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AI-assisted development of an interactive framework for SEM image processing and porous material characterization

Caio P. Fernandes[1], Katia F. A. Torres[1], Daniel S. Raimundo[1], Priscila B. C. Gonçalves[2]
[1]Universidade Federal do ABC (UFABC) - Centro de Engenharia, Modelagem e Ciências Sociais Aplicadas (CECS)
[2]Instituto Federal de São Paulo (IFSP) - Departamento de Elétrica

Introduction

The characterization of porous materials from SEM images is essential for evaluating their morphology and properties. However, quantitative image analysis often involves time-consuming and operator-dependent processing steps. Artificial intelligence (AI) has emerged as a promising approach to automate and accelerate materials characterization. In this context, AI-assisted image processing can facilitate pore detection and quantitative morphological analysis, contributing to more efficient and reproducible characterization of porous structures.

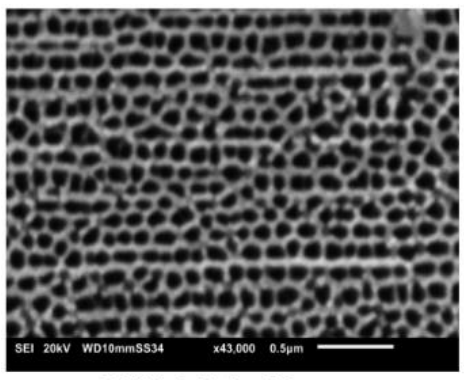
Objectives

The objective of this work is to develop an AI-assisted computational pipeline for automated morphological characterization of porous materials from scanning electron microscopy (SEM) images. The framework integrates dimensional calibration, image segmentation, pore identification, porosity calculation, extraction of morphological parameters, and statistical analysis into a single platform. The study also aims to evaluate its performance using anodic aluminum oxide (AAO) samples produced under different anodization conditions.

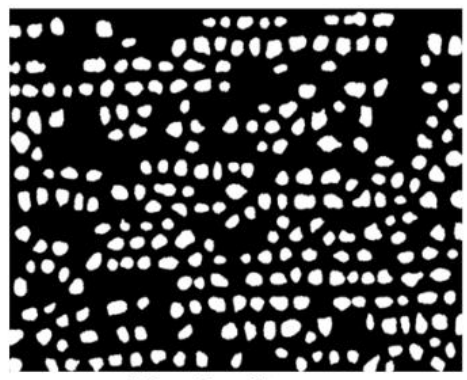
Materials and Methods

AAO samples were produced by electrochemical anodization using aluminum and platinum electrodes under different acidic electrolytes and applied voltages, followed by gold sputtering and SEM characterization. The AI-assisted framework was developed in Python and Google Colab, with ChatGPT (OpenAI, GPT-5.5) supporting implementation and optimization. The workflow performs dimensional calibration, image segmentation, pore detection, morphological analysis, and automatic statistical processing, with user-defined area in pixels and circularity filters for selective pore characterization.

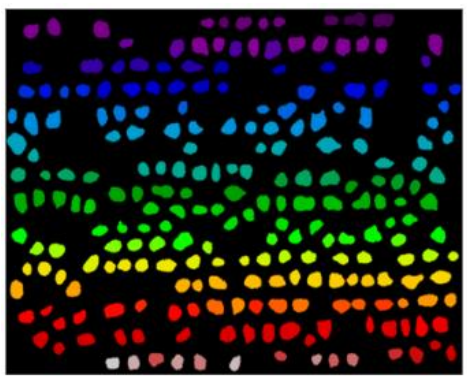
Results and Discussion



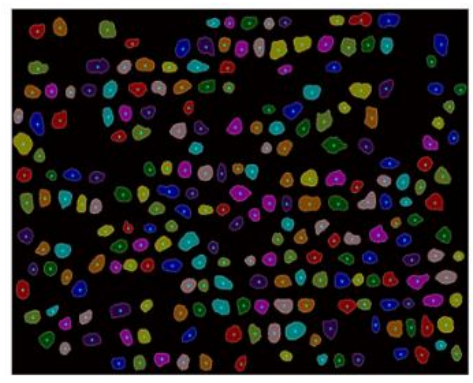
SEM Original Image
Electrolyte: H_3PO_4 (0.3 mol/L)
Potential: 90 V



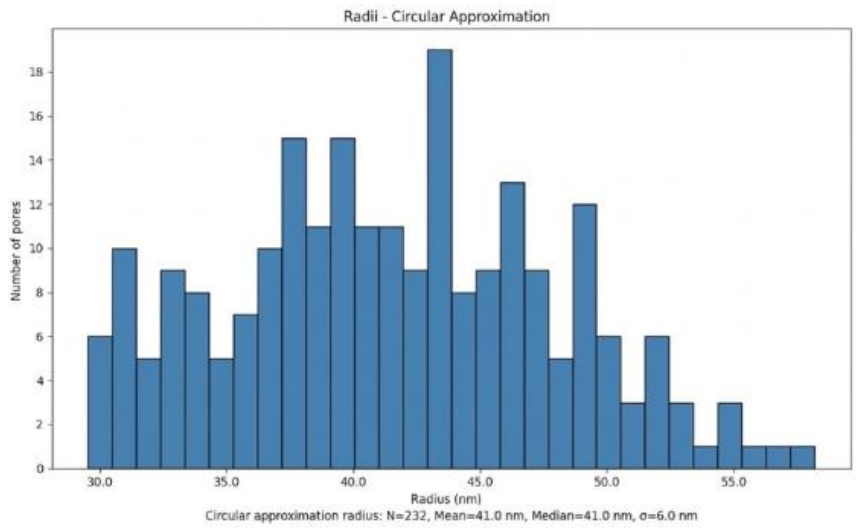
Binarized Image
Area filter: 500 - Infinity pixels
Circularity: 0.55 - 1.00



Segmented Pores



Centroids



Conclusions

The developed approach demonstrated reliable performance in the quantitative characterization of AAO, achieving excellent agreement with ImageJ and confirming the robustness of the obtained measurements. Beyond reducing the effort associated with microstructural analysis, the automated generation of statistical and morphological outputs facilitates the interpretation of large experimental datasets and supports more efficient material development. Its flexible structure also enables application to other porous systems, while future integration with deep learning may further expand its automation and applicability.

References

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SULKA, G. D. Highly Ordered Anodic Porous Alumina Formation by Self-Organized Anodizing. **Nanostructured Materials in Electrochemistry**. [s.l.] Weinheim : Wiley-VCH Verlag GmbH & Co. KGaA, 1–116, 2008.

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