Modeling Of Solid Oxide Fuel Cell System Multi Scale Modeling And Simulation Of Thermal Fluid And Electrochemical Transport In A Solid Oxide Fuel Cell

Modeling of Solid Oxide Fuel Cell Performance with Coal Gasification

A comprehensive membrane-electrode assembly (MEA) model of Solid Oxide Fuel Cell (SOFC)s is developed to investigate the effect of various design and operating conditions on the cell performance and to examine the underlying mechanisms that govern their performance. We review and compare the current modeling methodologies, and develop an one-dimensional MEA model based on a comprehensive approach that include the dusty-gas model (DGM) for gas transport in the porous electrodes, the detailed heterogeneous elementary reaction kinetics for the thermo-chemistry in the anode, and the detailed electrode kinetics for the electrochemistry at the triple-phase boundary. With regard to the DGM, we corrected the Knudsen diffusion coefficient in the previous model developed by Multidisciplinary University Research Initiative. Further, we formulate the conservation equations in the unsteady form, allowing for analyzing the response of the MEA to imposed dynamics. As for the electrochemistry model, we additionally analyzed all the possibilities of the rate-limiting reaction and proposed rate-limiting switched mechanism. Our model prediction agrees with experimental results significantly better than previous models, especially at high current density.

Multiscale Modeling of Solid Oxide Fuel Cell Stack

The development of mathematical models and numerical simulations is crucial to design improvement, optimization, and control of solid oxide fuel cells (SOFCs). The current study introduces a novel and computationally efficient pseudo-two-dimensional (pseudo-2D) model for simulating a single cell of a high-temperature hydrogen-fueled SOFC. The simplified pseudo-2D model can evaluate the cell polarization curve, species concentrations along the channel, cell temperature, and the current density distribution. The model takes the cell voltage as an input and computes the total current as an output. A full-physics three-dimensional model is then developed in ANSYS Fluent, with a complete step-by-step modeling approach being explained, to study the same cell with the identical operating conditions. The 3D model is validated against the other numerical and experimental studies available in the literature. It is shown that although the pseudo-2D solution converges significantly faster in comparison with the 3D case, the results of both models thoroughly match especially for the case of species distributions. The simplified model was then used to conduct sensitivity analysis of the effects of multi-physiochemical properties of porous electrodes on the polarization curve of the cell. A systematic inverse approach was then used to estimate the mentioned properties by applying the pattern search optimization algorithm to the polarization curve found by the pseudo-2D model. Finally, nine different
input parameters of the model were changed to find the hydrogen distribution for each case, and a huge dataset of
nearly half a million operating points was generated. The data was successfully employed to design a novel classifier-
regressor pair as a virtual hydrogen sensor for online tracking of hydrogen concentration along the cell to avoid fuel
starvation.

Aspects of mathematical modeling of solid oxide fuel cells

In chapter 4 and chapter 5, the relationship between SOFC electrode micro parameters and SOFC cell performance is
developed, aiming at improving SOFC performance by optimizing SOFC electrodes. The whole relationship can be
divided into 2 parts: the relationship between electrode micro parameters and electrode effective properties (content
in Chapter 4) and the relationship between electrode effective properties and cell performance (content in Chapter 5).
The effective TPB length and effective conductivity are two important electrode effective parameters. However, by
now, the relationship between electrode micro parameters and the effective TPB length are well investigated while the
relationship between electrode micro parameters and the effective conductivity are still lacking. In chapter 4, the
composite electrode is numerically constructed using a random particle packing procedure, followed by a particle
geometric dilating to simulate the sintering process. The effects of various electrode micro parameters on the electrode
effective conductivity are investigated, including material composition, porosity, particle size and contact angle.
Results show that, the effective conductivity of electrode solid phase is mainly determined by its total volume fraction
in electrode (including the gas phase). Based on the numerical results, the conventional percolation model describing
the relationship between electrode micro parameters and electrode effective conductivity is improved. In chapter 5, a
macro SOFC model is developed bridging the electrode effective properties to the cell performance (section 5.1 & 5.2).
In the model, the electron transport, ion transport and gas transport are coupled with local electrochemical reactions
in electrodes. The model can be used for SOFC electrode design and optimization by incorporating with electrode
micro-models. As a step towards electrode optimization, the electrochemical active thickness (EAT) in SOFC anode is
investigated using the developed multi-scale model (section 5.3). The EAT indicates the key part to be optimized in
SOFC electrode. By both numerical and theoretical analysis, an positive relationship between the EAT and the ratio
Ract, con/Rohmic is finally concluded.

