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Zirconia Ceramic As Implants In Medical Science

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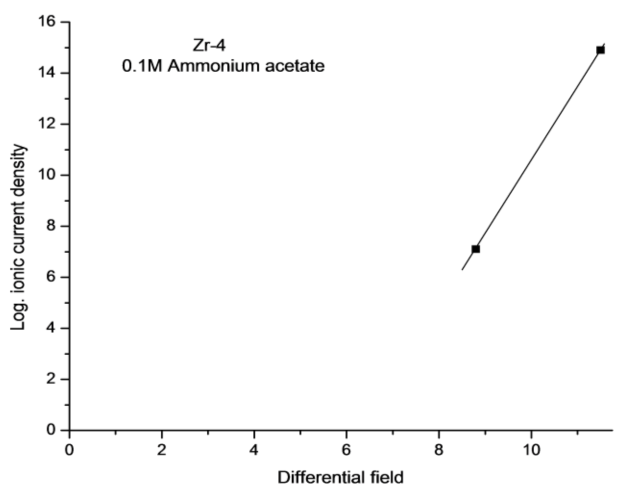
Highlights

- Galvanostatic technique by faraday 1st law of zirconia ceramics as implant material
- The growth kinetics of zirconia studied at constant current densities
- Investigated the ionic current density on differential field strength
- The half – jump distance and height of the energy barrier deduced by Cabrera – Mott theory.
- Graphical Representation



Abstract

Anodic polarization of zircaloy-4 implies the cabrera-mott theory is limited by the field-facilitated activated jumps of the free-metal ions at the metal-oxide interface was originally proposed to interpret growth of thin oxide coloured films on plane metal surfaces. The growth kinetics of Zircaloy-4 have been studied by Faraday 1st law in 0.1M ammonium acetate at constant current densities ranging from 16 to 18 $mA.cm^2$ at room temperature in order to investigate the dependence of ionic current density on the field across the zirconia ceramics. Thickness of the oxide coloured films was estimated from capacitance data. The formation rate, faradaic efficiency and differential field were found to increase with increase in the ionic current density for coloured thin film zirconia ceramic. Investigated the Growth kinetics of different anodization voltages shown colour zirconia ceramics formed on the surface of entire thin oxide film by the acetate anions and applicable in medical sciences as implant material. A plot of logarithm of ionic current density vs. Differential field and applying the Cabrera-Mott theory. The half-jump distance (a) and height of energy barrier (W) were deduced. Zirconia ceramic is recorded for exhibiting enhanced mechanical properties as well as biocompatibility in hip orthroplastyas well as bone implants.

Keywords Zirconia as ceramics, implant material, ammonium acetate, Anodic polarization by faraday 1st law, Cabrera-Mott theory, constant current densities.

Introduction

A large number of populations in the world suffer from various types of bone issues including age related degenerative bone problems. [1] In addition, accidents can lead a person to extensive rehabilitation. [1] For example, in 2017, primary total knee and hip replacements in Australia alone have increased by 139.8% and 73.3% respectively since 2003. [2]
Age, like other parts of the body, accidents, and disease, cause's bones to weaken and be damaged. Bone fractures, low back pain, osteoporosis, scoliosis, and other musculoskeletal problems are common in the elderly, but not always. Implants and other biomaterials are used to treat injured bones, cartilage, ligaments, and tendons. [3]
Anodization of zirconium alloys have been studied in some electrolytes. [4]
The theory advanced by Cabrera and Mott [5] on the basis of earlier work by Mott [6] to explain the rate of growth of oxide films on metals usually has been regarded as directly applicable to the case of anodic oxidation. When valve metals such as zirconium and its alloys like Zr – 2, Zr – 4, etc are anodically polarized, interference colored oxide films are formed. These smooth and mechanically perfect anodic films can act as dielectrics in capacitors. The phenomenon of anodic oxidation plays a basic role in micro-circuitry [7] and in thin film methods [8].
Anodic oxide films formed on valve metals are useful in the field of electrical and electronic components (such as capacitors, resistors, dioxides and photo electric devices), corrosion protection and for decorative purposes. Applications of anodic films have been reviewed [9]. Guntherschultze and Betz [10] were the first to investigate the kinetics and mechanism of the anodic oxidation of metals.
The kinetics of anodic film formation on zirconium in various electrolytes has been reviewed [11]. Vermilyea [12] has published data covering a range of temperatures, which dispute some of the predictions of the theory of Mott and Cabrera. Their theory predicts a logarithmic increase of forming field with current density (or rate of formation). Zirconium and its alloys have been studied for being used in the nuclear power industry and have been recently commercialized for its use in medical implants, especially for total knee and hip replacements after hydrothermally grown oxide [13]. Zr and Zr alloys have greater strength, lower cytotoxicity and lower magnetic susceptibility than titanium [14]. These advantageous properties make Zr and its alloys good promising candidates as materials in orthopaedic surgery.
In the current research work, to study the effect of constant current densities on the anodic polarization of implant material zirconia ceramic anodic layer on zircaloy-4 in 0.1M ammonium acetate by faraday 1st law and Cabrera – Mott theory to deduce the half – jump distance (a) and height of energy barrier (W).

Materials and Methods

Zircaloy-4 was of 98% nominal purity, supplied in the form of plate by **Nuclear Fuel Complex, Hyderabad** as gift samples. Thinning of this Zr-4 plate was done by **Defence Metallergical Research Lab, Hyderabad**. Cutting of the thinned sheet was done at **tools and techniques, Hyderabad.** The chemical composition of zircaloy-4: 0.07 wt. % chromium; 0.23 wt. % iron; 1.44 wt. % tin and balance is zirconium.
In the present work, the foil samples used were cut with the aid of a punch into flag-shaped specimens of 1 cm2 working area on both side and 1 ½ cm 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.

