

COMPOSITE COATINGS WITH FULLERENE C₆₀

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Introduction

Composite electrochemical coatings (CEC) are one of perspective directions of electroplating. It is composition of metal and dispersive particles of various sizes and sorts. Dispersive particles largely define properties of CEC. Fullerenes are of interest in this respect because of antifriction properties. The obtaining of CEC on the basis of nickel with fullerene C₆₀ and investigation of its properties were purposes of this work.

Results and discussion

Composite coatings are deposited from suspension electrolytes and therefore we worked out method of preparing of stable dispersion of C₆₀ in water without organic solvents. Solution of C₆₀ in toluene slowly dripped to water-acetone (1:3) mixture with stabilizer (sodium dodecyl sulfate). This solution distilled with intensive agitating. At distillation acetone separates firstly. Toluene and water form constant boiling mixture and distilled by second fraction. Gradually fullerene disperses in water. It was obtained colloidal dispersions with fullerene C₆₀ content to 0.50 g/l. The average size of particles is 24 nm. Suspension of C₆₀ flowed to electrolyte to receive a solution with concentration, g/l: NiSO₄·7H₂O 220; NiCl₂·6H₂O 40; CH₃COOK 30; C₆₀ 0,05 (electrolyte "Irina"). CEC nickel – C₆₀ deposited on steel matrix at room temperature with permanent mixing of electrolyte. Cathode fixed at angle 45° to anode for attain high consistent of dispersive particles in deposit. Pure nickel deposited from given over electrolyte without addition of C₆₀.

CEC nickel – C₆₀ deposition have been studied by potentiostatic method at potentials from – 0.60 V to – 1.0 V. Currents increase at CEC nickel – C₆₀ deposition in comparison with pure nickel that points out to process rate increase. Hence fullerene participates in electrochemical reaction. It is possible to assume that C₆₀ being electrons acceptor in electrolyte solution at current flow will be sorbed positive nickel ions, they will promote advance of dispersive particles to cathode and inclusion to crystalline lattice of deposit.

Addition of fullerene particles to electrolyte facilitates deposition process at potentials – 0.60 ÷ – 0.95 V. CEC precipitates at less negative potentials than

nickel coating. Transfer coefficients α were calculated from slop of $\lg i_0 - E$ dependencies. These coefficients characterize energy of double electric layer which is spent for main electrode process. Values of coefficients α decrease at transition from nickel coating to CEC nickel – C₆₀ (Table 1). It indicates that dispersive particles of C₆₀ facilitate deposition process.

Table 1.

Coefficients b and α at deposition of nickel and CEC nickel – C₆₀

Coating	b	α
Ni	0,13	0,22
CEC Ni – C ₆₀	0,21	0,14

Deposition of CEC nickel – C₆₀ have been studied in galvanostatic regime at current densities $i_c = 1 - 12 \text{ A/dm}^2$. Values of polarization capacity have been calculated. Capacity at CEC nickel – C₆₀ deposition decreases in 2 – 2.5 times in comparison with nickel. It serves as confirmation that entry of large fullerene particles to double electric layer enlarges it.

Structure of CEC nickel – C₆₀ is non-uniform with micro ledges which probably form at overgrowth of fullerene particles by nickel. In a case of thin deposit micro ledges significantly less i.e. obviously those dispersive particles of fullerene which includes depositing are crystallization centers and they determined mechanism and kinetics of deposit growth. Including of fullerene aggregates to coating leads to deformation and squeeze of crystals however with deposit growth are not occurs its loosening and deterioration of adhesion to matrix. Analysis of CEC nickel – C₆₀ by method of secondary-ionic mass spectrometry reveals carbon and C–H bonds. Probably fullerene particles occlude hydrogen on cathode at inclusion to coating.

Deposit structure is to have influence its properties and lead to change physicochemical and mechanical characteristics of coating. One of the most important characteristic of metallic surfaces is friction coefficient. In this work sliding friction coefficients of nickel coatings and CEC

nickel – C₆₀ have been defined. Steel used as a counterbody. Weight of steel sample was the same in all experiments. The friction coefficients of CEC nickel – C₆₀ has decreased more than twice in comparison with nickel (Table 2). It may be explained that fullerenes at deposition remains partly on surface of coating and work as dry lubricant. High values of friction coefficients connect by that experiment was carried out at dry friction. With lubricant friction coefficients will be significantly less. Fullerene being chemically active will interact with lubricant molecules and form friction polymers bonded with metal surface.

Table 2.
Sliding friction coefficients of nickel and
CEC nickel – C₆₀

Coating	Current density i_c , A/dm ²				
	6	7	8	9	10
Ni	0,54	0,48	0,47	0,44	0,38
CEC Ni – C ₆₀	0,24	0,22	0,21	0,19	0,16

Corrosion resistance is one of practically important properties of galvanic coatings. Dispersive particles of fullerene slightly increase free corrosion potential of studied coatings. It is necessary

to note that properties of composite coatings substantially defined by properties of metal matrix. That is why passivation potentials of nickel coating and CEC nickel – C₆₀ are close. Increase of passive interval is characteristic feature of CEC nickel – C₆₀. It is necessary to expect that corrosion resistance of CEC nickel – C₆₀ will higher than one of nickel coatings.

Conclusions

1. Colloidal dispersion of fullerene C₆₀ in water without impurities of organic solvents have been obtained for the first time. The average size of particles is 24 nm.
2. It is revealed that addition of fullerene particles to nickel electrolyte facilitates deposition process. Experimental data allow assuming that fullerene C₆₀ particles include to deposit not only under action of gravitation forces but also owing to participation in electrochemical reaction.
3. It is determined that friction coefficients of CEC nickel – C₆₀ decrease more than twice in comparison with nickel coating. It is showed that passive interval of composition coating much more widely than one of electrodeposited nickel.