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Fabrication of Aluminum Using Casting Method Made For Anodizing Process On Biomaterial Applications

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Abstract. One type of non ferrous material that has quite a number of applications is aluminum. In addition, this metal is quite easy to obtain and can be made in various ways and has good corrosion resistance. One method commonly used in producing aluminum is by casting. This method is quite often used because it can produce finished products in large quantities and high levels of product precision, especially by using permanent molds. This casting result will later be used as an anode in the anodizing process. Anodizing process is one of the electrochemical processes used to repair the aluminum surface by using an electrolyte solution applied to a certain voltage to obtain an oxide layer with characteristics. This anodizing process is starting to be widely used in the biomaterial realm and began to be applied with the use of aluminum oxide coating membranes in the bodies of living things.

Keywords : Aluminum, casting process, anodizing, biomedical applications

1. Introduction

Definition of biomaterials in general is a replacement material that is used to replace part of a living system or to function bound with living tissue [1]. This material can be derived from natural or synthetic materials used in the given time period on a part or the whole system to replace tissue, organ or function of the body. However, the biomaterial has shortcomings when compared with the organs of the body, such as the absence of a response such complex organs in general [2]. Biomaterials only have a single response. Additionally arise following the introduction of the biomaterial tissue response in the form of the toxin response and foreign body response.

Aluminum is known as one type of metal that has quite diverse applications because this material has a good corrosion resistance because it is able to form an oxide layer on the surface, has the ability to form and is capable of excellent machines and can be produced by various methods, so that aluminum is quite widely used in the world of automotive and manufacturing [3]. However, this material also began to be applied in the medical world as an application of biomaterials and drug delivery using anodic aluminum oxide membrane (AAO) [4]. The successful application of alumina as a biomaterial began in the early 1970s with the development of hip bone replacement technology [5].

One method of making aluminum is by casting process [6]. The process of metal casting itself is widely used for the process of forming an object because many geometrical shapes of complicated objects can only be made with a metal casting process. Metal casting is divided into two types, namely metal casting with permanent molds and single-use molds. Permanent molds are often used because

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they can be used repeatedly and can produce workpieces with more precise sizes. Besides that, the metal casting process using permanent molds is suitable for producing objects with complicated shapes and mass production.

2. Casting Process

Metal casting is a manufacturing process that is carried out by pouring molten metal into a mold to get a certain shape [6-7]. There are four factors that influence the casting process, namely the flow of molten metal into the printing cavity, the transfer of heat during metal freezing and cooling in the mold, the effect of the mold material and the solidification of the metal in liquid conditions [6].

One type of mold that is widely used in the casting process is a permanent mold. In this casting process, the mold used can be used repeatedly [8]. Permanent mold casting is divided into two sides which are easy to remove and install. The cavity is divided into two with precision and has a smooth surface [9]. This mold is usually made of steel or cast iron. Cores can also be applied to permanent molds, usually made of metal and the shape must be easy to remove from castings by considering size tolerance. This mold is usually used for casting non-ferrous metals or alloys, such as aluminum, magnesium and copper alloys. Other materials including lead, zinc and tin and iron and steel are also sometimes casted in permanent molds [10].

The advantage of casting using permanent molds is the result of a smooth surface and a more precise dimension than the mold for expable mold casting. In addition, molds with fine grain structure result in rapid solidification, resulting in stronger castings products [11]. The casting process using permanent molds is suitable for forming workpieces that have not too complicated shapes but are required to carry out mass production.

3. Anodizing Process

Before the anodizing process takes place, the quality of the substrate, surface structure and surface treatment will have a significant impact on the morphology and nanostructures produced on the surface during the anodizing process [12]. The aluminum substrate naturally has an oxide layer on its surface, which is usually produced by oxygen in the atmosphere. In addition, the substrate can also have a different surface structure when processed mechanically, heat, chemically and electrochemically. All treatments on the surface before this anodization can have a decisive effect on the formation of pore structures formed on the surface of the substrate during the anodizing process.

The formation mechanism consists of two stages. In the first stage, there is a linear increase in voltage over time, so that the thickness of the barrier layer increases and the formation is reached. In the second stage, the tension at the formation of the formation is maintained while the barrier layer continues to increase by moving the ions out of Al^{3+} into the electrolyte and the incoming movement of O^{2-} and OH^- ions, as shown in Figure 1 [13].

