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Electromagnetic effects model and design of energy systems for lithium batteries with gradient structure in sustainable energy electric vehicles

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ABSTRACT

Lithium batteries with electromagnetic gradient structure have special macroscopic equivalent performance. In this Review, methods to characterize this macroscopic property have been proposed in both theory and practice. The goal is to address the heterogeneity of the energy system as well as the electromagnetic effects caused by microstructure. In this Review, electromagnetic effect model and design theory of vehicle energy systems, gradient structure are introduced. The mechanism of heterogeneity and the electromagnetic effect are highlighted. Methods and experimental gradient structure characterization techniques under electric, magnetic, and temperature fields are reviewed, with emphasis being placed on gradient structure multi-field characterization, test, and evaluation. The comprehensive evaluation of energy system architecture and gradient structure design methodology is to support the application of electromagnetic lithium battery use in electric vehicles.

Contents

1. Introduction

Lithium batteries with electromagnetic gradient structure (piezoelectric/piezomagnetic, electrostrictive, magnetostrictive, and ferroelectric/ferromagnetic composite structures) have excellent properties such as intelligent charging and energy storage optimization. These batteries then have the potential to play an important role in vehicle, aerospace and energy storage industries [1,2]. In the field of electric sustainable vehicles, for example, vehicles equipped with lithium batteries have already emerged. Lithium battery technology is developing rapidly and is attracting worldwide attention. See Fig. 1 for research and development trends involving lithium batteries [3].To reduce the internal stress of the energy system and improve thermal stability of materials, gradient structure has been introduced into lithium batteries of electric vehicles. Subsequent research has shown favorable characteristics under magnetic, electric, and temperature fields. This has become a research focus because the technique improves battery life and stability [4–6]. Electromagnetic lithium batteries

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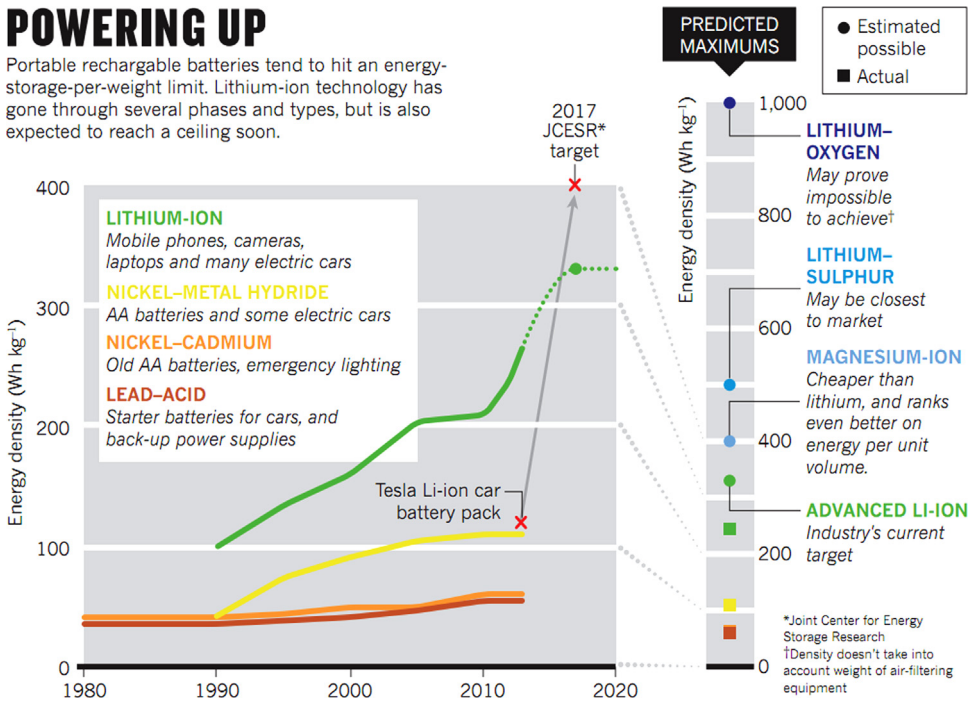

Fig. 1. Status and trends of research on lithium battery [3]. (a) Magnetic domain propagation at piezoelectric layer. (b) Local stress applied to control magnetic domain propagation. (c) Electromagnetic gradient domain and electrode structure.

look very promising for use in the field of high-density energy storage batteries, super capacitors, balanced battery packs, and wireless energy transfer [7,8].

