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Growth Kinetics of Zr-2 in L-Ascorbic acid: Solvent Studies by Scanning Electron Micrographs.

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ABSTRACT

Anodization of Zircaloy-2 in 0.1M L-Ascorbic acid has been carried out. Kinetics of anodic oxidation of Zircaloy-2 has been studied at a constant current density of 8 mA.cm^{-2} and at room temperature. The plots of formation voltage vs. time, reciprocal capacitance vs. time and reciprocal capacitance vs. formation voltage were drawn. From these plots, formation rate, current efficiency and differential field were calculated. The Addition of Solvent (Ethylene glycol) showed better kinetic results. For 20%, 40%, 60% and 80% aquo-glycolic media, the dielectric constant values are low leading to the marked improvement in the kinetics. The surface morphology of the anodic films was also studied by Scanning Electron Micrographs (SEM)

Keywords: Anodization, formation rate, current efficiency, differential field, Zircaloy-2, L-Ascorbic acid

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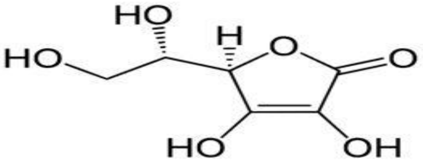
INTRODUCTION

Zirconium based alloys are used as structural material in the water cooled thermal reactors [1,2]. Zr-2, due to their low cross-section for thermal neutrons and because of their relatively good corrosion resistance against water and steam, used in water cooled reactors. Zirconium & its alloys are of primary importance in nuclear technology. Anodization of Zirconium alloys have been studied in some electrolytes [3-6].

In the present work, the kinetics of anodic oxidation of Zr-2 in aqueous solutions of 0.1M L-Ascorbic acid and aquo-glycolic media in various proportions (v/v) of water-ethylene glycol mixtures ranging from 0% to 80% ethylene glycol are studied. Scanning Electron Microscopic studies was also carried out to observe the changes in the surface morphology of the anodic films formed.



L-Ascorbic acid

EXPERIMENTAL

Zircaloy-2 was of 98% nominal purity, supplied in the form of annealed sheet by Nuclear Fuel complex, Hyderabad as gift samples. The chemical composition of Zircaloy-2: 700-2000 ppm of Fe, 500-1500 ppm of Cr, 300-800 ppm of Ni, 1400 ppm of O_2 & Sn as major impurity with 1.2 to 1.7 %

In the present work, the foil samples used were cut with the aid of a punch into flag-shaped specimens of $1cm^2$ working area on both sides and 2cm long tag. The chemical polishing mixture consisted of acids such as HNO_3, HF and water in a definite volume ratio of 3:3:1.

For anodizing, a closed shell of 200ml capacity was used. The cathode used was a platinum foil of $20cm^2$ superficial area to make double layer capacitance as large as possible. Electrolytes used were 0.1M L-Ascorbic acid in 20%, 40%, 60% and 80% aquo-glycolic mixtures, the solvent being ethylene-glycol.

All the experiments were carried out at a constant current density of $8mA.cm^{-2}$. The experimental procedure for the anodization is given elsewhere [7]. The kinetic results calculated are formation rate in Vs^{-1}, current efficiency (ᶯ) % and differential fields of formation (F_D) in MV cm^{-1} from the conventional plots V vs. t , 1/C vs. t and 1/C vs. V.

The surface morphology of the anodic film was examined using Scanning Electron Microscope (SEM). The SEM's were taken at IICT-CSIR, Hyderabad.

The surface was thoroughly rinsed with distilled water and dried under infrared lamp and cleaned gently with fine tissue paper. The surface was coated with gold, palladium conducting material using evaporation technique and signal processed secondary electron images were taken from scanning electron microscope model SEM Hitachi- S520 at 10 KV, Hitachi instruments made in Japan (Oxford link ISIS- 300 UK).

RESULTS AND DISCUSSIONS

Anodization of Zircaloy-2 was done in 0.1M L-Ascorbic acid. The formation rate, current efficiency and differential field were calculated. The effect of solvent on Zircaloy-2 was studied in 0.1M L-Ascorbic acid to check whether there was enhancement in kinetics of film formation[8,9].