Finite Element Modeling of Solid Oxide Fuel Cells

Solid Oxide Fuel Cells

Numerical Modeling of Solid Oxide Fuel Cell

Growing concern over greenhouse gas emissions has driven research into clean coal power production alternatives.
Novel coal power plant designs that lower CO2 emissions are imperative in the coming decades to mitigate global
temperature rise. High-efficiency stationary power systems that integrate coal gasification with solid oxide fuel cells
(SOFCs) have been championed by the Department of Energy for the past couple of decades. However, many
fundamental questions about this system still need to be addressed by modeling the complex coupling between SOFC’s
and gasification. More specifically, work is needed to characterize SOFC performance with a range of syngas
(H2+CO) mixtures produced by coal gasification. This thesis used a multiscale modeling approach to analyze SOFC
performance with coal syngas at both the systems level and at the surface reaction scale. The first investigation in this
thesis couples an equilibrium gasifier model to a detailed ID SOFC model to study the theoretical performance of the
coupled system run on steam or carbon dioxide. The results of this study indicate that the system performs
substantially better with steam gasification than with CO2 gasification as a result of the faster electro-oxidation
kinetics of H2 relative to CO. The coupled system is then shown to reach higher current densities and efficiencies
when the heat released by the fuel cell is sent to the gasifier instead of a bottoming cycle. 55-60% efficiency is then
predicted for the system with heat transfer and steam gasification, making this technology competitive with other
advanced system designs and almost twice as efficient as conventional coal-fired power plants. The second study in
this thesis investigates SOFC behavior with H2 and CO (syngas) mixtures that come from coal gasification. SOFC
models typically neglect CO electrochemistry in the presence of H2 and H2O, assuming that the water-gas-shift
reaction proceeds faster than CO electrooxidation. The results of this study show, however, that CO electro-oxidation
cannot be neglected in syngas mixtures, particularly at high current densities for high CO-content syngas. First the
simulations demonstrate that incoming CO is not all shifted to form H2 by reforming reactions before reaching the
electrochemical reaction sites. Furthermore, the results of this study confirm that direct electro-oxidation of CO
contributes non-negligible current relative to H2 at high anode overpotentials. Together these results show that CO
electro-oxidation plays an important role in SOFC performance not only via water-gas-shift reforming, but also via

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Direct electro-oxidation when H2 is also present. This work suggests that accurate models for both surface reforming and direct electro-oxidation of CO in SOFC anodes must be included in order to capture performance when using coal syngas mixtures. Finally, a multi-step mechanism for the simultaneous electro-oxidation of H2 and CO in SOFCs is implemented and studied. This mechanism combines a couple of reaction pathways: hydrogen (H) spillover to the electrolyte, and oxygen (O) spillover to hydrogen and CO on the anode. This mechanism is successfully verified in the model against a wide range of experimental data for mixtures of CO/CO2, H2/N2, H2/H20, H2/CO, and H2/CO2. The simulations show that H spillover is the dominant source of current at low anode activation overpotentials, but also demonstrate that the currents produced by 0 spillover are non-negligible at high overpotentials. Furthermore, it is shown that the current produced by 0 spillover to CO is not limited by the rate of CO adsorption on nickel, which leads CO to contribute more to cell performance at high currents. Together these three modeling studies demonstrate how coal can be efficiently converted to electricity via gasification and the simultaneous electro-oxidation of H2 and CO in a solid oxide fuel cell.

**Models for Solid Oxide Fuel Cell Systems**

“Solid oxide fuel cell (SOFC) technology has been of great interest over many years due to its flexibility in using different fuels for operation; including the fundamental fuel i.e. Hydrogen. Various computational and numerical models have been developed along with experimental work to evaluate the performance as well as to identify and overcome the problems faced in the development of SOFC’s. In an attempt to achieve efficient operation with respect to design and combined thermal and electrochemical perspective, the main objective of the proposed study is to present a three-dimensional computational model, which will serve as a framework for the analysis and optimization of SOFC’s. A three-dimensional model of a tubular SOFC was developed to study the effect of temperature and electrolyte thickness variations on its performance. A commercial Computational Fluid dynamics (CFD) software ANSYS FLUENT 12.0 was used for the development of the model which incorporates an interactive 3-D electro-thermo-chemical fluid flow analysis. The particular model, after validation against experimental observations for selected benchmark cases, was demonstrated to be compatible for intermediate temperature operations using hydrogen as fuel. The performance of the model was analyzed by varying electrolyte thicknesses from 2-100 [mu]m. The same model was further evaluated using different fuels such as CH4 (methane) and CO (carbon monoxide), including the modeling of the reforming and the water-gas shift reactions. The results were compared to other computationally less expensive, analytical and empirical models, thus confirming the given model to be used as a basic model for future research on intermediate temperature solid oxide fuel cells."--Abstract, leaf iii.

