Laser Post Annealing Of Cold-Sprayed Al–Ni Composite Coatings For Green Energy Tasks

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Nowadays, a lot of research around the world is aimed at developing technologies in the field of green energy. The gradual exhaustion of mineral resources and environmental pollution makes people pay more attention to renewable energy sources such as solar, wind, and water. Several promising technologies use flowing water or its properties and composition for energy production. Technical implementation of the principles of these technologies is one key objective in the application of green energy.

Ni-Al intermetallic alloy can be a solution to the material aspect of the objective. It is an electrically conductive material with high mechanical and chemical properties. Recent studies showed successful implementation of this material for the purposes of green energetics.

M. Vanags et al. used Ni-Al protective coating for steel electrodes in DC electrolysis process for hydrogen production [1]. In a long-term (24 h) process, the anode corrodes strongly, losing Cr and Ni ions, which are transferred to the electrolyte, while only minor corrosion of the cathode occurs. At the same time, the composition of anode and cathode electrodes protected by Ni-Al coating changes only slightly during a prolonged electrolysis. As the voltammetry and Tafel plots evidence, Ni-Al coating protects both the anode and cathode from corrosion and reduces the hydrogen evolution potential.

The Ni-Al material can also be used in Molten Carbon Fuel Cell (MCFC) [2]. The MCFC are high-temperature fuel cells that operate at temperatures of 600 °C and above. Owing to its heat-resistant properties and conductivity, Ni-Al material is suitable for use in the MCFC as a metallic current collector incorporated into the anode structure.

Another field of application of this material is water-activated batteries. This is a promising technology that does not contain an electrolyte and hence produces no voltage until it is soaked in water for several minutes. In this way, the Ni-Al intermetallic alloy is considered an important material for green energy development.

Intermetallic coatings and functional graded multilayers on their base can be fabricated by means of various additive approaches: reactive hot compaction of Ni and Al powders [3], pulse plasma sintering [4], plasma spray [5], layerwise selective laser sintering [6, 7], etc. However, these thermal processes are characterized by high heterogeneity due to incompleteness of the solid state reaction during the intermetallic synthesis of compounds like Al_3Ni, Al_3Ni_2, and AlNi and semi-melting of contacting Ni and Al particles on the background of high speed crystallization—all these deteriorate the prospects of their future industrial applications.

Cold gas dynamic spraying (hereinafter, cold spraying (CS)) is an emerging nonthermal spray process [8]. The process occurs at temperatures lower than melting point of spraying material, forming coatings due to high kinetic energy.

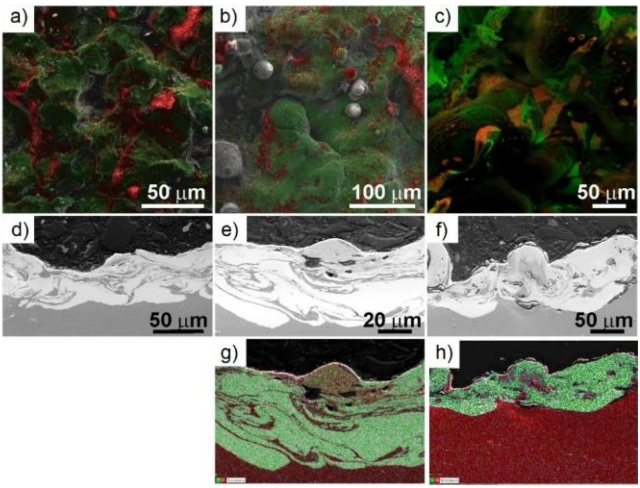

Figure 1: SEM of the CS Coating (Ni+Al12Si) and EDS data (Ni, green; Al, red): top row, surface appearance; middle and bottom rows, the coating cross-section. a) CS without laser annealing; b) LaCS under laser power 10 W; c) LaCS under laser power 20 W.

Laser-assisted cold spraying (LaCS) is a new manufacturing process, which combines the advantages of supersonic CS and laser post-treatment of fabricated coatings [9], which meets the demands of the intermetallic synthesis. The ability to deposit materials of various nature, high build rates and reduced operation cost, and more adherent coating are attractive characteristics of this hybrid additive process.

In the current study, the Al and Ni alloy powders were sprayed on the Aluminum substrate using the CS technology. After a laser-assisted post-annealing process, Al_xNi_y phases were observed in the cold-sprayed Al–Ni coatings. Microstructures of CS-sprayed and laser-annealed coatings were investigated by using optical and scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and X-ray diffractometry (XRD). The effects of laser processing parameters, such as scanning speed, power, and beam shape on the microstructural evolution of the composite coatings were discussed, and optimal regimes for laser assisted CS were determined.

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