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"Sustainable Materials for Transitional and Alternative Energy"

Edited by Mufrettin Murat Sari (Texas A&M University, USA), Cenk Temizel (Saudi Aramco, Kingdom of Saudi Arabia), Celal Hakan Canbaz (Ege University, Turkey), Luigi A. Saputelli (ADNOC Frontender Corp, USA) and Ole Torsæter (Norwegian University of Science and Technology, Norway), Modern Materials and Sensors for the Oil and Gas Industry Series, Gulf Professional Publishing, an Imprint of Elsevier, Oxford, UK, 2021, 294 pages, ISBN 978-0-12-824379-4, £106.50, €132.41, US$138.75

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Introduction

"Sustainable Materials for Transitional and Alternative Energy" is a 294-page, five-chapter book which forms one part of the Modern Materials and Sensors for the Oil and Gas Industry Series. The book is authored and edited by Mufrettin Murat Sari (Texas A&M University, USA), Cenk Temizel (Saudi Aramco, Kingdom of Saudi Arabia), Celal Hakan Canbaz (Ege University, Turkey), Luigi A. Saputelli (ADNOC Frontender Corp, USA) and Ole Torsæter (Norwegian University of Science and Technology, Norway), in collaboration with a further 15 contributors.

Mufrettin Murat Sari is a Chemistry Professor at the Department of Chemistry, Texas A&M University, and Life and Health Science Department, University of North Texas at Dallas, USA. Beginning with his PhD degree from Hacettepe University, Turkey, in 2005, he has 20 years of experience in the fields of materials chemistry, applied biochemistry and nanotechnology. Throughout his illustrious career, he has published about 40 scientific articles and proceedings with hundreds of citations. Cenk Temizel is a Senior Reservoir Engineer with Saudi Aramco. His career spans around 15 years in industry working on reservoir simulation, smart fields, heavy oil, optimisation, geomechanics, integrated asset modelling, unconventionals and enhanced oil recovery (EOR) across the Middle East, USA and UK, prior to which he was a teaching and research assistant at the University of Southern California, USA, and Stanford University, USA. Like Temizel, Celal Hakan Canbaz is a Senior Reservoir Engineer with 16 years industrial experience. He is highly regarded in the fields of special core analysis, reservoir wettability characterisation, well testing analysis, perforation and testing design, multiphase flow meters, carbon dioxide/oil/water interactions, wellbore flow dynamics and pressure-volume-temperature data interpretation. He has made contributions to industrial projects, conference and journal papers, two books and a US patent. Luigi A. Saputelli is a Reservoir Engineering Expert Advisor with 30 years of experience as a reservoir, drilling and production engineer. Alongside his industrial contributions, he is a researcher, lecturer and active volunteer in the Society of Petroleum Engineers, and has published in excess of 100 industry papers on digital oilfield, reservoir management and real-time production optimisation. Ole Torsæter is a Professor of reservoir engineering at the Norwegian University of Science and Technology and Adjunct Professor at the University of Oslo, Norway, as well as a research associate at PoreLab, a Norwegian Centre of Excellence. He has supervised a staggering 220 Masters and 25 PhD candidates, alongside publication of 200 research papers himself, with the most recent focusing on nanofluids for EOR.

"Sustainable Materials for Transitional and Alternative Energy" addresses today's energy needs in a fast-paced world in which nanotechnology is of vital importance for maintaining environmental sustainability and protecting human health. This book keeps pace with advancements in the energy industry by addressing the latest research involving advanced nanomaterials which engineers can apply to nanoparticle applications beyond the petroleum industry. Additional topics in Volume 2 include carbon capture-focused, green-based nanomaterials, the importance of coal gasification in terms of fossil fuels and advanced materials for fuel cells.

This book has been written with the intention of targeting a wide range of readers from academics to researchers, and undergraduate to graduate students, from various backgrounds, including petroleum engineers and researchers, nanotechnology researchers in the oil and gas industry, chemical engineers and material scientists.

