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Review

A review on lithium combustion

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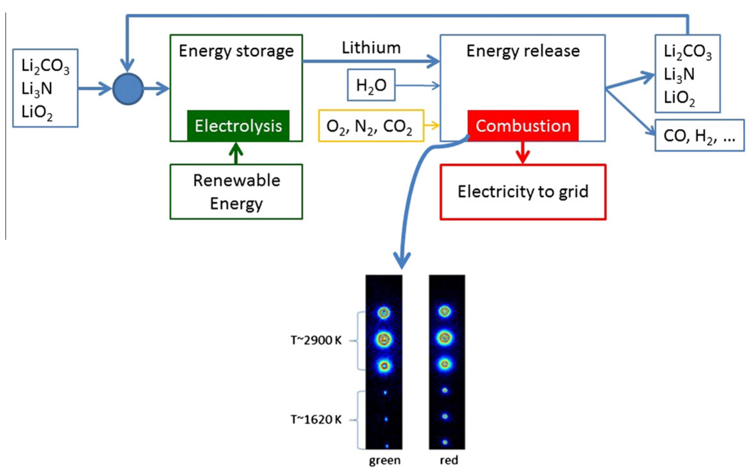
HIGHLIGHTS

- Lithium has the potential to act as energy fuel.
- Combustion techniques comparable to oil spray or pulverized coal combustion seem promising.
- Carbon free or carbon reducing processes are possible.
- Experimental and numerical results on lithium particle combustion already highlight the technical feasibility.

GRAPHICAL ABSTRACT



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ABSTRACT

Lithium combustion has been studied for several decades, with a primary focus on safety issues, such as lithium fires resulting from spills in nuclear reactors. Several studies have also considered the use of lithium as a fuel within propellants, or within propulsion systems that burn lithium in the atmospheric "air" of other planets. Lithium safety has typically been investigated through combustion of molten pieces of lithium or within pool fires. For propulsion applications, experiments were carried out using packed beds of lithium particles.

A novel approach that has recently been proposed is the use of lithium as a recyclable fuel, or energy carrier that can compactly store renewable energy. In this scheme, lithium is burned with air, or power-plant exhaust, to generate heat for thermal power systems when power is needed. The solid-phase combustion products would be collected and recycled, via electrolysis, back into elemental lithium when excess renewable power is available.

This paper summarizes the existing knowledge on lithium combustion. It presents the available findings on lithium combustion for large single pieces of lithium, on pool fires, reaction in packed beds, as well as the combustion of sub-mm sized particles and droplets which are needed for the use of lithium as an energy carrier. The combustion reactions of lithium with O_2, H_2O, CO_2 and N_2 are discussed. Modelling of lithium-particle combustion is at the early stages of development and available results are discussed.

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Contents

1. Introduction

Lithium combustion with different gaseous species has been of interest for several reasons in the past. In fusion reactors, lithium is used as a tritium breeder blanket and as coolant [1–3]. As lithium spills are known to be extremely hazardous [4], research on lithium fires has been carried out to understand the combustion process and to improve procedures for extinguishing such fires [5]. Lithium has also been considered as a possible fuel within torpedoes [6] or rockets [7,8].

The increasing demand for environmentally-friendly energy provision, motivated by the need to reduce greenhouse-gas emissions to mitigate climate change [9], has led to a growth in renewable energy from solar or wind power. As the temporal availability of these energy sources does not necessarily coincide with the demand for energy, large-scale storage techniques are needed. As will be shown, lithium is a potential storage material in combination with a combustion process.

Metals have been considered as energy storage materials over longer periods, due to their high energy densities and specific energies [10–19]. Indeed, the high energy content in metals has long motivated their use as energetic additives in energetic materials, slurry fuels and propellants [20–30]. In order to harness the chemical energy in the metal fuels, most previous studies have considered the reaction of various metals, specifically aluminium and magnesium, with water to produce hydrogen on demand [10,11,13–15,17,31,32], with only a small number of studies considering the combustion of the metal fuels to produce heat [12,16,19,33,34].

Lithium has a very low electronegativity (0.98 on the Pauling scale). It is situated near hydrogen on the periodic table of the elements, with an atomic number of 3 and atomic weight of 7 a.m.u., such that it has a high amount of chemical energy, because of its available valence electron, compared to its mass – leading to its high specific energy. Indeed, lithium has the third highest specific energy (kJ/kg) of all metals/metalloids, behind only boron (atomic number 5) and beryllium (atomic number 4) [19]. The high specific energy of lithium motivates its use as the anode material within lithium-ion, as well as lithium–oxygen or lithium–air, batteries [35–37]. Lithium has been proposed as an energy carrier, or energy-carrying component, within systems that would generate hydrogen using the lithium–water reaction, or lithium hydrides and borohydrides [38–41]. It has also been used as a chemical fuel for underwater propulsion systems [42–44].

Like all electro-positive metals, lithium shows properties which make it a promising candidate to act as storage material in energy circuits based on renewable energy [16,45,46]. Lithium can react with many gaseous species, including N_2, in addition to CO_2, H_2O, and O_2. Its ability to react exothermically with these typical components in the exhaust gases of fossil-fuelled power plants leads to the idea to build a thermal process, in which lithium is burned to produce heat within an exhaust-gas mixture or a pure gas

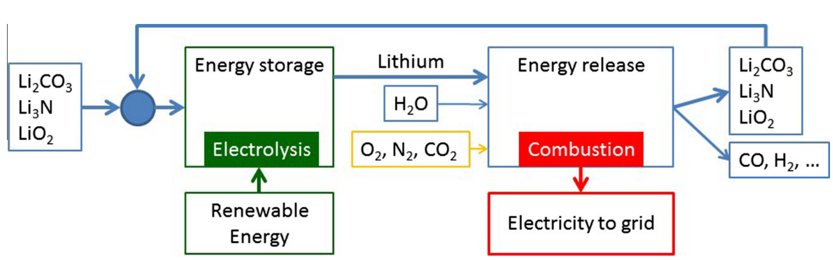

Fig. 1. Process flow sheet of lithium-based energy storage and production cycles.