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Electrochemical Oscillations during Cathodic Polarization Process of Aluminum Covered with Talc Coating

Hong Bo DING[1,3], Zhong Xiao PAN[1,*], Fu Yang ZHENG[2],
Guo Mou WEN[2], Renato SEEBER[3]

[1]Department of Applied chemistry, University of Science and Technology of China, Hefei 230026
[2]Fujian Institute of Research on the Structure of Matters,
Chinese Academy of Science, Xiamen 361012
[3]Department of Chemistry, University of Modena and Reggio Emilia, 41100 Modena, Italy

Abstract: Talc coatings were produced with chemical method on the surface of pure aluminum. The characteristics of cathodic polarization in a 3.5% NaCl solution have been studied through the observation of the 'current oscillations' phenomenon.

Keywords: Aluminum, talc coatings, current oscillations.

The lightweight aluminum alloys are increasingly replacing steel in automobile industry and in other industrial areas. However, surface modifications are necessary in order to enhance their poor corrosion-resistance properties in corrosive environments. Due to the toxicity of the conventional chromate method, scientists are engaged in the research of alternatives[1,2,3]. Talc coatings have attracted great attention as promising tools for replacing chromate-coatings[4]. The optimization of the process of coating formation and the study of the resulting electrochemical properties in corrosive environment is therefore of both theoretical and technological significance. In this paper, we report the current oscillations occurring during the cathodic polarization process of aluminum covered with talc, which was formed with chemical method, in a 3.5% NaCl solution. The aluminum for experiments is industrial pure and annealed, its composition(%) is: Cu 0.016, Fe 0.22, Si 0.17 and Al ~99.5.

The sample was embedded in epoxy resin, one side being uncovered, i.e., exposed to the atmosphere; the cross sectional area was $1cm^2$. The method followed for the formation of talc coating was taken from the work of Buchheit *et al.*[4]. After 24h of aging in air atmosphere, the sample was immersed into a 3.5% NaCl solution for 3h. When the open circuit potential reached a stable value, the polarization experiments were carried out. The initial potential was -0.75V and the final potential was -1.0 V vs. SCE reference electrode; the potential scan rate was $1.\times10^{-4}$V/s. The temperature was 25 ± 2^{o}C. The experimental setup consisted of a conventional three-electrode cell system, controlled through a CHI604 electrochemical instrument.

According to the experimental current-potential curves recorded on a talc-coating-covered aluminum electrode in a 3.5% NaCl solution, when the polarization potential is within the range of -0.75~-0.80 V, the polarization curve is smooth, indicating that the electrode system is at a steady state; while, when the polarization potential further sweeps to negative values, the polarization curve shows a kind of oscillation phenomenon. Furthermore, at even more negative values of the sweep the amplitude of the oscillations progressively but slowly increases according to a smooth trend, except for some ‘pulses’, which could be however caused by experimental noise.

This behavior can be qualitatively explained as follows, in view of the bifurcation theory[5,6]. In this system, the polarization potential can be considered as the controlling parameter, while the resulting current can be treated as the state parameter, which indicates the actual state of the system. When the values of the controlling parameter are higher than about-0.80 V, the electrode system is in a non-equilibrium steady state and the state parameter assumes a deterministic value. On the other hand, when the controlling parameter assumes values lower than about-0.80V, the original steady state loses the stability property and ‘Hopf bifurcations’ appear. A new bifurcation state occurs with one stable periodic state (in nonlinear dynamics theory, this can described as a ‘limit cycle’), which was the actually observed oscillation, and possibly another non-observable unstable state. When the conditioning parameter goes on towards more and more negative values, the diameter of the limit cycle becomes wider and wider, which is accounted for by larger and larger oscillation amplitudes. Further studies about the operative mechanism are now under consideration.

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