This book will be reviewed in order of chapter due to its methodological breakdown starting with the oil and gas industry, before moving onto 'greener' technologies involving nanomaterials.

Chapter 1: Smart and State-of-the-Art Materials in Oil and Gas Industry

The objective of this chapter is to define the field of smart and state-of-the-art materials together with their current status and potential benefits. In the future, more focus will be placed on additives, nanoparticles, shape memory materials and piezoelectric materials: those that can generate electricity on the application of mechanical stress.

Chapter coverage is equally divided among smart materials and state-of-the-art materials. The former refers to those materials that can change their composition or structure, their electrical and mechanical properties or even their functions in response to environmental stimuli. The state-of-the-art materials included in this chapter are additives (bacterial control, corrosion inhibitor, fluid loss, lubricants, fluid viscosifiers, synthetic-based muds, clay stabilisers, antifreeze, odorisation and defoamers) and nanoparticles (for improving sweep efficiencies, stabilised foam, polymer flooding and reduced water production). Their properties and applications are discussed in detail throughout this book, and specifically, this chapter.

Chapter 2: Advanced Materials for Geothermal Energy Applications

Geothermal energy is one of the largest renewable energy sources in existence. Chapter 2 addresses investigation methods used in the exploration, discovery and monitoring phases of geothermal systems, the structural characterisation of which can be implemented through the use of geophysical tools. The latest technology is compared with conventional counterparts in terms of efficiency and cost-effectiveness. This includes the use of nanotechnological materials and advanced tools (for example, fibre optic sensors, distributed temperature sensing systems, thermal infrared remote sensing tools and advanced technology carriers such as drones, aircrafts and satellites) for measuring physical properties of geothermal fluids and rocks. Furthermore, advanced materials and nanomaterials starting to be used in geothermal downstream parts, such as heat transfer and energy conversion in thermoelectrical power plants, are introduced and discussed in appropriate detail.

Chapter 3: Functional Green-based Nanomaterials Towards Sustainable Carbon Capture and Sequestration

CO_2 capture and sequestration (CCS) technologies have received increasing interest in recent years due to the pressing global demand to reduce CO_2 emissions and slow down global warming. This chapter explores the development of reusable, low-cost and green-based adsorbents which are important for efficient and environmentally-friendly removal of CO_2 from the atmosphere. The absorbents discussed in detail include halloysite nanotubes, nanofibrillated cellulose, enzyme immobilised on bioinspired nanosorbents, green metal-organic frameworks and bio-derived porous carbons. The advantages of each are given, alongside research study results and their many uses in CCS, which are well summarised in Sub-chapter 3.7, 'Conclusion and Outlook'. Looking forward to the future, there is a need to investigate CO_2 selectivity of nanomaterials over other gases (for example nitrogen and methane) as research currently focuses on adsorption characteristics.

Chapter 4: Nanocatalysts and Sensors in Coal Gasification Process

As global energy needs increase, so does the importance of addressing energy security, environmental problems and the cost of energy. Since renewable energy sources are yet to reach the required energy demand, and issues of radioactive waste from nuclear energy remain, the gasification process (conversion of hydrocarbon fuels into gases) stands out as an alternative technology that enables the production of clean gas products that can be used in many areas. This book's penultimate chapter provides a comprehensive background for nanocatalysts and sensors in the coal gasification process. Emphasis is placed on the use of catalysts, specifically nanocatalysts with their superior physical properties (namely, large surface area to volume ratio), in the gasification process which have the potential to increase carbon conversion rates and economically reduce processing times.

Inconsistent with the first three chapters of this book and the subsequent final one, Chapter 4 does not have a 'Conclusions' section. This emphasises the point raised at the end of this review which highlights the book's lack of editorial consistency and disruptive flow of content.