**Computer Modeling of Solid Oxide Fuel Cells**

High Temperature Solid Oxide Fuel Cells: Fundamentals, Design and Applications provides a comprehensive discussion of solid oxide fuel cells (SOFCs). SOFCs are the most efficient devices for the electrochemical conversion of chemical energy of hydrocarbon fuels into electricity, and have been gaining increasing attention for clean and efficient distributed power generation. The book explains the operating principle, cell component materials, cell and stack designs and fabrication processes, cell and stack performance, and applications of SOFCs. Individual chapters are written by internationally renowned authors in their respective fields, and the text is supplemented by a large number of references for further information. The book is primarily intended for use by researchers, engineers, and other technical people working in the field of SOFCs. Even though the technology is advancing at a very rapid pace, the information contained in most of the chapters is fundamental enough for the book to be useful even as a text for SOFC technology at the graduate level.

**An Introduction to the Study of Mineralogy**

This book presents methodologies suitable for the optimal design of control and diagnosis strategies for Solid Oxide Fuel Cell (SOFC) systems. One key feature of the methodologies presented is the use of modeling tools with an ideal balance between accuracy and computational burden. Particular emphasis is given to the useful combination of models within a hierarchical framework to reduce the experimental efforts required for characterization and testing. Such tools are proven to be highly effective for SOFC systems destined for both residential and transportation applications. Throughout the book, optimization is always conceived in such a way so as to allow the SOFC systems to work efficiently while guaranteeing safe thermal operation, as well as an extended lifetime. This book is aimed at scientists and engineers involved in the design of marketable SOFC systems. It gathers the knowledge and experience derived from other research and industry practice for which control and diagnosis have proven to be the main keys to success and market penetration.

**Advanced Methods of Solid Oxide Fuel Cell Modeling**
**Dynamic Modeling and Predictive Control in Solid Oxide Fuel Cells**

Abstract: Planar solid oxide fuel cells (SOFCs) are made up of repeating sequences of electrolytes, electrodes, seals, interconnects, and current collectors. For electro-chemical reasons it is best to keep the electrolyte as thin as possible. However, for electrolyte-supported cells, the thin electrolytes are susceptible to damage during production, assembly, and operation. To produce cells with sufficient mechanical robustness, electrolytes can be made with a co-sintered honeycomb structure that supports the thin, electro-chemically efficient electrolyte membranes.

**Dynamic Modeling and Predictive Control in Solid Oxide Fuel Cells**

The book summarizes the current state of the solid oxide fuel cell (SOFC) technology in power generation applications. It describes the single cells, SOFC stacks, micro-combined heat and power systems, large-scale stationary power generators and polygeneration units. The principles of modeling, simulation and controls of power systems with solid oxide fuel cells are presented and discussed. Authors provide theoretical background of the technology followed by the essential insights into the integrated power systems. Selected aspects of the design, construction and operation of power units in range from single kilowatts to hundreds of kilowatts are presented. Finally, the book reports the selected studies on prototype systems which have been constructed in Europe. The book discusses the theoretical and practical aspects of operation of power generators with solid oxide fuel cells including fabrication of cells, design of stacks, system modeling, simulation of stationary and non-stationary operation of systems, fuel preparation and controls.

**Multi-Level Mathematical Modeling of Solid Oxide Fuel Cells**

**Mathematical Modeling of Solid Oxide Fuel Cells**

**Three Dimensional Computational Fluid Dynamics Modeling of Solid Oxide Fuel Cell Using Different Fuels**

**Mechanical Characterization and Modeling of Solid Oxide Fuel Cell Electrolytes with Honeycomb Support**

**Modeling and Simulation for Solid Oxide Fuel Cell Power System**

The model simulations were in good agreement with experimental data from studies in the literature and demonstrate the essential role of the exchange current density and the volume-specific effective anode surface area, whose values are often not reported in the literature.

