学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　AYALEW Adane Adugna

学 位 論 文 題 名

Localized Electrochemical Additive Manufacturing Using Solution Flow type Microdroplet Cell
(溶液フロー型マイクロ液滴セルを用いた局所電気化学的積層造形)

Nowadays, the fabrication of numerous micro- and nano-structured materials, as well as their technical applications has received much attention. Additive manufacturing through electrochemical deposition and anodizing are promising approaches to fabricating good electrical and mechanical properties of metal micro- and nanostructures. Conventional lithographic and masking-based fabrication techniques are not widely used due to the sophisticated facilities required and significant material waste. Electrochemical droplet cell fabrication techniques are getting specific consideration for microstructure fabrication and localizing oxide films on selective substrate areas. The ability to fabricate local surface patterns with electrochemical microdroplet cells on various substrates will play a significant role in many industrial activities. Solution flow type microdroplet cell (SF-MDC) is the latest mask-less technology proposed to fabricate metallic micro- and nano-structured materials on selective substrate areas. The SF-MDC has a capillary tube, allowing for electrolyte droplets to move on the substrate. Previously used SF-MDC has some problems for making due to the complex design of geometries. A combination of computer-aided design software and 3D printing is one possible technique used for the fabrication of an electrochemical droplet cell with intricate geometry. In this research, a 3D-printed SF-MDC is proposed for the fabrication of Ni microstructures on the Cu substrate and area-selective anodizing for the formation of a through-hole porous anodic alumina layer on the Al. The effect of current densities and scanning speeds on the height of deposited Ni and the influence of scanning speeds, substrate temperatures, and electrolyte compositions on thickness of anodized aluminum oxide lines were investigated.

An overview of additive manufacturing through electrochemical deposition and fabrication of some metallic microstructures in anodic pores of the aluminum membrane is given in Chapter 1. The background of additive manufacturing techniques, electrochemical deposition parameters, and the mechanism of electrochemical deposition are discussed in detail. In Chapter 2, a SF-MDC is designed with one inner capillary and an outer capillary for the fabrication of 2D and 3D microstructures on a Cu substrate. The influence of current density and moving speed on the thickness of Ni deposition is studied. Free-standing 3D Ni micro-rods and different patterns are fabricated on a Cu substrate using SF-MDC. In Chapter 3, a simplified design of SF-MDC is proposed for fabrication of through-hole porous anodic aluminum oxide layer locally. The influence of anodized voltages and scanning speeds on the thickness and pore structure of the alumina layer are investigated. The effect of anodizing substrate temperatures and electrolyte compositions on the fabrication of through-hole porous AAO membranes are studied. A 0.3 M oxalic acid solution was used as an anodizing electrolyte. Through-hole porous AAO was successfully fabricated at room temperature without chemical etching. A 0.3

M oxalic, phosphoric and sulfuric acid solutions are used as an anodizing electrolytes. The anodizing substrate temperature greatly influenced the regularity of nanopore structure and the degree of oxide film growth. In Chapter 4, the fabrication of Ni nanorods into a porous anodic aluminum oxide template through an electrochemical deposition technique is investigated. The effect of anodic scanning speed on the formation of pore size distribution, alumina etching time, and deposition time are investigated on the electrochemical fabrication of Ni nanorods. The uniformity and completeness of filling Ni nanorods into the pores of the AAO layer are attained by controlling the deposition time and current density. The general conclusion of the research work is presented in Chapter 5.