Chapter 5: Advanced Materials for Next-Generation Fuel Cells

The fifth and final chapter of this book introduces the reader to fuel cell technology and its importance as one of the main solutions for the next generation of environmentally friendly energy. It provides a general perspective on fuel cell types, namely polymer electrolyte membrane, microbial, alkaline, phosphoric acid, solid oxide and protonic ceramic, their mechanisms and applications, alongside the nanostructures used to produce catalysts in this field.

For background context, fuel cells are electrochemical devices that directly convert chemical energy from oxygen and hydrogen into electrical energy in a single step. Several improvements and developments regarding the increase in hydrogen production, improvements in cell design, removal of membrane, utilisation of microbial catalysts or platinum-free catalysts have been successfully demonstrated in the field of electrocatalysts. These are addressed in this chapter and summarised in **Figure 1** and **Table I**.

While proton exchange membrane fuel cell development is the most highly anticipated area, traditional catalysts, such as platinum nanoparticles on carbon (Pt/C) are still being used in current fuel cells as well as nonprecious metal catalysts. Nanoscale materials used in fuel cell technology include nanoparticles, nanoframes, nanorods and core-shell structures – the latter of which has shown

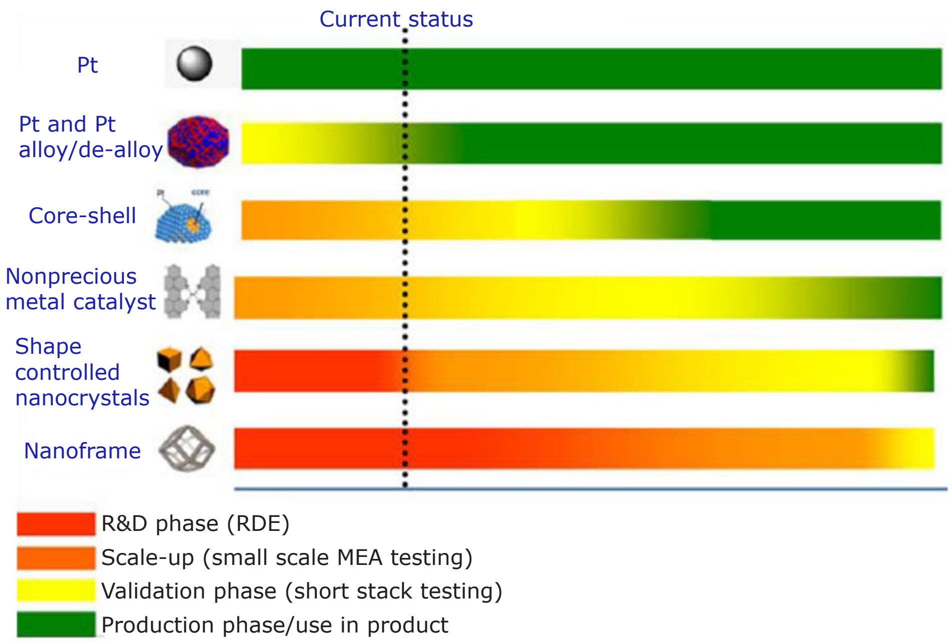
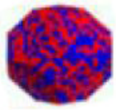
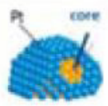
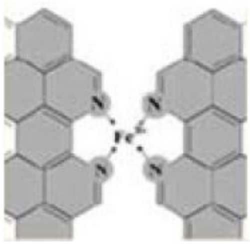


Fig. 1. Timeline giving a general ranking of technology readiness for each catalyst family for fuel cells. R&D = research and development, MEA = membrane electrode assembly. Copyright 2021 Elsevier

Table I Benefits and Remaining Challenges for each of the Primary Categories of Electrocatalysts