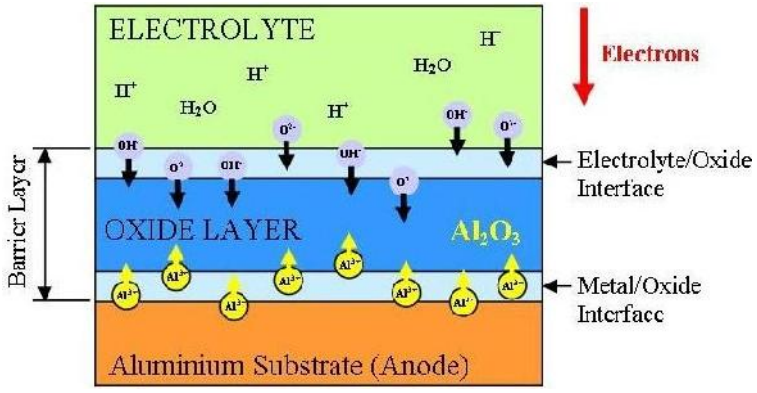


Figure 1. Barrier layer formation scheme [14]

Oxide formation occurs both in the metal / oxide interface and also the oxide / electrolyte interface where Al3 + ions react with water molecules in the electrolyte. When the thickness of the barrier layer increases, the electrical resistance also increases, the metal / oxide and the oxide / electrolyte interface remain planar and the flow of current decreases with time. At the end of this stage, the barrier layer is fully formed and remains constant.

Meanwhile the process of pore layer formation is a fairly complicated process that produces organized hexagonal pore, this honeycomb structure has been mentioned by several researchers [15]. In contrast to the barrier layer formation mentioned in the previous section, this pore structure consists of a thin non-pore oxide layer at a constant thickness adjacent to a metal substrate that regenerates continuously at the bottom of the pore when the pore wall is forming, this wall increases over time [16]. Special electrolytes, concentrations held, anodic stresses and room temperature are the main parameters in determining the size and distance between pores.

There are two mechanisms that contribute to the loss of Al^{3+} ion from metal substrate. The first is through the release of ion directly through the electric field used and the second is the dissolution of the formed oxide layer. In addition, if there is a region of current flow when the electric field is applied, the level of solution that continues to increase can be generated by the dissolution process with the help of an electric field [17].

In the early stages of the anodizing process, Al^{3+} ion move from the metal across the metal / oxide interface into the formed oxide layer [18]. While O^{2-} ions formed from water in the oxide / electrolyte interface move towards the oxide layer. During this stage, about 70% of Al^{3+} ion are dissolved in the electrolyte. This condition has been shown to be the initial stage of pore growth, where Al-O bonds in the oxide molecule break down and release Al^{3+} ions [19]. During oxide formation, the barrier layer regenerates with oxide growth and transforms into a semi-spherical oxide layer at a constant thickness that forms the pore base, as shown in Figure 2.

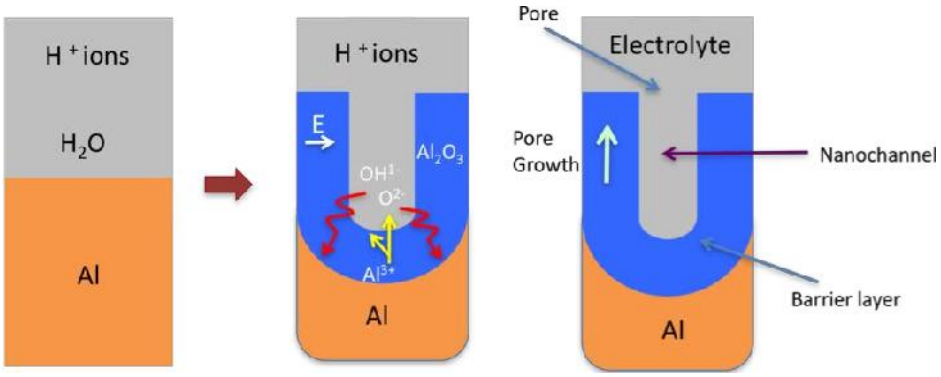


Figure 2. Scheme of pore formation mechanism in acid electrolyte [14]

