Renewable and Sustainable Energy Reviews 65 (2016) 685–697

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Structural model, size effect and nano-energy system design for more sustainable energy of solid state automotive battery

Yong Li [a,c,*], Jie Yang [b], Jian Song [c]

[a] Key Laboratory of Dynamics and Control of Flight Vehicle, Ministry of Education, School of Aerospace Engineering, Beijing Institute of Technology, Beijing 100081, PR China
[b] E & M School, Beihang University, Beijing 100191, PR China
[c] State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, PR China

ARTICLE INFO

Article history:
Received 19 January 2015
Received in revised form
12 May 2016
Accepted 15 July 2016

Keywords:
Structural model
Electric nanoenergy system design
Renewable and sustainable energy battery
Size effect
Solid state battery

ABSTRACT

As compared to traditional batteries, solid state nano-energy batteries have a higher voltage and a wider potential range. In addition, they possess unique characteristics such as high specific capacity, high energy density, fast charging and discharging, explaining why they are considered the reliable energy batteries for electric vehicles. Since these batteries are capable of achieving larger capacity and longer life through nanotechnology, they are prospective in the field of renewable and sustainable energy for electric vehicles. This Review comprehensively summaries and discusses the work of new structural models, size effect and energy system design of solid state batteries. It also analyzes the main challenges and battery's industrial potential for electric vehicles, focusing on the compatibility between solid state electrolyte and battery electrode. With respects to the life span, power density and energy capacity, this Review indicates the prospects of solid state batteries, combines design with application and outlines the research direction of the technologies.

Contents

1. Introduction

As human activity continues to emit carbon dioxide, growths in economy and population are bound to increase the emissions of CO_2 (Fig. 1a) [1]. Combustion of fuel in transportation and industrial sectors also contribute greatly to CO_2 emissions [2,3], particularly the vehicle industry [4,5]. Comparison of CO_2 emissions between traditional internal combustion engine vehicles and electric vehicles power systems are shown in Fig. 1b [1]. According to scientists, excessive emission of CO_2 has brought about disastrous effects to both the planet Earth and human beings [1–6]. Therefore, controlling and reducing the emission of CO_2 are the serious development challenges facing the world today. For the development of electric vehicle power system technology, solid state nano-energy batteries are proving to be a new highlight in energy technologies that continue to draw the world's attention [7–9]. The demand for renewable and sustainable energy from

* Corresponding author at: Key Laboratory of Dynamics and Control of Flight Vehicle, Ministry of Education, School of Aerospace Engineering, Beijing Institute of Technology, Beijing 100081, PR China.
E-mail address: yongli@bit.edu.cn (Y. Li).