Catalyst type	Benefit	Remaining challenges
Platinum 	(a) Mature technology	(a) Unable to meet long term automotive Pt loading and catalyst layer durability targets
Platinum alloy/de-alloy 	(a) Mature technology (b) Improved performance over Pt/C (c) Enhanced membrane/MEA durability	(a) Difficult to meet long term automotive Pt loading target
Core-shell 	(a) Improved mass activity over Pt alloy (b) Improved durability over Pt/C (c) Highest reported ECSA	(a) Difficult to maintain quality of 'shell' (b) Dissolution of 'core' still a concern
Shape controlled nanocrystal 	(a) Significantly higher mass activity (~15 x) over Pt (b) Chemical synthesis (*vs.* electrochemical) may allow for easier scale-up *vs.* core-shell	(a) Scale-up is at an early stage (b) Conflicting data on stability (c) MEA performance has not been demonstrated yet
Nanoframe/nanocage 	(a) Significantly higher mass activity (>20 x) over Pt (b) Highly stable (improved durability over Pt/C)	(a) Scale-up is at an early stage (b) Ionomer penetration into nanocage will likely be difficult (c) MEA performance at high current density may be challenging
Nonprecious metal catalyst 	(a) Potentially offer the largest benefit (significant cost reduction) (b) Tolerant to common contaminants	(a) Close to meeting targets for non-automotive applications (for example, backup power) but far from meeting automotive targets (b) At current volumes, pgm loading is not a major concern for non-automotive applications

MEA = membrane electrode assembly; ECSA = electrochemical surface area; pgm = platinum group metal

enhanced results in the cathodes and anodes in fuel cells electrodes – which have contributed immensely to fuel cell commercialisation expansion. Current and potential fuel cell applications are discussed in detail in this chapter and summarised in **Figure 2**.

Conclusions

In summary, this book provides a detailed introduction and assessment of the use of sustainable materials in the energy industry. Scientific papers and research are heavily referenced throughout; these are highly detailed and often require the reader's full attention and specialist background knowledge in order to be fully understood. This book is best suited to a subject matter expert interested in making technological advances in the energy industry using smart and state-of-the-art materials, namely nanomaterials.

In general, this is a poorly written book which made for an unnecessarily difficult read. It is riddled with grammatical errors, such as the omission of conjunction words which greatly impacts upon the flow of the material. Material flow is also disrupted by poor figure placement throughout; there are multiple examples where figures are placed in the middle of sentences rather than at the end of paragraphs making it difficult for the reader to link information.

Inconsistencies exist between chapters due to having multiple contributory authors. The most significant of these concerns the level of background

