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Short report
Краткое сообщение

On limited possibility of using Al_2O_3 and Al–Zn for corrosion protection of GdTbDyHoSc and GdTbDyHoY alloys in a salt mist chamber

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Abstract. Nowadays high-entropy alloys (HEAs) with a hexagonal close packed structure consisting of rare-earth metals (REM) are of particular interest. In this work, we investigated the possibility of using of Al_2O_3 and Al:Zn (1:1) as a protective coatings for REM HEAs GdTbDyHoSc and GdTbDyHoY. The REM HEAs samples were synthesized from metals of purity ≥99.9 % by melting in an electric arc furnace under Ar atmosphere (99.99 %). The samples were coated by supersonic plasma spraying. Corrosion resistance was determined in a salt mist chamber for 48 h. It was found that for all studied samples corrosive effect in conditions of salt mist leads to degradation of the base material of the alloy. Samples coated with Al:Zn (1:1) under salt mist conditions showed less resistance than samples coated with Al_2O_3 due to the chemical interaction between aluminum and sodium chloride solution.

Keywords: corrosion, protective coatings, corrosion resistance, limitation of use, high-entropy alloy (HEA), rare-earth metal (REM)

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Об ограниченной возможности использования Al_2O_3 и Al–Zn для защиты от коррозии в камере соляного тумана сплавов GdTbDyHoSc и GdTbDyHoY

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Аннотация. В настоящее время особый интерес представляют высокоэнтропийные сплавы (ВЭС) с гексагональной плотноупакованной структурой, состоящие из редкоземельных (РЗМ) элементов. В работе проведено исследование возможности Al_2O_3 и Al:Zn (1:1) играть роль защитных покрытий для ВЭС РЗМ GdTbDyHoSc и GdTbDyHoY. Образцы ВЭС РЗМ синтезированы из металлов чистотой ≥99,9 % расплавлением в электродуговой печи в атмосфере Ar (99,99 %). Покрытия на образцы наносились методом сверхзвукового плазменного напыления. Коррозионную стойкость определяли в камере соляного тумана в течение 48 ч. Установлено, что для всех исследованных образцов коррозионное воздействие в условиях соляного тумана приводит к деградации основного материала сплава. Образцы с покрытием Al:Zn (1:1) в условиях соляного тумана показывают меньшую стойкость, чем образцы с покрытием из Al_2O_3 вследствие имеющего место химического взаимодействия между алюминием и раствором хлорида натрия.

Ключевые слова: коррозия, защитные покрытия, коррозионная стойкость, ограничение применения, ВЭС, РЗМ

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The hypothesis regarding the potential formation of high-entropy alloys (HEA) featuring a hexagonal close-packed (HCP) structure comprising rare earth (RE) elements was initially proposed in [1]. Building upon this assumption, Japanese scientists [2] pioneered the development and production of equiatomic alloys such as YGdTbDyLu and GdTbDyTmLu, showcasing a singular-phase HCP structure. Subsequently, HoDyYGdTb HEAs were fabricated through arc melting [3]. Research indicates that these alloys also exhibit an HCP structure, showcasing macroscopic and microscopic homogeneity without peculiarities related to compositional changes, secondary phase separation, dendrite formation, and similar phenomena. Further investigations substantiated the HCP structure within these alloys [4]. In [5], the authors successfully synthesized multiple pure HCP REM (rare earth metal) alloys devoid of any second-phase, examining their mechanical properties and the reinforcing impact of the solid solution.

Rare-earth metals (REM) possess similar atomic sizes and crystal structures, enabling them to form homogeneous solid solutions. Despite garnering considerable interest within the scientific community, REM HEAs remain relatively understudied materials to date. It is postulated that by combining magnetic rare earth metals with non-magnetic elements like yttrium or scandium, each with distinct atomic radii, it becomes possible to create materials with varying densities of defects in their crystal structures. This approach allows for a comprehensive examination of the role played by the size factor in the structure formation of REM HEAs and their resulting functional characteristics.

These alloys exhibit high chemical reactivity, thus necessitating either a specialized working environment or additional surface protection against both chemical and, in certain cases, electrochemical corrosion.

The investigation aimed to explore the viability of using Al_2O_3 and Al:Zn (1:1) as protective coatings for HEA compositions comprising rare-earth metals like GdTbDyHoSc and GdTbDyHoY. The synthesis of samples involved melting metals with a purity level of ≥99.9 % in a Centorr Vacuum and Industries 5SA arc furnace within an Ar environment of 99.99 % [6]. To apply coatings onto the samples, supersonic plasma spraying methodology was employed [7]. Corrosion resistance tests were conducted in a Q-FOG, SSP60 salt mist chamber for 48 h.

Conclusions

It has been confirmed that exposure to salt mist conditions results in the degradation of the base material of the alloy across all examined samples. Findings indicate that when samples were coated with Al_2O_3 under salt mist conditions, the destructive process occurred through localized surface activation, leading to the formation of pitting corrosion. Interestingly, a substantial portion of the coating on the base material persisted concurrently. This occurrence can be attributed to the interaction between Al_2O_3 and the NaCl solution, enabling temporary protection of the rare-earth alloy under salt mist conditions, albeit for a limited duration. Samples coated with Al:Zn (1:1) demonstrated lower resistance compared to those coated with Al_2O_3 under salt mist conditions. This reduced resistance is attributable to the chemical interaction between aluminum and the sodium chloride solution, exacerbated by the considerable difference in the standard electrode potentials of the system components.

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N. I. Il'inykh – finding and analyzing of literary data, discussion of the results, writing and editing the text.

E. V. Ignat'eva – investigation of the materials' properties, discussion of the results.

Вклад авторов

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