



# Polypyrrole- and polyaniline-surface modified nanosilica as quasi-solid state electrolyte ingredients for dye-sensitized solar cells

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## Abstract

Polyurethane nanocomposites were formulated to entrap liquid electrolyte for quasi-solid state electrolytes (QSEs) in dye-sensitized solar cells (DSSCs). Polypyrrole- and polyaniline-surface engineered silica nanoparticles (NPs) were each incorporated to form polyurethane nanocomposites. The formation of nanosilica and its surface modification, as well as the size, aggregation, and isoelectric point of the synthesized NPs were analyzed using ATR-FTIR, TEM, and DLS. In addition, the filler (silica)–matrix (polyurethane) interaction, NP distribution, surface morphology, surface porosity, and the thermal stability of the polyurethane nanocomposite were analyzed by ATR-FTIR, transmitted and reflected light microscopes, imageJ, and TGA. The polymer matrix absorptivity, conductivity, and ion diffusion of the polyurethane nanocomposite-based QSE was investigated by using a digital analytical balance, the AC impedance method, and the cyclic voltammetry. Lastly, all of the formulated QSEs were applied in DSSCs and their photovoltaic performance was measured. The QSE based on polyaniline-surface engineered nanosilica demonstrated the highest light-to-energy conversion efficiency, namely 3.10%, with an open circuit voltage of 715 mV, a short circuit current of 3.88 mA cm<sup>-2</sup>, and a fill factor of 0.67. A reasonable lifespan stability was also found for 100 min illumination and a corresponding efficiency of 2.47% obtained.

## 1 Introduction

Solar cells are a promising substantial renewable energy source. Among the several types of solar cells, dye-sensitized solar cells (DSSCs) as an emerging technology have found much attractions due to their low manufacturing cost, ease of fabrication, and high light-to-energy conversion efficiency [1]. Lifespan is one of the challenging issue in developing the conventional DSSCs based on liquid electrolyte (LE). LE suffers from solvent evaporation and leakage, which eventually reduce the lifespan [2]. Numerous studies have been carried out to improve or replace the LE, such as the use of solid electrolyte, gel electrolyte, ionic liquids, and polymeric film toward generate quasi-solid state electrolyte (QSE) [3, 4]. Ion diffusivity and the filling into the dye-sensitized TiO<sub>2</sub> layer are poor in solid electrolyte, gel electrolyte and ionic liquids, leading to a poor DSSCs

performance even though lifespan is greatly enhanced. The use of polymeric film seems to have a great potential as the polymeric framework absorb and entrap LE during the cell assembly process. LE absorbed inside the polymeric film can be easily squeezed and penetrate into the TiO<sub>2</sub> layer. Polymeric film also delays the evaporation of the LE.

Thus far, different polymeric QSE have been studied; for example: polyvinylidene fluoride [5], polyvinylidene fluoride/polymethacrylate [6] polymethylacrylate [7], polyvinyl butyral [8], polyacrylic acid/acetyltrimethylammonium bromide [9], polyacrylic acid/polyethylene glycol [10], polyhydroxyethylacrylate/polyethylene glycol [11], and polycarbonate [12]. Moreover, several studies were done on the electrolyte based on polyurethane (PU), but they were all solid-state electrolyte [13–16]. PU is well-known as a great water absorber and has been widely applied as sponge material. Therefore, it has a great potential to be applied as a polymeric film to absorb LE. Furthermore, PU has a unique soft and hard segment contributed by polyols and isocyanates, respectively [17]. The soft segments, which are in the rubbery phase acts as a polymeric solvent to solvate the redox couple electrolyte (I<sup>-</sup>/I<sub>3</sub><sup>-</sup>). The low glass transition temperature and high segmental motion of the soft segments lead to a high mobility of the dissolved ions [18]. The hard

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