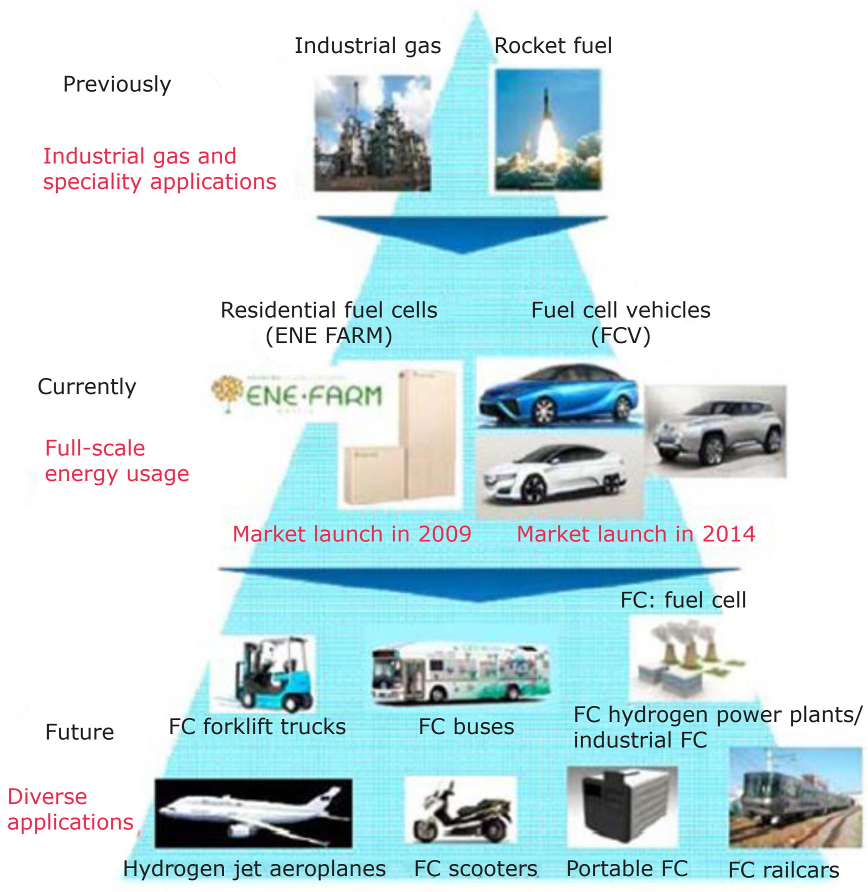
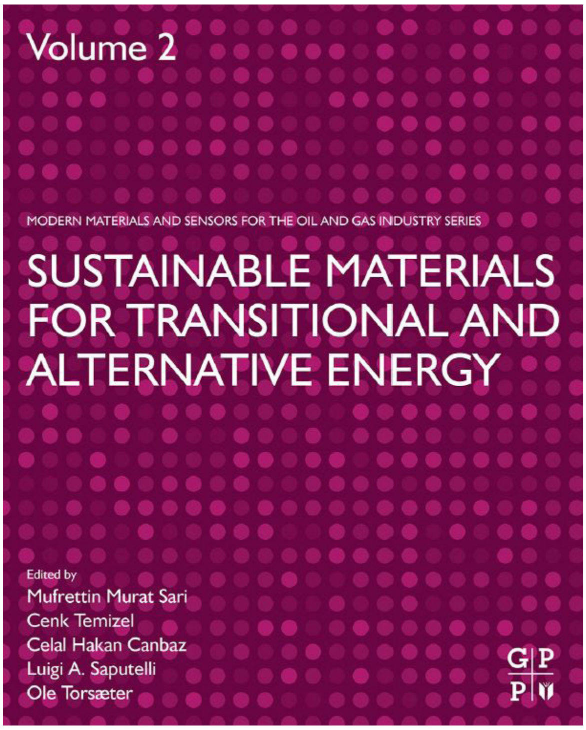


Fig. 2. Potential fuel cell applications. Copyright 2021 Elsevier

or introductory information provided. For example, in Sub-chapter 4.2, fossil fuels, CO_2 formation and global warming are explained in detail, but assumptions are often made in other chapters of a high level of understanding on much more complex and less familiar topics. This is inconsistent with the fact that the book claims to be targeted to undergraduate students from various backgrounds.

Furthermore, the impact of multiple authors on the fluidity of this book is evident through the inclusion of several introductions to nanotechnology and nanomaterials across numerous chapters. This is tedious for the reader when reading the book as a whole; however, if chapters are viewed in isolation, a case can be made for the need for several introductions. Nevertheless, repeated content could be removed, thus saving on space, by cross-referencing information between chapters; this would also have the added benefit of improving the fluidity of the book's content.

Resultantly, this book could have been better edited to ensure consistencies between chapters and eliminate repetitive information.



"Sustainable Materials for Transitional and Alternative Energy"

The Reviewer

Hannah Dixon is a graduate at Johnson Matthey, UK, who has a broad range of experience and knowledge of Johnson Matthey's operations having worked in various sectors of the business. Hannah graduated with a MEng Chemical Engineering degree from The University of Edinburgh, UK, in 2020 having completed optional courses in 'Nanomaterials in Chemical and Biomedical Engineering' and 'Oil and Gas Systems Engineering'. She coauthored an article titled 'Smart Nanotechnologies to Target Tumor with Deep Penetration Depth for Efficient Cancer Treatment and Imaging' published in *Advanced Therapeutics*. Lessons learned during Hannah's time at university and subsequently in industry, initiated her interest in reviewing this book. As a prospective future leader, Hannah has always prioritised sustainability in her work and consistently seeks opportunities to expand her knowledge base in this area and develop personally in line with advancing technologies.