Effect of Solvent

Anodization of Zircaloy-2 in 0.1M L-Ascorbic acid was performed by mixing various proportions of ethylene glycol to the aqueous solution (20%, 40%, 60% and 80%). There was an improvement in the kinetics as given in Table-1. The relevant plots are shown in Figures-1 & 2. Aquo-organic solutions aid in the formation of good oxide films and act as better electrolytic capacitors [10]. These facts support the current results obtained in aquo-organic mixtures of 0.1M L-Ascorbic acid. It can be explained on the basis of decrease in the dielectric constant of the medium (Table-2).

In solutions of low dielectric constant there is less chance of ion-dipole interactions (solvent-ion interactions) which do not interfere in the oxide film formation. However, the ions in the high dielectric constant solutions interact with oxide ions responsible for oxide film formation due to high solvation with water molecules. In such solutions, the kinetics are poor.

The kinetics are better in low dielectric constant solutions for 20%, 40%, 60% and 80% aquo-glycolic media, the dielectric constant values are low leading to a marked improvement in the kinetics.

Scanning Electron Micrographs:

Figure -3 and Figure - 4 are the Scanning Electron Micrographs of anodic films formed on Zircaloy-2 in aqueous and aquo-glycolic solutions of 0.1M L-Ascorbic acid upto 200V.

Figure 1: Plot of formation voltage as a function of time in aquo-glycolic solution

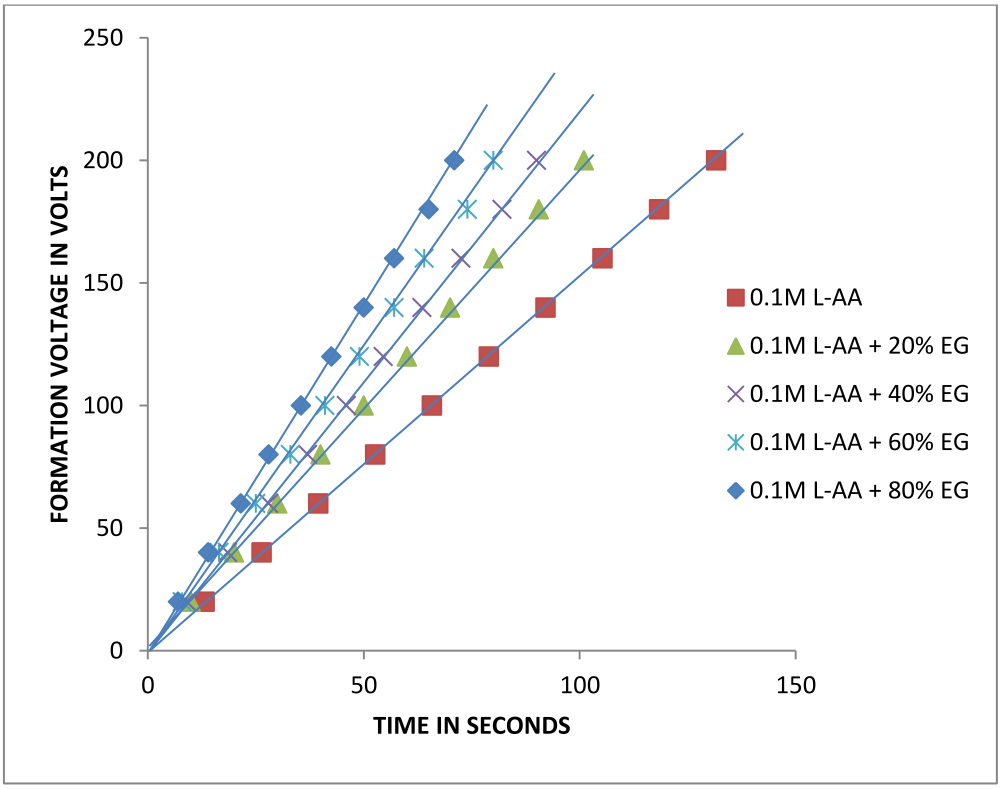


Table 1: Effect of solvent on the Anodization of Zircaloy-2 in 0.1 M L-Ascorbic acid

Electrolyte	Formation Rate, dV/dt (V.s^{-1})	Current efficiency, η (%)	Differential field, F_D (MV.cm^{-1})
0.1M L-AA	2.00	68.0	5.810
0.1M L-AA + 20%EG	2.12	81.0	5.741
0.1M L-AA + 40% EG	2.19	87.4	5.620
0.1M L-AA+ 60% EG	2.30	93.5	5.540
0.1M L-AA+ 80% EG	2.40	97.5	5.495

LAA= L-Ascorbic Acid EG = ethylene glycol

Figure 2: Plot of reciprocal capacitance as a function of time in aquo-glycolic solution.

