusing distance of 5.5 mm and an overlap of 50% at a scanning speed of 2.5 mm/s.

Hot corrosion test of the coatings were performed in a muffle furnace in static air. The bare nickel (substrate) and CoWSi/WSi_2 composite coating samples were placed on a hot iron plate and then brushed with salt mixture Na_2SO_4/NaCl (3:1, by weight). The samples were weighed before and after importing salt to ensure a salt supply of about 2 mg/cm^2. Afterwards, the samples were placed inside alumina crucibles and loaded into muffle furnace to carry out the corrosion experiment at 900 °C. At regular intervals (17 h), the specimens were taken out, cooled down to room temperature and then washed in boiling distilled water to obliterate the remaining salt. Then, the samples were dried and weighed by electronic balance with sensitivity of 10^{-5} g. Subsequently, a uniform fresh salt coating was brushed again to continue the experiment. The corrosion test lasted for 51 h in the salt. Phase constituents of the coatings and all corrosion scales were analyzed by Philips X-ray diffraction (XRD) with a Cu K_α tube operated at 30 mA and 40 kV and a scan rate of 0.5°/min. The cross-section for microstructure observations of both as-coated and hot corroded samples were examined in a Seron AIS 2300 scanning electron microscope (SEM) equipped with EDS. Etching of the cross-sectional microstructure was carried in limited cases using H_2O-7% HF-43% HNO_3 water solution

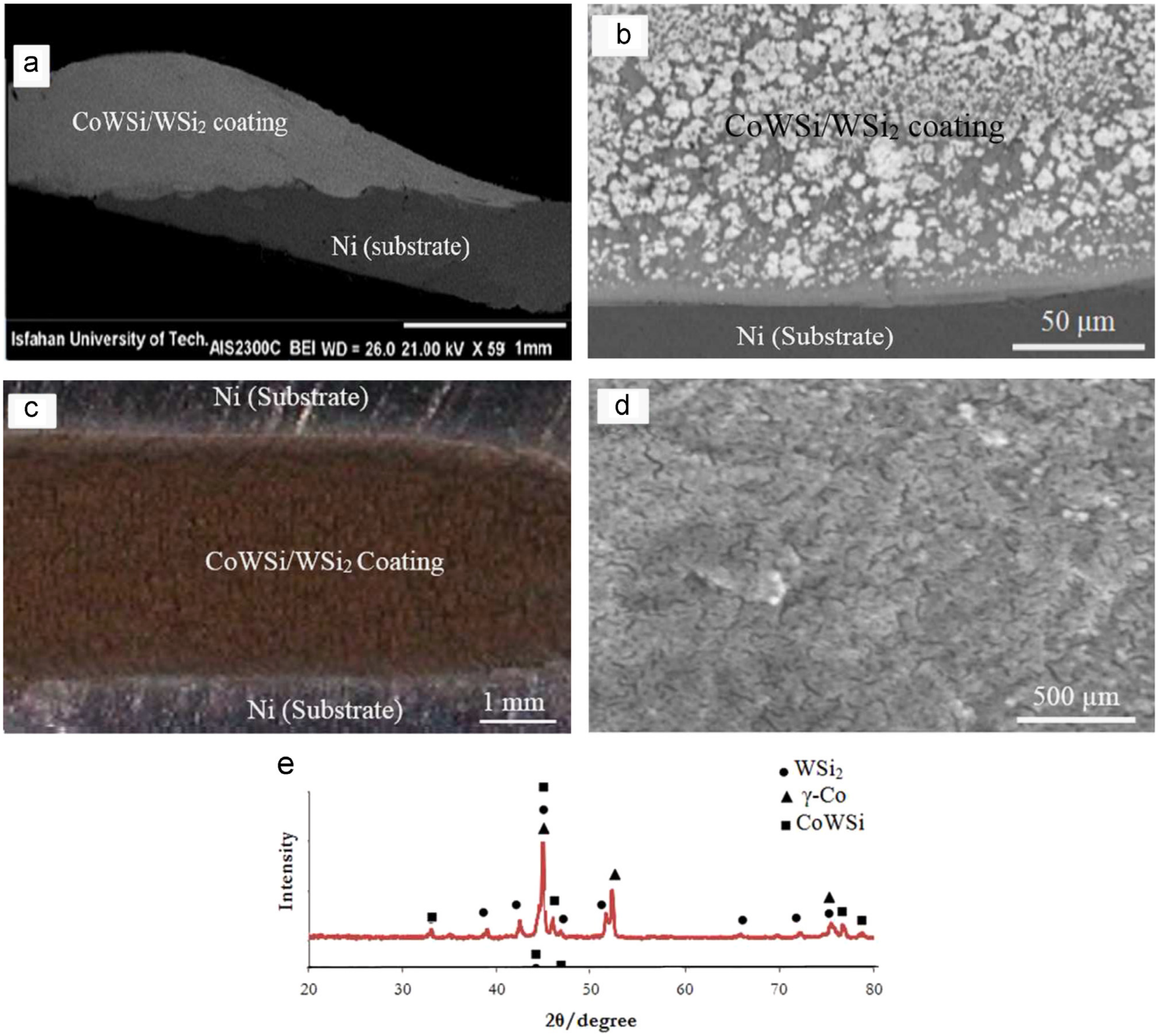

Fig. 1. (a, b) Cross-sectional morphology, (c, d) surface morphology and (e) XRD result of the laser clad of CoWSi/WSi_2 coating.