Ink with Kesterite Precursors as Electrolyte for Dye-Sensitized Solar Cell

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Abstract

Each type of ink is designed for specific applications, and each has its own characteristics, such as composition, color, electrical conductivity, and others. It is important to note that the use of inks in the manufacturing of photovoltaic solar cells has been a significant milestone in the evolution of inks. In this context, the production and characterization of ink containing kesterite precursors are reported here. Based on electrical characterization, it is observed that the ink exhibits electrical conductivity. Through the photovoltaic characterization of the dye-sensitized solar cell containing the ink layer, it is inferred that the ink has the potential for use as an electrolyte. Photovoltaic devices are one of the highlights of humanity because they can directly convert photons into electricity and this ability is used to build devices for both power generation and photodetection.

Keywords: ink, photovoltaic, kesterite, dye-sensitized solar cell, electrolyt.

1. Introduction

The photovoltaic solar cells have a p-n junction formed by the link between a p-type semiconductor and n-type semiconductor. The sensitivity of the p-n junction to light can be exploited to use photovoltaic devices in electrical power generation (Khan, 2010) and photometers (Bhattacharyya, 2025). Photovoltaic conversion is the direct conversion of sunlight into electricity without the use of a thermal engine (Goswami, 2015). The photovoltaic solar cell is the device used for this purpose. Different strategies have been explored to increase the understanding of the photovoltaic response of solar cells under different conditions.

Any photovoltaic solar cell is a system composed of semiconductors and auxiliary components. Among the semiconductors that have been explored in the photovoltaic is kesterite (Valdés et al., 2025; Hjal et al., 2025). The dye-sensitized solar cell (DSSC), whose architecture consists of layers of semiconductors, dye, and electrolyte is one of the classes of solar cells that has been studied in photovoltaic yield (Ayaz et al., 2024; Baskaran et al., 2021). The photovoltaic effect in a dye-sensitized solar cell (DSSC) with the presence of a Cu_2NiSnS_4 kesterite layer was observed, resulting in an efficiency of 2.81% (Baskaran et al., 2021).

Among the routes that has been explored for obtaining kesterite is the use of inks with kesterite precursors. Kesterite with the composition $(Ag,Cu)_2Zn(Sn,Ge)(S,Se)_4$ was obtained through thermal treatment and a selenization process in an argon atmosphere at temperatures of 340ºC and 560ºC, using ink made from precursor salts mixed with thiourea and hydrochloric acid in a dimethylformamide solvent (Scaffidi et al, 2024). By preparing ink with precursor salts of copper, tin, zinc, and thiourea in ethylene glycol, Cu2ZnSnS4 kesterite was obtained through the conversion of precursors into CZTS films on a substrate heated to 473 K in an air atmosphere for 1 hour (Ghediya et al., 2016). The synthesis of Cu_2ZnSnS_4 (CZTS) nanocrystals from precursor salts in a vacuum chamber at 130ºC for 30 minutes, followed by ink production through the mixing of CZTS nanocrystals with toluene, has been reported (Guo et al, 2009).

This study shows the use of ink containing kesterite precursors as an electrolyte in DSSC. Electrical resistance measurements are used to analyze the conductivity of the ink layer. The current versus voltage curve is used to evaluate the photovoltaic effect in the DSSC with an electrolyte made from ink containing kesterite precursors. This study demonstrates that, in addition to being used for kesterite production, kesterite precursors have potential for another application.

2. Materials and methods

Ink is produced by mixing copper (II) acetate, tin (II) chloride, zinc (II) chloride, and thiourea in an aqueous DMSO solution with tin dioxide powder. The produced ink is then deposited onto glass and polymeric substrates, which are exposed to natural solar radiation for 1 hour. Electrical conductivity measurements using a Fluke multimeter are performed on the ink-coated substrate after 1 hour of exposure to natural solar radiation. Subsequently, the ink is used as an electrolyte in DSSC, where the photovoltaic effect in the cell is analyzed through the current versus voltage curve using a photo kit (Metrohm) equipped with a white light LED connected to a Potentiostat/Galvanostat PGSTAT302N (Metrohm), operated with the NOVA 1.10 software (Metrohm).

3. Results and discussion

The ink has a gel-like appearance. Figure 1 shows the produced ink inside a beaker and a polymeric PLA (polylactic acid) substrate, a biodegradable and thermoplastic polymer, with part of its surface covered by a layer of ink. After exposure to solar radiation, the ink layer on both glass and polymeric substrates becomes adherent, with the resistance of the dried films being on the order of 10^6 **Ω**. Figure 2 illustrates a DSSC and the photovoltaic behavior (I-V curve) of two different DSSC compositions.

Figure 2a illustrates the CSSC in which clips are used to hold the materials together. The photovoltaic behavior of the CSSC was investigated by comparing its electrical behavior in relation to the current and voltage in both the dark and under light irradiation. Figure 2b depicts the electrical behavior of the CSSC for FTO/SnO_2:N719 dye/ink/FTO: Pt assembly, while in Figure 2c, the associated system is FTO/ink: SnO_2:N719 dye: electrolyte/FTO: Pt. In this study the ink is used in the form of a gel layer, and its application as a solid electrolyte is under investigation.