Recently, a rapid decline in cost together with other advantages has made lithium battery a more popular mainstream choice to power pure electric vehicles. Lithium batteries are small and thin, and they take up less room and are lighter in weight than other batteries. Further, the capacity of a lithium battery increases with higher output power density. Newer lithium batteries also recharge more quickly [1,3,5]. These features improve the cruising capacity of lithium-powered electric vehicles in three ways: (1) the recharge time for newer vehicles is significantly reduced over previous models. On average, a full recharge can take as little as two hours [1–3]; (2) when the vehicle is used continuously at maximum performance, its operating time is now extended to two hours [4–6]; (3) different power consumption schemes are possible. Limiting loads allows vehicles to operate for longer periods. However, a better power consumption configuration between high-load performance and cruising capacity is required to make lithium batteries increasingly competitive and to encourage the continued adoption of lithium batteries.

In 2012, Sun et al. [1] reported in the Journal of Nature Materials the development of a new gradient battery. All batteries store energy as an electrochemical potential, which is released as electricity when the chemicals in the battery interact. The less energy that is consumed in creating the chemical reactions in the battery, the more energy the battery is able to produce. Gradient batteries have a particularly high energy density. In the new gradient battery, the material concentration varies continuously from core to shell with no obvious distinction between core and shell. The new battery also can reduce surface impurities within its chemical components. Further, the battery's sensitivity to temperature and humidity is improved. Consequently, the chemical reactions absorb less energy, and the new gradient battery is able to reserve greater electrical power than conventional lithium batteries of the same size. The new gradient battery is also lower in weight than conventional lithium batteries of the same size. In addition, the new gradient battery works as an intelligent battery

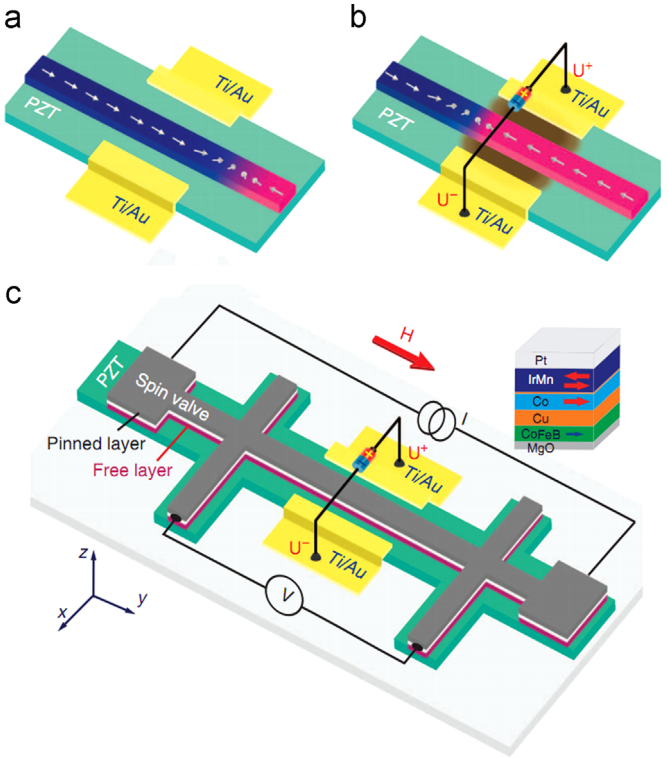

Fig. 2. Electromagnetic coupling model with gradient structures [11]. (a) Discharge process with sodium ionization. (b) Charging process with sodium ionization. (c) Discharge process with lithium ionization. (d) Charging process with lithium ionization.

that, when paired with a dedicated smart recharger, produces the shortest recharging time for a maximum life cycle and maximum capacity.

Electromagnetic effect refers to the phenomenon of polarization of lithium structure in response to an external magnetic field,