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Introduction and Outline

Mankind's energy demand is increasing exponentially. Between 1900 and 1997, the world's population more than tripled and the average energy demand per human being has also more than tripled, resulting in greater than thirteen times higher overall global emissions [1]. Thus the carbon dioxide concentration rose from 295 parts per million in 1900 to 364 parts per million in 1997 [1]. In 1997 almost all European countries committed to reducing greenhouse gas emissions to an amount 8% below the emissions of 1990 in the period from 2008 to 2012. With this scenario, fuel cell technology is attracting increasing attention nowadays, because it offers the potential to lower these emissions, owing to a potentially superior efficiency compared with combustion engines. Fuel cells require hydrogen for their operation and consequently numerous technologies are under investigation worldwide for the storage of hydrogen, aimed at distribution, and mobile and portable applications.

The lack of a hydrogen infrastructure in the short term, along with the highly attractive energy density of liquid fossil and regenerative fuels, has created widespread research efforts in the field of distribution and on-board hydrogen generation from various fuels. This complex chemical process, generally termed fuel processing, is the subject of this book.

The electrical power output equivalent of the fuel processors that are currently under development world wide covers a wide range, from less than a watt to several megawatts. Portable and small scale mobile fuel cell systems promise to be the first commercial market for fuel cells, according to a market study of *Fuel Cell Today* in July 2003 [2]. According to the same report, the number of systems built has increased dramatically to up to more than 3000 in 2003. To date, most of these systems have used Proton Exchange Membrane (PEM) fuel cells.

Low power fuel processors (1–250 W) compete with both conventional storage equipment, such as batteries, and simpler fuel cell systems, such as Direct Methanol Fuel Cells (DMFC).

Fuel cell systems for residential applications are typically developed for the generation of power and heat, which increases their overall efficiency considerably, because even low temperature off-heat may be utilised for hot water generation, which reduces energy losses considerably.

Fuel Processing for Fuel Cells. Gunther Kolb

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For mobile applications, systems designed to move a vehicle need to be distinguished from the Auxiliary Power Unit (APU), which either creates extra energy for the vehicle (e.g., the air conditioning and refrigerator system of a truck) or works as a stand alone system for the electrical power supply.

This book provides a general overview of the field of fuel processing for fuel cell applications. Its focus is on mobile, portable and residential applications, but the technology required for the smaller stationary scale is also discussed.

In the second chapter fundamental definitions and the basic knowledge of fuel cell technology are provided, as far as is required to gain an insight into the interplay between the fuel cell and its hydrogen supply unit – the fuel processor.

The third chapter deals with the reforming chemistry of conventional and alternative fuels, and with the chemistry of catalytic carbon monoxide clean-up, sulfur removal and catalytic combustion.

An overview of catalyst technology for fuel processing applications is provided in Chapter 4, covering all the processes described in Chapter 3.

The design of the individual components of the fuel processor is the subject of Chapter 5. Design concepts and numerical simulations presented in the open literature are discussed for reforming, catalytic carbon monoxide clean-up and physical clean-up strategies, such as membrane separation and pressure swing adsorption. In addition, fuel processor concepts are then presented and the interplay between the various fuel processor components is explained. Details of the basic engineering of fuel processors and dynamic simulations are discussed, covering start-up and control strategies. Some tips and the basic knowledge required to perform such calculations are provided.

There are three basic types of fuel processing reactors, namely fixed catalyst beds, monoliths and plate heat-exchangers, which are explained in Chapter 6.

Chapter 7 then shows the practical applications of such reactors, as published in the literature.

In Chapter 8 some important aspects of balance-of-plant components are discussed, and Chapter 9 presents complete fuel processors for all types of fuels, while cost and production issues are the subject of Chapter 10.