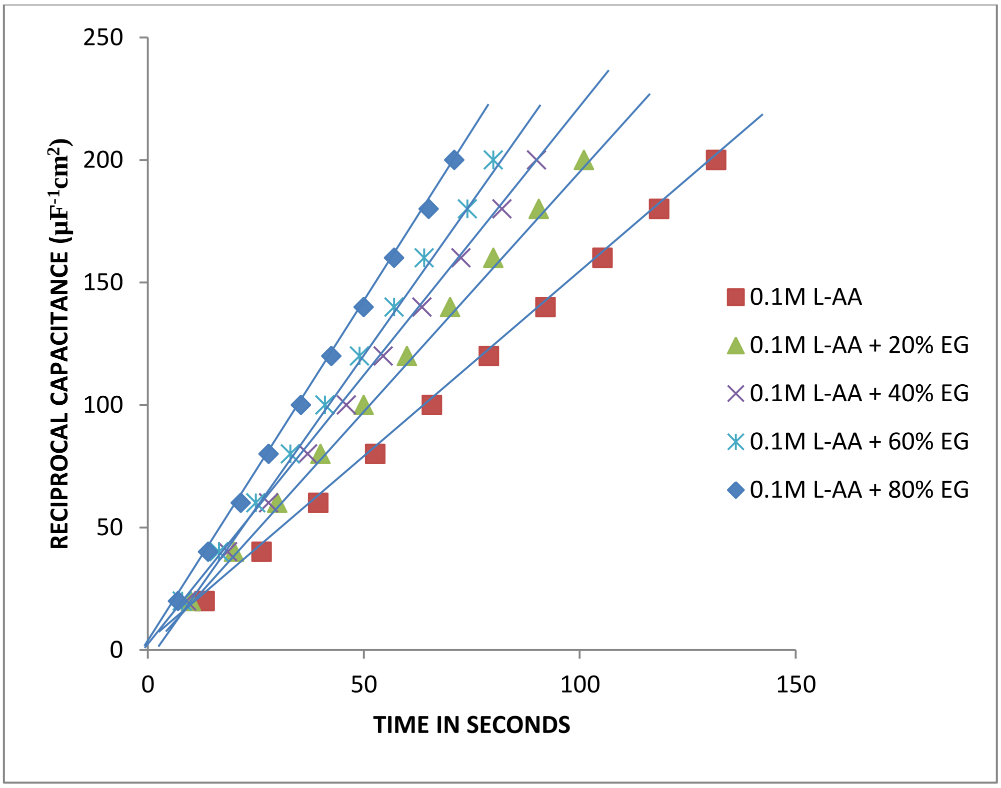


Table 2: Variation of dielectric constant as a function of solution composition

EG , %	0	20	40	60	80	100
Dielectric constant	80.0	72.8	69.2	57.8	43.2	37.7

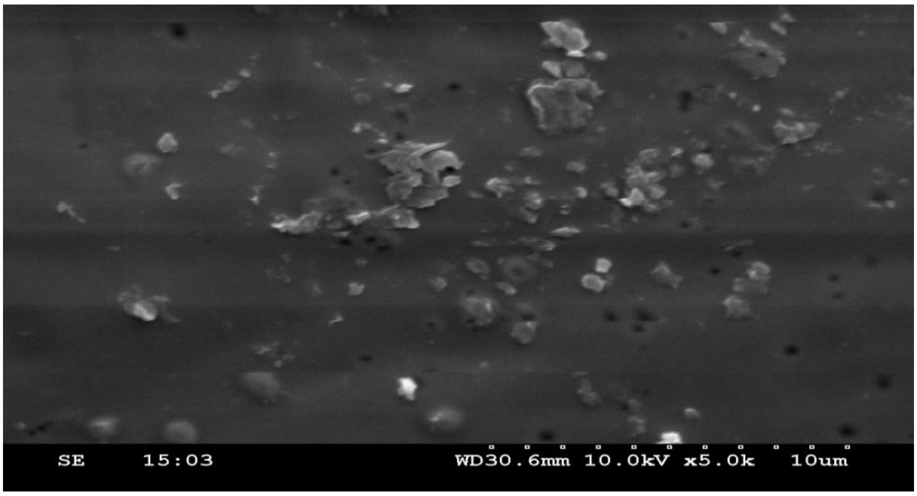


Figure 3: SEM of the film formed upto 220V in 0.1M L-ascorbic acid (aqueous medium) at room temperature (Magnification of the micrograph is X 5000)