**Hybrid Systems Based on Solid Oxide Fuel Cells**

A comprehensive guide to the modelling and design of solid oxide fuel cell hybrid power plants. This book explores all technical aspects of solid oxide fuel cell (SOFC) hybrid systems and proposes solutions to a range of technical problems that can arise from component integration. Following a general introduction to the state-of-the-art in SOFC hybrid systems, the authors focus on fuel cell technology, including the components required to operate with standard fuels. Micro-gas turbine (mGT) technology for hybrid systems is discussed, with special attention given to issues related to the coupling of SOFCs with mGTs. Throughout the book emphasis is placed on dynamic issues, including control systems used to avoid risk conditions. With an eye to mitigating the high costs and risks incurred with the building and use of prototype hybrid systems, the authors demonstrate a proven, economically feasible approach to obtaining important experimental results using simplified plants that simulate both generic and detailed system-level behaviour using emulators. Computational models and experimental plants are developed to support the analysis of SOFC hybrid systems, including models appropriate for design, development and performance analysis at both component and system levels. Presents models for a range of size units, technology variations, unit coupling dynamics and start-up and shutdown behaviours. Focuses on SOFCs integration with mGTs in light of key constraints and risk avoidance issues under steady-state conditions and during transient operations. Identifies interaction and coupling...
Mathematical Modeling of Solid Oxide Fuel Cells

High-temperature Solid Oxide Fuel Cells, Second Edition, explores the growing interest in fuel cells as a sustainable source of energy. The text brings the topic of green energy front and center, illustrating the need for new books that provide comprehensive and practical information on specific types of fuel cells and their applications. This landmark volume on solid oxide fuel cells contains contributions from experts of international repute, and provides a single source of the latest knowledge on this topic. A single source for all the latest information on solid oxide fuel cells and their applications illustrates the need for new, more comprehensive books and study on the topic. Explores the growing interest in fuel cells as viable, sustainable sources of energy

Modeling, Design, Construction, and Operation of Power Generators with Solid Oxide Fuel Cells

Modeling Solid Oxide Fuel Cells

Design and Operation of Solid Oxide Fuel Cells: The Systems Engineering Vision for Industrial Application presents a comprehensive, critical and accessible review of the latest research in the field of solid oxide fuel cells (SOFCs). As well as discussing the theoretical aspects of the field, the book explores a diverse range of power applications, such as hybrid power plants, polygeneration, distributed electricity generation, energy storage and waste management—all with a focus on modeling and computational skills. Dr. Sharifzadeh presents the associated risks and limitations throughout the discussion, providing a very complete and thorough analysis of SOFCs and their control and operation in power plants. The first of its kind, this book will be of particular interest to energy engineers, industry experts and academic researchers in the energy, power and transportation industries, as well as those working and researching in the chemical, environmental and material sectors. Closes the gap between various power engineering disciplines by considering a diverse variety of applications and sectors. Presents and reviews a variety of modeling techniques and considers regulations throughout. Includes CFD modeling examples and process simulation and optimization programming guidance

Thermal Modeling of Solid Oxide Fuel Cell Based Biomass Gasification Systems

This book fills the need for a practical reference for all scientists and graduate students who are seeking to define a mathematical model for Solid Oxide Fuel Cell (SOFC) simulation. Structured in two parts, part one presents the basic theory, and the general equations describing SOFC operation phenomena. Part two deals with the application of the theory to practical examples, where different SOFC geometries, configurations, and different phenomena are analyzed in detail.

Modelling and Diagnosis of Solid Oxide Fuel Cell (SOFC)

Solid oxide fuel cells (SOFCs) are promising electrochemical power generation devices that can convert chemical energy of a fuel into electricity in an efficient, environmentally-friendly, and quiet manner. Due to their high operating temperature, SOFCs feature fuel flexibility as internal reforming of hydrocarbon fuels and ammonia thermal cracking can be realized in SOFC anode. This book presents an overview of the SOFC technology with a focus on the recent developments in new technologies and new ideas for addressing the key issues of SOFC development. This book first introduces the fundamental principles of SOFCs and compares SOFC technology with conventional heat engines as well as low temperature fuel cells. Then the latest developments in SOFC R&D are reviewed and future directions are discussed. Key issues related to SOFC performance improvement, long-term stability, mathematical modelling, as well as system integration/control are addressed, including material development, infiltration technique for nano-structured electrode fabrication, focused ion beam – scanning electron microscopy (FIB-SEM) technique for microstructure reconstruction, the Lattice Boltzmann Method (LBM) simulation at pore scale, multi-scale modelling, SOFC integration with buildings and other cycles for stationary applications.

