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論　文　要　旨
Thesis Abstract

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主論文題名　（Title）　Optimization Design of Solid Oxide Fuel Cell Electrodes' Microstructure Using a Machine Learning Approach

内容の要旨　（Abstract）

Solid oxide fuel cells (SOFCs) are highly promising devices for the conversion of hydrogen's chemical energy into electrical energy. Their wide power output range, coupled with the potential for combined heat and power generation, has generated significant interest from both the scientific community and industry. While SOFC technology is already being tested and applied worldwide, there remains substantial untapped potential for enhancing its scalability and applicability.

Solid oxide fuel cells consist of two porous electrodes, namely the anode and cathode, separated by a gas-tight, ion-conducting electrolyte. By supplying hydrogen to the anode and oxygen to the cathode, the hydrogen oxidation reaction produces a potential difference between the electrodes, allowing the conversion of chemical energy into electricity. Researchers and companies worldwide are actively exploring novel designs, manufacturing methods, and materials to further improve this technology.

Methods for the three-dimensional microstructural reconstruction of fuel cell electrodes enabled research and modeling of fuel cells at a fundamental level. These developments have paved the way for efforts to design microstructures of fuel cells and maximize the efficiency of fuel cell stacks within the constraints imposed by materials and manufacturing techniques.

The goal of this work is to propose methodology and tools for microstructure optimization of electrodes under specific operating conditions. This work covers various topics, including quantitative analysis and geometrical modeling of solid oxide fuel cells microstructures, mathematical and numerical modeling of transport and electrochemical phenomena at the microscale, using artificial intelligence to enhance the mathematical model of solid oxide fuel cells, formulation of optimization problems for an inhomogeneous anode and cathodes microstructures, and optimization using the design of experiments methodology and evolutionary algorithms.

The results of this research include the utilization of microstructure generation and quantification methods to establish crucial dependencies of microstructural parameters. Additionally, the electrochemical model has been improved through the incorporation of artificial neural networks and experimental data sets. Furthermore, a finite element method has been formulated for modeling the operation of solid oxide fuel cells, with gas transport modeled using the dusty-gas model. u Finally, a combination of the design of experiments methodology and evolutionary algorithms have been employed to optimize inhomogeneous electrodes by minimizing thermodynamic losses associated with transport phenomena and electrochemical reactions.

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