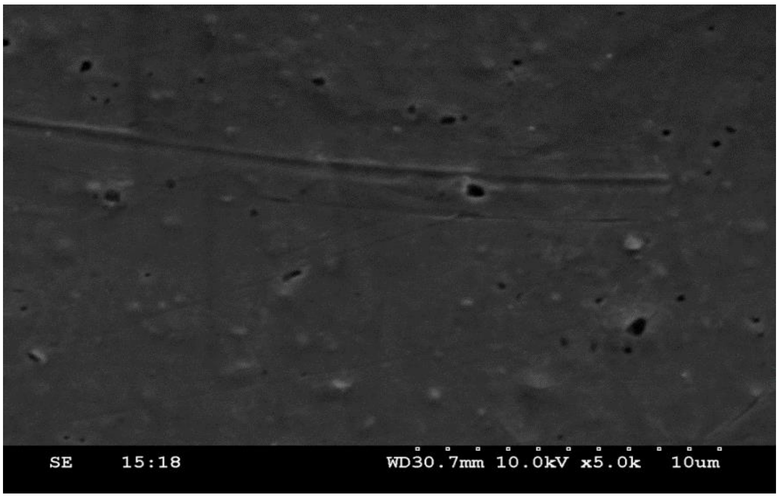


Figure 4: SEM of the film formed upto 220V in 0.1M L-ascorbic acid (glycolic medium) at room temperature (Magnification of the micrograph is X 5000)

When compared, the roughness and non-uniformity of the surface are decreased when electrolytic medium is changed from aqueous to aquo-glycolic medium (fig-4) is observed to be smoother than the film formed in aqueous medium.

Vermilyea studied the formation of anodic films on tantalum in aqueous [11] and non-aqueous [12] solutions. He suggested that the composition of film depends on the solution in which it is formed.

Seregina et al [13] studied the anodization of aluminium alloys in the solution of sulpho-salicylic acid (90g/cc) and found that thick films are possible during anodization at room temperature. Nageshwar rao et al [14] observed a change in the dielectric constant of oxide films by changing the medium from aqueous to glycolic.

Aparna [15] also observed the same trend of increasing kinetic results with increase in glycol content in 0.1M picolinic acid and sodium methoxide for Zr-2 and Ti. Vermilyea [12] reported that the optical thickness was smaller in the non-aqueous solutions, and the increase in weight for a given charge passed could be as much as twice that expected.

Moshashi Koyama [16] carried out anodization of titanium in non-aqueous media and confirmed that the oxide film consists of double layers and suitable for electrolytic capacitors. Wei Wei et al [17] reported the growth of layers by anodization of tantalum in a non-aqueous electrolyte consisting of an optimized glycerol/ethylene glycol mixture with the addition of NH_4F.

Schmidt et al [18] observed that the layers of TiO_2 obtained in non-aqueous electrolytes are much adherent and uniform than those realized in aqueous media. Climent Montoliu et al [19] studied the anodization of titanium in acid, alkali and neutral baths (aqueous and aquo-glycolic) and suggested from the structure and dielectric properties, that the anodic coatings formed in non-aqueous media acts as better dielectric capacitors.

Panasa Reddy et al [20] and Lavanya et al [21] also studied in trisodium citrate,0.1M KOH(aquo-glycolic) respectively and found that the breakdown voltage was higher when anodized in ethylene glycol medium. This was also supported by other workers [22]. Shukla [23] carried out the study of effect of aquo-glycolic media on Anodization of zircaloy-4 in 0.1M sulphamic acid and found that the addition of solvent improved the kinetic results.

CONCLUSIONS

By changing the solvent medium from aqueous to glycolic, the kinetics of film formation on Zircaloy-2 in 0.1M L-Ascorbic acid have been studied and it is observed that the peak voltage, formation rate, current efficiency are increased but differential field of formation decreased with the glycol content of solution. This can be attributed to the decrease in the dielectric constant of the solution with the increase in glycol content of the solution.

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