http://dx.doi.org/10.1016/j.rser.2016.07.063
1364-0321/

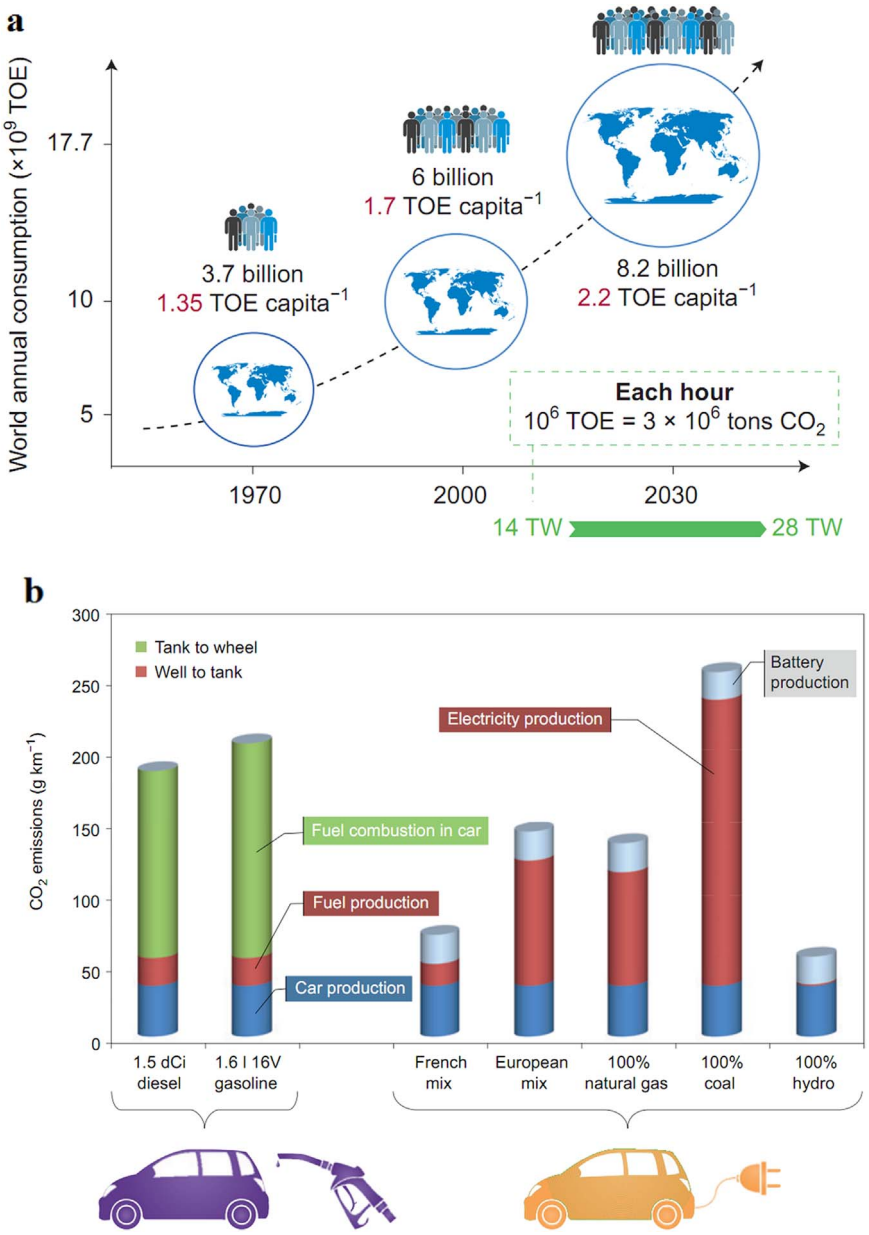

Fig. 1. Schematic of global CO_2 emissions [1]: (a) population growth and CO_2 emission, (b) internal combustion engine versus electric vehicles for CO_2 emissions.

modern industries, electric vehicles and power systems has been growing at a significant rate over the past few years [10]. Energy conversion and transmission architecture between modern industry, power systems, vehicles, and battery are shown in Fig. 2 [11]. Additionally, while broadening the field of sustainable energy applications, more and more researchers put emphasis on nanotechnology for energy saving and design diversification [12–14]. This explains why the development of renewable and sustainable alternative to traditional sources of energy is vital to the growth of the electric vehicle industry.

Traditional energy batteries use liquid electrolyte, which often results in adverse reactions between electrolyte and electrode [15–17]. To improve the stability and lifespan of a battery, it is important to replace liquid electrolyte with solid electrolyte [18–20]. Since there are no additional components needed to maintain stability, the size of the battery becomes smaller as a result of this. Solid electrolyte is compatible with many different types of energy batteries and is capable of providing higher power and energy density. This is why solid state batteries are safer and more durable as compared to traditional batteries [21–24], having significant advantage in sustainable energy for electric vehicles. With the growing demand for large energy battery pack, solid state batteries are forming an integral part in the development of electric vehicles, which is in line with the requirements for customization and diversification.

Through the years, solid state battery has been widely tested in laboratories, making the technology for industrialization a hot topic. However, there are still a number of issues that need to be resolved before industrial applications [25–28]. For example, solid state batteries are relatively expensive as compared to conventional batteries and reducing the cost is a big challenge that faces electric vehicle and power system application [29]. Like other industrial solid energy systems, the manufacturing and designing processes limit the size of solid state batteries, which in turn limits the energy storage capacity [30–32]. This explains why in the past, solid state batteries could only be used in small devices but not in electric vehicles and other large industrial packs [33–35]. Furthermore, solid state technology that is currently being applied to