Materials Challenges in Alternative and Renewable Energy

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A Collection of Papers Presented at the Materials Challenges in Alternative and Renewable Energy Conference February 21–24, 2010, Cocoa Beach, Florida

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Preface

Materials Challenges in Alternative & Renewable Energy (Energy 2010) was an important meeting and technical forum held in Cocoa Beach, Florida, on February 21–24, 2010. This represented the second conference in a new series of inter-society meetings and exchanges, with the first of these meetings held in 2008, on “Materials Innovations in an Emerging Hydrogen Economy.” The current Energy Conference- 2010 was larger in scope and content, and included 223 participants from more than 25 countries and included more than 160 presentations, tutorials and posters. The purpose of this meeting was to bring together leaders in materials science and energy, to facilitate information sharing on the latest developments and challenges involving materials for alternative and renewable energy sources and systems.

Energy 2010 marks the first time that three of the premier materials organizations in the US have combined forces, to co-sponsor a conference of global importance. These organizations included The American Ceramic Society (ACerS), ASM International, and the Society of Plastics Engineers (SPE), representing each of the materials disciplines of ceramics, metals and polymers, respectively. In addition, we were also very pleased to have the support and endorsement of important organizations such as the Materials Research Society (MRS) and the Society for the Advancement of Material and Process Engineering (SAMPE), in this endeavor.

Energy 2010 was highlighted by nine “tutorial” presentations on leading energy alternatives provided by national and international leaders in the field. In addition, the conference included technical sessions addressing state-of-the art materials challenges involved with Solar, Wind, Hydropower, Geothermal, Biomass, Nuclear, Hydrogen, and Batteries and Energy Storage. This meeting was designed for both scientists and engineers active in energy and materials science as well as those who were new to the field.

We are very pleased that ACerS is committed to running this materials-oriented conference in energy, every two years with other materials organizations. We believe the conference will continue to grow in importance, size, and effectiveness and provide a significant resource for the entire materials community and energy sector.

GEORGE WICKS

Savannah River National Laboratory

Energy Conference-2010 Co-Organizer/President-Elect of ACerS

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Technology Access

Energy Conference-2010 Co-Organizer/Past President ASM International

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HYDROGEN STORAGE TECHNOLOGIES – A TUTORIAL WITH PERSPECTIVES FROM THE US NATIONAL PROGRAM

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ABSTRACT

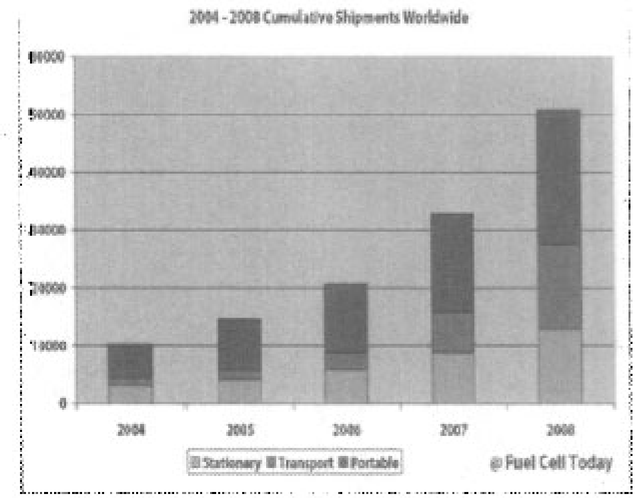
While the demand for electrical power generated by clean, efficient hydrogen fuel cells is rapidly growing, one of the key technical issues that remains to be resolved is the storage of hydrogen, or hydrogen-bearing fuels, to be available to the fuel cell within the design and performance constraints of the total power system. Criteria such as hydrogen storage capacity, weight, volume, lifetime and cycle-life, and certainly cost, become important factors in determining the best storage system for a particular application. In this paper we review the various storage approaches that are currently under investigation and provide a brief materials science tutorial on the storage mechanism for each approach.

Physical storage approaches store hydrogen as a compressed gas, a cryogenic liquid or as a cryo-compressed gas. Materials-based storage systems are based on storing hydrogen by adsorption, absorption or chemical bonding to various materials such as reversible or regenerable hydrides. Each of these storage systems will be discussed and the particular materials science challenges involved will be noted. At the present time no hydrogen storage approach meets all volume, weight and cost requirements for automotive fuel cell power systems across the full range of vehicle platforms. It is clear that materials science will play a key role in the ultimate solution of the hydrogen storage challenge.

INTRODUCTION

Hydrogen fuel cells are emerging as a leading candidate in the search for a clean, efficient alternate energy source. Fuel cells fueled with hydrogen are coming out of the Laboratory and moving toward commercialization in a variety of important applications. Initially fuel cells provided high-value power for both manned and unmanned spacecraft, but more recently they are being developed for “down to earth” applications such as back-up power for telecommunications and uninterrupted power systems (UPS), stationary power for residential, commercial and industrial uses, and portable power for hand-held instrumentation and military applications. Longer term transportation deployments are targeted toward the personal automobile market with specialty vehicles (e.g., forklifts), transit buses, and fleet vehicles leading with early market entry. In 2008 world-wide cumulative shipments of fuel cells exceeded 50,000 units (see Figure 1).

Figure 1. Worldwide Cumulative Fuel Cell Shipments. (Source Fuel Cells Today)



As hydrogen fuel cells become a viable contender in the alternative energy arena, attention is being focused on overcoming the major technical challenges that may ultimately impact introduction in potential early markets. For example, fuel cell cost is a significant factor that must be addressed for this technology to be competitive with conventional, petroleum-based power systems. Likewise the availability of hydrogen to fuel the system is a technical challenge. For the ultimate transportation application – the consumer automobile – a sufficient amount of hydrogen must be stored on-board the vehicle to allow a 300-mile driving range.

Hydrogen continues to receive intense study and support as a leading candidate to provide clean, safe and efficient power as an alternative to petroleum/hydrocarbon sources. Like all potential fuels hydrogen has both advantages and disadvantages. It is the lightest of all the elements. Based on its lower heating value (LHV) hydrogen has a very attractive specific energy of 120 kJ/g or 33.3 kWh/kg – approximately three times that of gasoline. Of course, with a normal boiling point of 20 K, hydrogen is a gas in its normal state with a density of ~0.09 g/L or 11 L/g. So while hydrogen has a high specific energy, due to its low density it has a normal energy density of only 10 kJ/L compared to