Microstructural Characterisation, Modelling and Simulation of Solid Oxide Fuel Cell Cathodes
Advanced Methods of Solid Oxide Fuel Cell Modeling

"A timely treatment of the modeling and advanced control of the most promising fuel cell technology - SOFC (solid oxide fuel cells) - from cell to system level Dynamic Modeling and Predictive Control in Solid Oxide Fuel Cells: Delivers comprehensive coverage of SOFC dynamic models and modeling approach from first principles, bringing together many aspects of SOFC technology in one book for the first time Provides parameters for all models developed for easy reference and reproducing of the results Discusses lumped model and distributed model from cell level to system level Applications to the state-of-the-art unscented Kalman filter, model predictive control, and monitoring techniques to SOFC systems Uses NMPC, which is well understood by both industry and academia Essential reading for Graduate students and researchers in the area of fuel cells, process systems engineering, control systems engineering, process control and electrochemical engineering"--

Porous Electrodes Modeling of Solid Oxide Fuel Cells and Advanced Lead Acid Batteries

Modeling of Solid Oxide Fuel Cell

Design and Operation of Solid Oxide Fuel Cells

Multi-Level Mathematical Modeling of Solid Oxide Fuel Cells.

Modeling of Solid Oxide Fuel Cells

The high temperature solid oxide fuel cell (SOFC) is identified as one of the leading fuel cell technology contenders to capture the energy market in years to come. However, in order to operate as an efficient energy generating system, the SOFC requires an appropriate control system which in turn requires a detailed modelling of process dynamics. Introducing state-of-the-art dynamic modelling, estimation, and control of SOFC systems, this book presents original modelling methods and brand new results as developed by the authors. With comprehensive coverage and bringing together many aspects of SOFC technology, it considers dynamic modeling through first-principles and data-based approaches, and considers all aspects of control, including modelling, system identification, state estimation, conventional and advanced control. Key features: Discusses both planar and tubular SOFC, and detailed and simplified dynamic modelling for SOFC Systematically describes single model and distributed models from cell level to system level Provides parameters for all models developed for easy reference and reproducing of the results All theories are illustrated through vivid fuel cell application examples, such as state-of-the-art unscented Kalman filter, model predictive control, and system identification techniques to SOFC systems The tutorial approach makes it perfect for learning the fundamentals of chemical engineering, system identification, state estimation and process control. It is suitable for graduate students in chemical, mechanical, power, and electrical engineering, especially those in process control, process systems engineering, control systems, or fuel cells. It will also aid researchers who need a reminder of the basics as well as an overview of current techniques in the dynamic modelling and control of SOFC.

Dynamic Modelling and Predictive Control in Solid Oxide Fuel Cells

Advances in Medium and High Temperature Solid Oxide Fuel Cell Technology

An Introduction to the Study of Mineralogy is a collection of papers that can be easily understood by a wide variety of readers, whether they wish to use it in their work, or simply to extend their knowledge. It is unique in that it presents a broad view of the mineralogy field. The book is intended for chemists, physicists, engineers, and the students of geology, geophysics, and soil science, but it will also be invaluable to the more advanced students of mineralogy who are looking for a concise revision guide.

High-temperature Solid Oxide Fuel Cells for the 21st Century

In this book well-known experts highlight cutting-edge research priorities and discuss the state of the art in the field of solid oxide fuel cells giving an update on specific subjects such as protonic conductors, interconnects, electrocatalytic and catalytic processes and modelling approaches. Fundamentals and advances in this field are illustrated to help
young researchers address issues in the characterization of materials and in the analysis of processes, not often tackled in scholarly books.

