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Formation of superhydrophobic composite electrochemical coatings based on copper and chromium

Abstract

Relevance of the research

The phenomenon of superhydrophobicity is often observed in nature. These are the bristly legs of water striders, lotus leaves, rose petals, the wings of cicadas and butterflies, and many others. Recreated by humans, such water-repellent surfaces are capable of self-cleaning, protect against icing and corrosion, reduce hydraulic resistance in pipes, due to their lyophilic properties, they are able to separate oil particles from water, etc.

However, the widespread introduction of superhydrophobic coatings in the industry has not yet occurred. One of the main limiting factors here is often the low mechanical resistance and, as a result, the short lifespan of the superhydrophobic properties of the coatings, as well as, in some cases, the technical complexity and long processing time of large surfaces.

Relatively many methods of forming superhydrophobic surfaces, including electrochemical methods, have been described in the literature. The latter have the advantage of being relatively easily scalable, theoretically quickly allow processing large surface areas and require, as a rule, standard electrochemical equipment: a current source, an electrolyzer, etc However, in most literature sources, the authors propose electrochemical methods for obtaining a polymodal surface suitable for further hydrophobization based on the electrodeposition of dendrite-like metallic deposits under diffusion-limited conditions, which undoubtedly negatively affects the mechanical strength of such surface structures. In some cases, such a superhydrophobic coating is simply washed off with a jet of water.

In this regard, the development of electrochemical methods for the formation of superhydrophobic coatings with improved physical and mechanical properties is a vital task. Taking into account the physico-mechanical properties of composite electrochemical coatings (CEC), as well as the features of their growth and microstructure, the direction of obtaining superhydrophobic coatings based on CEC appears promising.

In addition, the formation of electrochemical deposits with a developed surface morphology possessing the polymodality necessary for superhydrophobization is of independent scientific interest, since processes for obtaining coatings with a smoother surface morphology are more traditionally developed in electroplating.

In this regard, composites based on copper and chromium are of interest to establish the physico-chemical patterns of the formation of superhydrophobic CECs as objects of research, due to the diametrically different features of the kinetics of their cathode deposition.

The degree of development of the research

The results obtained in the study were compared with known literature data and do not contradict the general principles of formation of composite electrochemical coatings, which are described in the literature. The methods used in the work to study the surface morphology and chemical composition of superhydrophobic coatings and test media make it possible to reliably compare and evaluate the results obtained. The data obtained during the study is reproducible, and the results are scalable.

The purpose of the work

Development of the physico-chemical principles of the processes of formation of superhydrophobic CECs based on copper and chromium with improved physico-mechanical properties, investigation of the functional properties of the obtained coatings.

In order to achieve this goal, the following interrelated **tasks** were solved in the framework of this work:

- To establish the influence of electrodeposition conditions and the composition of electrolyte suspensions, including dispersed particles, on the morphology of copper and chromium-based CEC. To determine the optimal parameters for the formation of polymodal roughness of deposits.

- To assess the effect of various hydrophobizers and their application methods on the superhydrophobic properties of coatings.

- To study the physico-mechanical and corrosion properties of coatings. Identify the most promising coatings.

- To conduct a comparative analysis and identify the main factors influencing the formation of superhydrophobic copper- and chromium-based CECs.

- To assess the possibility of practical application of superhydrophobic CECs based on copper and chromium for separation of polar and nonpolar liquids, to study the limits of their applicability.

Scientific novelty of the research

1. The conditions for the formation of Cu-SiC, Cu-MoS_2, Cu-MoS_2/Cr, Cr-Nb_2N and Ta_2N CECs have been determined, which, after treatment with a number of hydrophobic agents: stearic acid, Carnauba wax, etc., obtain superhydrophobic properties, have improved physico-mechanical and corrosion characteristics and can be used, in particular, for the separation of polar and non-polar liquids.

2. General approaches to the formation of new superhydrophobic CECs based on copper and chromium are formulated, taking into account the nature and size of dispersed particles, hydrodynamic conditions of electrodeposition of coatings, surfactant additives, as well as the properties of hydrophobizers and methods of their application.

Theoretical and practical significance of the research

Superhydrophobic CECs Cu-SiC, Cu-MoS_2, Cu-MoS_2/Cr, Cr-Nb_2N, and Ta_2N have been developed, combining a high contact angle, corrosion resistance, and comparative wear resistance. These materials have been used to create superhydrophobic sieves for separating polar and non-polar liquids with high performance properties. Their effectiveness is shown both in collecting oil pollution from the water surface and in regenerating oil fuels from moisture contamination to acceptable values.

General physico-chemical approaches have been formulated for the development of processes for the formation of superhydrophobic CECs based on copper and chromium.

Provisions for defense

1. The main influencing factors and physico-chemical approaches to the formation of superhydrophobic CECs based on copper and chromium.

2. The conditions for the formation of Cu-SiC, Cu-MoS_2, Cu-MoS_2/Cr, Cr-Nb_2N and Ta_2N CECs, which, after treatment with a number of hydrophobic agents: stearic acid, 1-dodecanthiol, Carnauba wax, etc., obtain superhydrophobic properties, have improved physico-mechanical and corrosion characteristics.

3. Physico-chemical and physico-mechanical properties of superhydrophobic CECs based on copper and chromium.

4. Data on the possibility of using superhydrophobic CECs based on copper and chromium for the separation of polar and nonpolar liquids.