The term FTO refers to glass with a thin surface layer of fluorine-doped tin dioxide (SnO_2), and when this material is modified with platinum (Pt), it is referred to as FTO: Pt. The term SnO_2:N719 refers to a layer of SnO_2 containing the immobilized Ruthenizer 535-bisTBA (N719) dye, while the term ink: SnO_2: N719 dye is associated with the mixture of all three components before forming the sandwich structure.

Under illumination, in both systems short-circuit currents are observed on the order of 10^{-6} A and low open-circuit voltages. In this study, ink containing kesterite and SnO_2 precursors is applied as the electrolyte in the CSSC, but the high electrical resistance of the electrolyte significantly affects the current and voltage of cells. In addition to impacting current and voltage, other electrical parameters of the CSSC, such as the fill factor and efficiency, degrade due to the adopted electrolyte composition. Therefore, further investigations are being conducted to improve the performance of the CSSC.

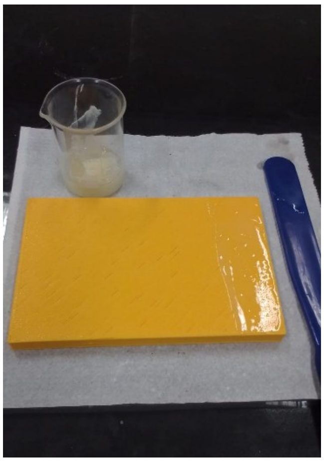

Figure 1: Ink and polymeric substrate with a surface partially covered by an ink layer before exposure to solar radiation.

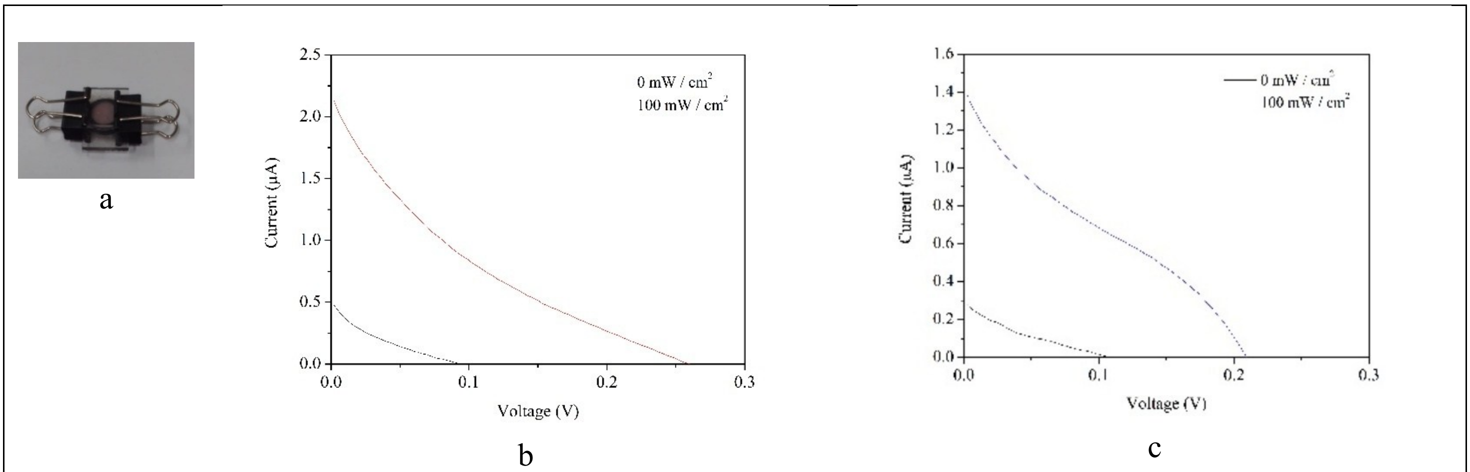

Figure 2: a) Cell and I-V curve: b) FTO/SnO2:N719 dye/ink/FTO: Pt, and c) FTO/ink: SnO2:N719 dye/electrolyte/FTO: Pt.

Photovoltaic devices are one of the highlights of humanity because they can directly convert photons into electricity and this ability is used to build devices for both power generation and photodetection. As can be seen previously, the electrical parameters of the photovoltaic solar cell are influenced by the amount of incident light. From this, it is possible to infer that the photovoltaic device illustrated in Figure 2 has potential for use as a light detection sensor.

4. Conclusion

The electrical resistance values of the dried ink layer indicate that the ink has potential for use in the fabrication of a solid electrolyte. This study demonstrates the potential use of kesterite precursors as an electrolyte for CSSC. However, the low current and voltage values suggest that further investigations are needed to optimize the ink preparation conditions and its application as a CSSC electrolyte.

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