Electrochemical conditions

The counter electrode was a sheet of Platinum (2x3 cm, weight 3.000 gm). The working electrode was the Zircaloy-4 sample as implant material. For anodizing, a double walled glass cell 100mL capacity was used. The experiments were performed in an electrolyte, 0.1M ammonium acetate. All experiments were carried out at constant current densities ranging from 8 to 20 $mA.cm^{-2}$. The experimental procedure for the anodic polarization by faraday 1st law is given elsewhere [15]. The kinetic results calculated are formation rate in Vs^{-}, faradaic efficiency (η) % from the conventional plots V vs. t, D_c vs. D_F. The Cabrera – Mott theory to deduce the half – jump distance (a) in Å and height of energy barrier (W) in eV.

Results

Anodic Polarization Studies

Specimens of biomaterial zircaloy-4 were separately polarized galvanostatically in 0.1M ammonium acetate at a constant current density of 16 $mA.cm^{-2}$ and at room temperature. The anodization voltage vs. anodization time plot **Fig. 1** consist of straight lines intersecting was found to be linear with a curve up to the breakdown voltage. The breakdown voltage was observed to be 215V for zircaloy-4. the calculated formation rate and faradaic efficiency are found to be 1.19**$V.s^{-1}$** and 88.86**%.**The plots of anodization voltage vs anodization time, thickness by capacitance (ΔDc) vs. thickness by faradaic (ΔD_F) and thickness by capacitance vs. anodizing voltage for zircaloy-4 are were drawn and observed to be linear up to break down voltage and plots are shown in **Fig. 1, 2 and 3.** From these plots the formation rate, faradaic efficiency, differential field were increased, estimated and are summarized in **Table 1.**

Dependence of ionic current density on the field of formation

Anodic polarization were carried out separately in 0.1M ammonium acetate on biomaterial at various current densities ranging at 16 & 18$mA.cm^{-2}$ at room temperature to investigate the dependence of the ionic current density on the field across the oxide film. The conventional plots are drawn and shown in **Fig.4, 5 & 6.** The formation rate, faradaic efficiency and differential field were found to increase with increase in the current density for zirconia ceramics. The details are summarized in the Table-1. The plot of log. ionic current density vs. field strength gave fairly a linear relationship in mentioned in graphical representation.

Table 1 Anodic polarized oxide film formed on zirconia ceramic

Current density, $mA.cm^{-2}$	Formation rate $V.s^{-1}$	Faradaic efficiency η (%)	Ionic current density $mA.cm^{-2}$	Log. Ionic current density, Log. i_i	Differential field, F_D ($MV.cm^{-1}$)
16	1.19	88.86	14.21	1.152	8.828
18	1.82	>100	18	1.255	18.09

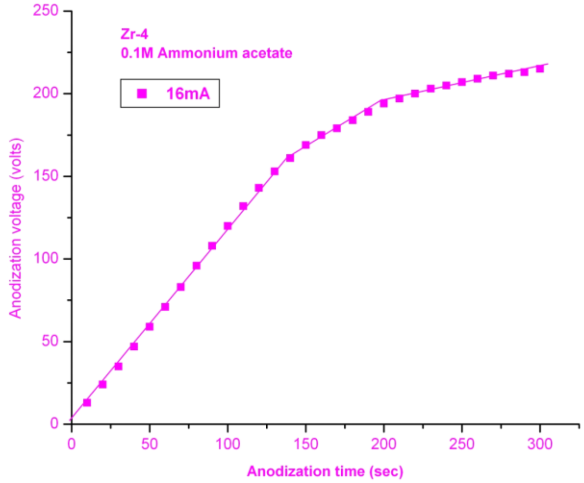


Figure. 1: Plot of anodization voltage as a function of anodization time.

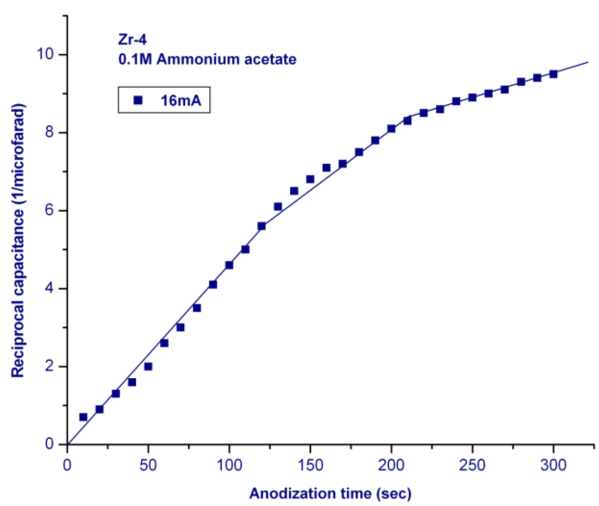


Figure. 2: Plot of thickness by capacitance as a function of faradaic.

Conclusion

Anodic oxide film formation in the electrolyte 0.1M ammonium acetate found to improve the kinetic results. The addition of anions found to improve the growth kinetics of different colours covering entire thin films on the surface at different break down voltages. On the basis of the evidence available the rate determining step is considered to be situated at the oxide/electrolyte interface, and Cabrera- Mott theory is applied to the growth kinetics, the deduced value of half jump distance (a) height of the energy barrier (W) are increased. Zirconia ceramics is in evidence as a dental biomaterial and it is the material of choice in contemporary restorative dentistry. Zirconia ceramic is also recorded for exhibiting enhanced mechanical properties as well as biocompatibility in hip orthroplastyas well as bone implants. it also serves application in bone cement to provides adhesion between the biomedical implants used for the treatment of injured bones, cartilage, ligaments and tendons.

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4 plate under rollers.

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