cbecimat26
26° Congresso Brasileiro de Engenharia e Ciência dos Materiais
22 a 26 de novembro de 2026
Costão do Santinho
Florianópolis-SC

Development of a 3D-printed electrochemical cell for process standardization in aluminum anodization

Caio P. Fernandes[1], Katia F. A. Torres[1], Daniel S. Raimundo[1], Jorge D. Marconi[1]
[1]Universidade Federal do ABC (UFABC) - Centro de Engenharia, Modelagem e Ciências Sociais Aplicadas (CECS)

Introduction

The synthesis of anodic aluminum oxide (AAO) via electrochemical anodization is a versatile, cost-effective technique for obtaining nanostructures with tunable properties. However, reproducibility remains challenging due to variability in conventional cell configurations. Additive manufacturing, particularly 3D printing, offers a promising approach for fabricating low-cost, custom-designed devices with precise geometries. Tailored cell architectures enable control of electric fields, mass transport, and electrolyte flow, contributing to efficient, standardized anodization.

Objectives

The objective of this work is to develop a 3D-printed acrylonitrile butadiene styrene (ABS) electrochemical cell designed to improve standardization and reproducibility in aluminum anodization. The customized geometry restricts anodization to a defined area, reduces electrolyte volume, and optimizes current distribution across oxalic, sulfuric, and phosphoric acid electrolytes. The study also evaluates current-time curves to identify nanotube formation regimes, estimate optimal processing times, and assess device performance and chemical compatibility.

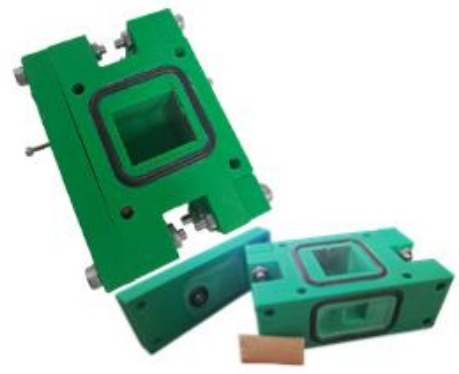
Materials and Methods

An enhanced electrochemical cell with customized geometry was designed using CAD software and fabricated by 3D printing with ABS filament as an alternative to the conventional anodization setup. The cell confines anodization to a defined area while reducing electrolyte volume. AAO samples were synthesized at varying voltages using oxalic, sulfuric, and phosphoric acid electrolytes. Current-time curves were analyzed to identify nanotube formation regimes and determine optimal processing times. SEM characterization was performed to evaluate the resulting nanostructures and compare the proposed system with the traditional method.

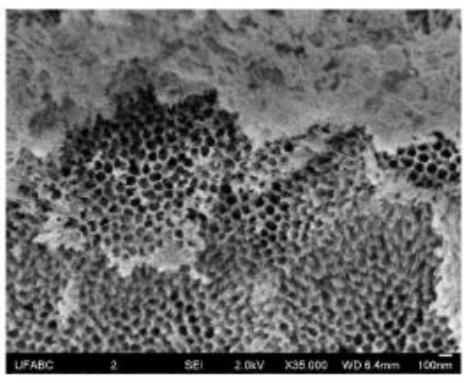
Results and Discussion



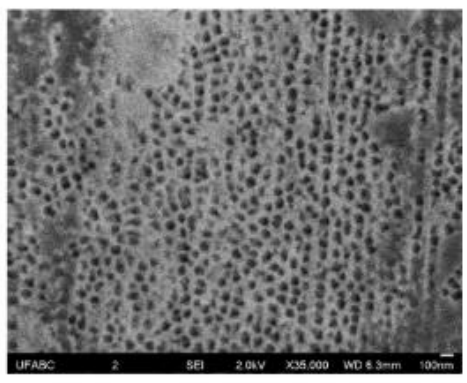
Conventional Anodization Setup
Electrode Distance: Adjustable
Electrolyte Volume: 200 mL



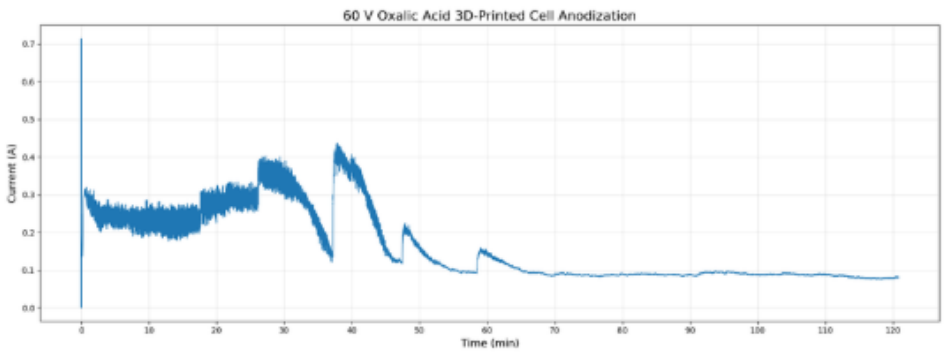
3D-Printed ABS Anodization Cell
Electrode Distance: 3.5 cm
Electrolyte Volume: 12.5 mL



Electrolyte/Voltage: $C_2H_2O_4$, 60 V
Process duration: 120 min



Electrolyte/Voltage: $C_2H_2O_4$, 60 V
Process duration: 12 min



Current (A) x Time (min)
Anodization Curve
60 V, 120 min, Oxalic Acid

Conclusions

The developed 3D-printed ABS electrochemical cell proved to be an effective strategy for promoting standardization and reproducibility in aluminum anodization. The customized architecture confined anodization to a well-defined area of 1 cm^2 while reducing electrolyte consumption from 200 mL to 12.5 mL. Analysis of current-time curves enabled the identification of nanotube formation regimes and estimation of optimal processing times for tailoring AAO morphology. Overall, the proposed platform provides a low-cost and versatile approach for fine-tuning anodization parameters, with SEM characterization confirming the successful formation of aluminum oxide nanostructures.

References

AMBROSI, Adriano; SHI, Raymond Rong Sheng; WEBSTER, Richard D. 3D-printing for electrolytic processes and electrochemical flow systems. **Journal of Materials Chemistry A**, v. 8, n. 42, p. 21902–21929, 20 Oct. 2020.
CARDOSO, Rafael et al. 3D printing for electroanalysis: From multiuse electrochemical cells to sensors. **Analytica Chimica Acta**, v. 1033, p. 49–57, 29 Nov. 2018.
SCHIMO, Gabriela; HASSEL, Achim Walter. 3D printed double flow cell for local through-thickness anodisation in aluminium. **Electrochemistry Communications**, v. 69, p. 84–88, Aug. 2016.

Acknowledgements

CNPq
UFABC
CEM
CENTRAIS EXPERIMENTAIS MULTIUSUÁRIO
Universidade Federal do ABC