During the pore layer process, the reaction at Al anode is indicated by the equation

$$2Al \rightarrow 2Al^{3+} + 6e^{-} \quad (1)$$

And the reaction produced at the cathode will produce hydrogen gas

$$6H^{+} + 6e^{-} \rightarrow 3H_2 \quad (2)$$

Anode reactions that occur at the metal / oxide boundary (oxygen anions react with Al)

$$2Al + 3O_2 \rightarrow Al_2O_3 + 6e^{-} \quad (3)$$

In the oxide / electrolyte interface there is a reaction between Al cations and water molecules

$$2Al^{3+} + 3H_2O \rightarrow Al_2O_3 + 6H^{+} \quad (4)$$

The number of separate reactions on the electrode (the whole anodization in the Al equation)

$$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2 \quad (5)$$

The balance between the dissolution of oxide which is helped by the presence of an electric field in the oxide / electrolyte interface at the bottom of the pore will be half-spherical because the electric field is high enough to push the Al^{3+} ion through the barrier layer resulting in the growth of oxide in the metal / oxide interface resulting from ion transfer O^{2-} and OH^{-} into the pore base oxide layer

The oxidation process occurs at the entire pore base and the resulting oxide layer grows upright to the surface. The pore layer thickness makes the pore height continue to grow many times the height of the barrier layer [20]. This usually takes place during the growth of oxides which make electrolytic anions able to integrate into hollow structures that form near the oxide / electrolyte interface while pure alumina is often found in layers close to the metal / oxide interface. In the pore wall structure, the main element consists of alumina (amorphous Al_2O_3), anion from the electrolyte which can amount to 20% depending on the electrolyte and the conditions of its formation [21].

4. AAO Application as A Biomaterial

Several studies that have been carried out using AAO began to be developed in the field of biomaterials and are research topics that are now emerging. In the last decade, there have been a lot of ideas in terms of potential applications of materials with nano-based structures. During this time, almost all simple methods of producing synthetic materials have reviewed the past and analyzed possible uses in nanomaterial manufacturing. One of them is by using anodizing process on aluminum using titanium cathodes [22-23]. An increase in corrosion resistance and titanium penetration to a certain depth in the anodic layer is the result obtained from this study.

Biomaterial investigations since 1970 have shown that osteoblasts have successfully attached and interacted with nanoporous structures of the AAO membrane, making the aluminum membrane suitable for cell culture substrates [24]. Cell culture that grows on both sides of the membrane is a promising finding in nerve tissue.

AAO membranes have also been used for cell interface substrates in biomaterial applications [25]. The membrane proved to be able to support cell adhesion. When compared with tissue tissue culture made from plastic, pores in AAO can increase cell proliferation ability which will increase albumin production in cases that occur in the liver.

There are three significant advantages in using AAO membranes for cell culture. First anodizing process is proven to be able to control the pore diameter size. Second, the membrane formed is colorless and transparent, making it possible to carry out routine checks to determine the cell growth and morphology using an optical microscope. This has been realized with the success of growing HepG2 hepatoma line cells on the AAO membrane. The cells formed are attached to the membrane and are able to develop during the culture period. [26]. Third is to have mechanical flexibility [27]. Unlike rigid alumina ceramics used in hard tissue engineering applications, membranes can be easily formed to suit the skin or body shape of individual patients.

Meanwhile the anodic layer formed on the aluminum surface begins to be used as a replacement for tissue in the skin [28]. Subsequent studies examine the use of AAO on cell culture substrates [29]. The study examined the use of AAO membranes in biomedical applications by culturing AAO in African monkey green kidney epithelial cells. The entire membrane showed no cytoxic effect after 72 hours of proliferation assay.

An in-depth study of the AAO application and the use of cast aluminum that has been anodized must be carried out to determine the material's biocompatibility in living things. Although the ability of aluminum biocompatibility to continue to be reviewed and there has not been found a rejection reaction from the culture tested in living things.

5. Conclusion

The casting process in aluminum is one of the most widely used manufacturing processes for various needs because it has many advantages and economic value. The use of this process also began to be applied in the realm of biomaterials as a means of providing raw materials for the implementation of the anodizing process. In this anodizing process, an electrochemical material engineering process is

carried out to obtain anodic coating that has the desired mechanical properties in the biomedical field, including increased corrosion resistance and the ability to control pores. This anodic aluminum layer is later widely used because it has good membrane attachment and is transparent and has excellent biomechanics. Besides that there is no rejection reaction on living creatures making this material an alternative use in the field of biomaterials. Further applications in the future will still require further research.

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