Progress in Materials Science 66 (2014) 1–86

Contents lists available at ScienceDirect

Progress in Materials Science

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

# Rechargeable magnesium battery: Current status and key challenges for the future

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A R T I C L E I N F O

*Article history:*
Received 19 November 2013
Received in revised form 18 April 2014
Accepted 23 April 2014
Available online 10 May 2014

*Keywords:*
Magnesium battery
Grignard reagents
Electrolyte
Current collector
Chevrel phase
Cathode
Anode

A B S T R A C T

There is a tremendous need to have perennial and continuous access to cost-effective electricity generated from the intermittent energy sources (wind, solar, geothermal, hydropower, wave etc.). This will require development of inexpensive and efficient electrical energy storage (EES) devices such as stationary battery for uninterrupted electricity (power storage back up) and load leveling as well as grid energy storage systems [1–6]. Magnesium based secondary batteries are a viable 'environmental friendly, non-toxic' alternative compared to the immensely popular Li-ion systems owing to its high volumetric capacity (3833 mA h/cc for Mg vs. 2046 mA h/cc for Li) for stationary EES applications. Following the successful demonstration of a prototype magnesium cell capable of offering energy density ~60 W h/kg in the early 2000, the last decade has witnessed tremendous amount of work dedicated to magnesium battery and its components. The present review is an earnest attempt to collect all of the comprehensive body of research performed in the literature hitherto to develop non-aqueous nucleophilic/non-nucleophilic liquid electrolytes, ionic liquid based polymer as well as solid/gel polymer electrolytes; intercala-

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http://dx.doi.org/10.1016/j.pmatsci.2014.04.001

tion/insertion/conversion type cathodes; metallic magnesium and their alloys/intermetallic/composites as anodes; and electronically conductive but chemically and electrochemically inert current collectors for magnesium battery. The limited electrochemical oxidative stability of current generation of electrolytes with inherently slow magnesium-ion diffusion in to electrodes as well as the inability of $Mg^{2+}$ to reversibly cycle in all but a few materials systems impede the growth of high power and high energy density magnesium cells, analogous to Li-ion systems. Before the successful fabrication of a prototype magnesium battery, optimization of electrolyte performance, the realization of suitable intercalation/insertion cathodes and the identification of alternative alloys, intermetallics, composites and compounds as anodes are highly critical. Exploration of the compatibility of various battery parts including metallic current collectors with currently used organochloro electrolytes sheds light on the electrochemical corrosion of metals such as Cu, Al, stainless steel (SS) toward chlorinated Grignard's salts warranting further investigation for identifying, electrically conducting and electrochemically inert current collectors. Results to date show the preferential selectivity of certain electronically conducting metallic and non-metallic current collectors for rechargeable magnesium batteries owing to its high anodic stability in the present electrolyte. Development of magnesium-ion battery therefore requires an interdisciplinary approach with a sound understanding of organometallic and inorganic chemistry, adequate knowledge of materials chemistry, materials science and engineering, as well as electrochemistry, and a comprehensive knowledge of metallic corrosion principles in basic/acidic electrolytic environments in order that a system with acceptable energy density ($\sim$150–200 W h/kg) and operational voltage $\sim$2–3 V can be developed in the near future.



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