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Perspectives for solid biopolymer electrolytes in dye sensitized solar cell and battery application

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ABSTRACT

Photovoltaic technologies represent one of the leading research areas of solar energy which is one of the most powerful renewable alternatives of fossil fuels. In a common photovoltaic application the batteries play a key role in storage of energy generated by solar panels. Although it will take time for dye sensitized solar cells (DSSCs) and batteries based on biopolymer electrolytes to take their places in the market, laboratory studies prove that they have a lot to offer. Most efficient DSSCs and batteries available in market are based on liquid electrolytes. The advantages of liquid electrolytes are having high conductivity and good electrode-electrolyte interface whereas, disadvantages like corrosion and evaporation limit their future sustainability. Biopolymer electrolytes are proposed as novel alternatives which may overcome the problems stated above. In this review, we focus on fabrication, working principle as well as up to date status of DSSCs and batteries using biopolymer electrolytes. The effects of structural and electrical properties of biopolymer based electrolytes on the solar energy conversion efficiencies of DSSCs and their compatibility with lithium or other salts in battery applications are summarized. Biopolymer electrolyte based DSSCs are categorized on the basis of types of additives and recent outcomes of author's laboratory studies on biopolymer electrolyte based DSSCs and batteries are also presented.

Contents

Abbreviations: DMSO, dimethyl sulfoxide; PC, Propylene carbonates; PG, Propylene glycol; 3EG, Triethylene glycol; 4EG, Tetraethylene glycol; MPII, 1-methyl-3-proplylimidazolium iodide; (AEII), 1-allyl-3-ethylimidadolium iodide; (APII), 1-allyl-3-propylimidazolium iodide; (DAII), 1-3-diallylimidazolium iodide; SDS, Sodium dodecyl sulphate; PVP, Polyvinylpyrrolidone; PEG200, Polyethylene glycol; TW-80, Polysorbate 80-TW-80; NMP, 1-methyl-2-pyrrolidinone; GBL, γ-butyrolactone; PEO–HPC, Poly (ethylene oxide)-2-hydroxypropylcellulose; BmImTf, 1-butyl-3-methylimidazolium trifluoromethanesulfonate; LITFSI, Lithium bis(trifluoromethanesulfonyl)imide; DES, Deep eutectic solvent; [Amim] Cl, 1-allyl-3-methylimidazolium chloride; BmImPF6, 1-butyl-3-methylimidazolium hexafluorophosphate; DMAc, N, N-dimethylacetamide; LiCl, Lithium chloride; [BMIM]Cl, 1-butyl-3-methylimidazolium chloride; EC, Ethylene carbonates; PEG, Poly (ethylene glycol); LiTFSI, Lithium trifluoromethanesulfonimide; SPEEK-CS, sulfonated poly(ether ether ketone)-chitosan; DAP, Diethanolamine modified pectin; BC, Bacterial cellulose; TEA, triethanolamine; GA, glutaraldehyde; DTAB, dodecyltrimethyl ammonium bromide; EMImSCN, 1-ethyl 3-methylimidazolium thiocyanate; N3, Cis-Bis(isothiocyanato)bis(4,40-dicarboxyl-2,20-bipyridine)-ruthenium(II), Ru(dcbpy)2 (NCS)2; N719, Cis-bis(isothiocyanato)bis(2,2′-bipyridy1-4,4′-dicarboxylato)-ruthenium(II)bis-tetrabutylammonium; (AN), acetonitrile; (MOZ), 3-methyl-2-oxazolidinone; (Pr)4NI, tetrapropylammonium iodide; TBP, 4-tertiary butylpyridine; MPIm-I, 1-methyl-3-propylimidazolium iodide; DMHIm, 1, 2-dimethyl-3-n-hexylimidazoliumiodide

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1. Introduction

Polymer electrolytes are one of the most important materials used in fabricating many electrochemical devices [1–5]. Polymers are classified into two main categories (1) synthetic and (2) natural. Most of the electrochemical devices available in market are based on liquid electrolyte. However solid polymer electrolytes (SPEs) which come into the category of synthetic polymers, offer more advantages over liquid electrolytes, such as higher energy density, flexible geometry, higher operating temperatures and safety, no-leakage of electrolyte and ease of application. The most commonly studied polymer electrolytes are the complexes of metal salts with high molecular weight polymer polyethylene oxide (PEO) [1–3]. However, one of the major drawbacks of PEO-based solid polymer electrolytes is their low ionic conductivity (10^{-7} S/cm) at ambient temperature, which limits their practical applications [4,5]. To date, a large number of other synthetic polymers, such as polymethyl methacrylate (PMMA), poly acrylonitrile (PAN), poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP), polyvinyl alcohol (PVA), and polyvinylpyrrolidone (PVP) etc, have been studied in electrolyte applications [6–9].

Especially in developing countries, environmental pollution caused by synthetic polymers is becoming a serious threat. Petroleum-derived plastics are not biodegradable; they do not undergo microbial degradation and hence accumulate in the environment. Together with the environmental concerns, tremendous increase in the prices of fossil fuel derived products force the scientist to focus on biodegradable polymers. Biopolymers fall into the natural polymers category, and represent one of the hot topics of polymer research. Since their introduction in 1980s, a vast number of biodegradable polymers have been synthesized [10–14] with the major goal of development of stable biopolymeric systems with excellent electrical and mechanical properties. Biopolymer electrolytes (BPEs) are solid ion conductors formed by dissolving salts in polymers having high molecular weight. They can be prepared in semi-solid or solid form through cheap and reliable processes [15–27]. BPE materials possess high ionic conductivity (10^{-2} to 10^{-4} S/cm), high energy density,wide electrochemical stability window, provides solvent-free and leak proof condition, easy processability and light weight which are essential for any kind of electrochemical device, *e.g.* fuel cells [28], supercapacitors, batteries [29–32], dye sensitized solar cells (DSSCs) [33–290], *etc*. Due to the large variety of energy related BPE applications, the scope of this review is limited to the application of BPEs in DSSCs and batteries.

Since the introduction of DSSC technology by O'Regan and Grätzel in 1991, it represents one of the most studied photovoltaic technologies [46]. The conversion efficiencies vary between 6% and 13% depending on the size of active area, preparation conditions and the type of electrolyte [33]. Although the highest conversion efficiency has been achieved by using liquid electrolytes due to the stability problems generate mainly from the leakage of electrolyte, quasi gel electrolytes are introduced. However this kind of electrolytes could not solve the stability problem and also caused efficiency reductions generating from the low ionic mobility and trapping of the gel in the metal oxide pores [53–56]. The next proposed alternative is solid polymer electrolytes in which polyether's and biopolymer-salt complexes are playing the dominant role [76–88,105–109]. In addition to their high conductivity and good thermal stability, biodegradable thin/thick film formation abilities make them suitable electrolyte candidates for DSSCs.