**Multi-Component and Multi-Dimensional Mathematical Modeling of Solid Oxide Fuel Cells**

**Dynamic Modeling of Solid Oxide Fuel Cell**

Solid Oxide Fuel Cell Lifetime and Reliability: Critical Challenges in Fuel Cells presents in one volume the most recent research that aims at solving key issues for the deployment of SOFC at a commercial scale and for a wider range of applications. To achieve that, authors from different regions and backgrounds address topics such as electrolytes, contaminants, redox cycling, gas-tight seals, and electrode microstructure. Lifetime issues for particular elements of the fuel cells, like cathodes, interconnects, and fuel processors, are covered as well as new materials. They also examine the balance of SOFC plants, correlations between structure and electrochemical performance, methods for analysis of performance and degradation assessment, and computational and statistical approaches to quantify degradation. For its holistic approach, this book can be used both as an introduction to these issues and a reference resource for all involved in research and application of solid oxide fuel cells, especially those developing understanding in industrial applications of the lifetime issues. This includes researchers in academia and industrial R&D, graduate students and professionals in energy engineering, electrochemistry, and materials sciences for energy applications. It might also be of particular interest to analysts who are looking into integrating SOFCs into energy systems. Brings together in a single volume leading research and expert thinking around the broad topic of SOFC lifetime and durability Explores issues that affect solid oxide fuel cells elements, materials, and systems with a holistic approach Provides a practical reference for overcoming some of the common failure mechanisms of SOFCs Features coverage of integrating SOFCs into energy systems

**Solid Oxide Fuel Cell Lifetime and Reliability**

**Modeling of Solid Oxide Fuel Cell Functionally Graded Electrodes and a Feasibility Study of Fabrication Techniques for Functionally Graded Electrodes**

**Modeling of Solid Oxide Fuel Cell/gas Turbine Hybrid Systems**

**Modeling of Solid Oxide Fuel Cells**

"A timely treatment of the modeling and advanced control of the most promising fuel cell technology - SOFC (solid oxide fuel cells) - from cell to system levelDynamic Modeling and Predictive Control in Solid Oxide Fuel Cells: Delivers comprehensive coverage of SOFC dynamic models and modeling approach from first principles, bringing together many aspects of SOFC technology in one book for the first time Provides parameters for all models developed for easy reference and reproducing of the results Discusses lumped model and distributed model from cell level to system level Applications to the state-of-the-art unscented Kalman filter, model predictive control, and monitoring techniques to SOFC systems Uses NMPC, which is well understood by both industry and academia Essential reading for Graduate students and researchers in the area of fuel cells, process systems engineering, control systems engineering, process control and electrochemical engineering"--

**High-temperature Solid Oxide Fuel Cells: Fundamentals, Design and Applications**

Fuel cells are widely regarded as the future of the power and transportation industries. Intensive research in this area now requires new methods of fuel cell operation modeling and cell design. Typical mathematical models are based on the physical process description of fuel cells and require a detailed knowledge of the microscopic properties that govern both chemical and electrochemical reactions. Advanced Methods of Solid Oxide Fuel Cell Modeling proposes the alternative methodology of generalized artificial neural networks (ANN) solid oxide fuel cell (SOFC) modeling. Advanced Methods of Solid Oxide Fuel Cell Modeling provides a comprehensive description of modern fuel cell theory and a guide to the mathematical modeling of SOFCs, with particular emphasis on the use of ANNs. Up to now, most of the equations involved in SOFC models have required the addition of numerous factors that are difficult to determine. The artificial neural network (ANN) can be applied to simulate an object's behavior without an
algorithmic solution, merely by utilizing available experimental data. The ANN methodology discussed in Advanced Methods of Solid Oxide Fuel Cell Modeling can be used by both researchers and professionals to optimize SOFC design. Readers will have access to detailed material on universal fuel cell modeling and design process optimization, and will also be able to discover comprehensive information on fuel cells and artificial intelligence theory.

**Solid Oxide-Based Electrochemical Devices**

Solid Oxide-Based Electrochemical Devices: Advances, Smart Materials and Future Energy Applications provides a complete overview of the theoretical and applied aspects of energy-related solid oxide technologies. The book presents detailed thermodynamic and other basic requirements for fuel cells, electrolyzers, supercapacitors, batteries, sensors and air treatment devices. It delves into physical-chemical, electrochemical and mechanical properties of smart materials developed and offers insights into fundamental analysis and modeling. Detailed protocols for operation are suggested and discussed, including component development to optimize functionality, cost and upscaling. Practitioners in the fuel cell or power to gas industries, engineering researchers developing new technologies in those areas, and device and system designers can use the in-depth, structured information about the relationship between technologies and materials offered to make better-informed decisions during the planning and implementation of those technologies. Covers the theoretical concepts, components, advances and applications of solid oxide fuel cell, electrolyzer, battery, sensor and pollution abatement technologies Explores applications of new smart and metamaterials in the construction of energy-related solid oxide devices Presents examples of prototypes, including their cost estimate and requirements for large-scale production, integration and operation

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