COMPARATIVE STUDY OF SOLVENTS IN CARBON PASTE ON PERFORMANCE OF CARBON-BASED PEROVSKITE SOLAR CELLS

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Abstract

Perovskite solar cell (PSCs) are promising photovoltaic devices due to their low fabrication cost and simple processing. To replace expensive metal electrodes, this study develops a carbon electrode fabricated from carbon sheets dissolved in chlorobenzene (CB), deposited via doctor-blading and thermal annealing under vacuum conditions.The optimized condition of process 3 (60 °C, 5 min) achieved a peak power conversion efficiency (PCE) of 11.36% (active area 0.96 cm²), attributed to improved film uniformity and enhanced HTL/carbon interfacial contact. Despite this success, the rapid evaporation of chlorobenzene was found to cause uneven carbon sheet dissolution, complicating the coating process. Although using sorbitol and mixing PGMEA in CB effectively slowed evaporation, the resulting electrodes exhibited poor electrical conductivity and a significant decline in PCE, rendering them unsuitable for electrode applications. Moreover, the developed electrode achieved a PCE = 11.36 %, Fill factor (FF) of 60.10% and a short-circuit current density (J_{SC}) of 17.81 mA/cm^2, markedly higher than the traditional electrode (PCE = 1.50 %, FF = 43.75 % and J_{SC} = 6.60 mA/cm^2). These findings indicate that the proposed preparation method effectively enhances the HTL/carbon interface.

Introduction

Solar energy represents a renewable energy source with significant potential and environmental sustainability. PSCs have garnered extensive attention within the research community owing to their high PCE, low fabrication costs, and compatibility with straightforward solution-based processing techniques. In recent years, carbon-based PSCs have exhibited substantial progress, achieving PCE of up to 22.07%.

Moreover, carbon electrodes offer a distinct economic advantage over noble metal electrodes, such as gold and silver, due to their considerably lower material costs. Consequently, they are regarded as a highly promising alternative for reducing overall production expenses and enhancing the economic feasibility of perovskite solar cell technologies.

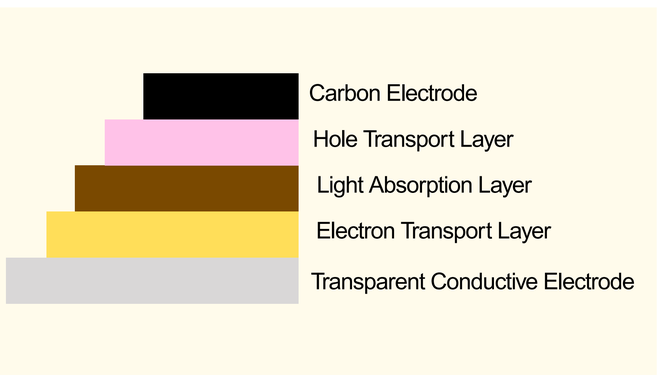


Fig 1 : Device structure of perovskite solar cells

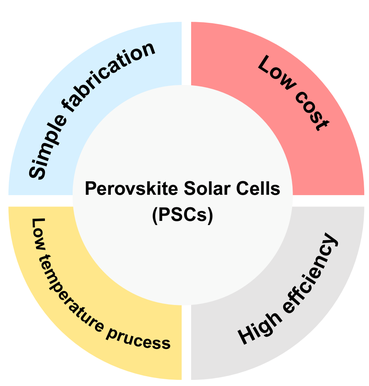
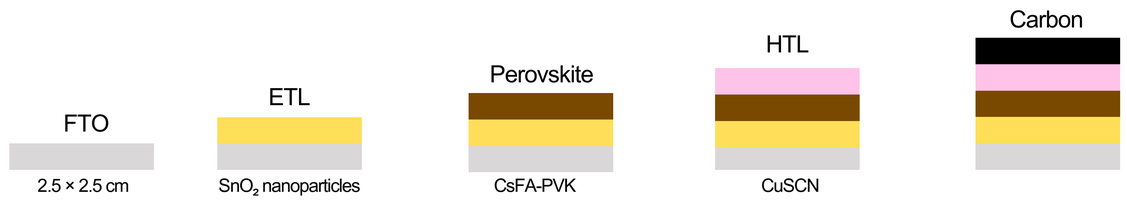


Fig 2: Advantages of PSCs

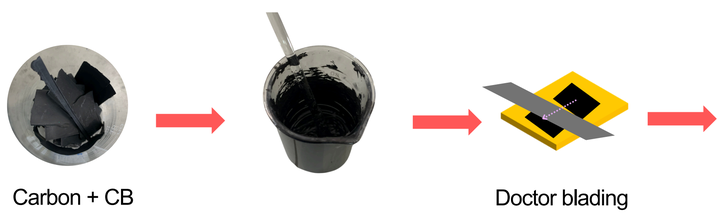
Experiments

1. Perovskite solar cell fabrication



2. Carbon electrode preparation

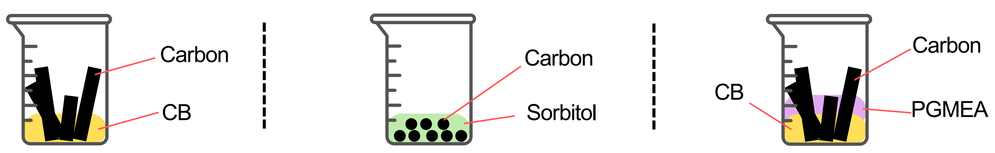
2.1 Variation of drying methods



Thermal annealing under vacuum conditions

Process 1 : Hot plate under vacuum
Process 2 : Hot plate under vacuum integrated with a pump
Process 3 : Vacuum oven

2.2 Variation of solvents



Results

Effect of drying methods on PSC performance

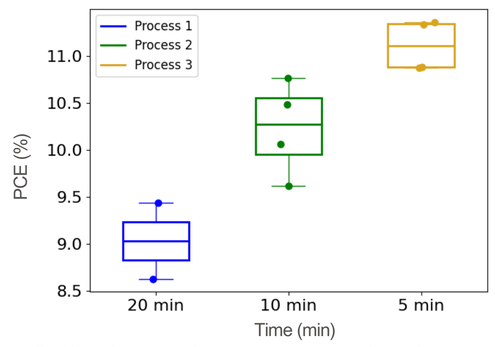


Fig 3: PCE of perovskite solar cells under different processing conditions

Table 1 : Photovoltaic performance under different processing conditions

Process	Condition		PCE (%)	Voc (V)	FF (%)	Jsc (mA/cm^2)
1	60 °C, 20 min	Avg.	8.63	0.93	54.16	17.18
		Max	(9.44)	(0.94)	(57.13)	(17.52)
2	60 °C, 10 min	Avg.	10.25	1.02	56.68	17.66
		Max	(10.83)	(1.03)	(56.91)	(18.44)
3	60 °C, 5 min	Avg.	11.11	1.06	59.95	17.46
		Max	(11.36)	(1.07)	(60.10)	(17.81)

- Process 3 (60°C, 5 min) achieved the highest PCE of 11.36% with an active area of 0.96 cm².
- Limitation: Rapid evaporation of chlorobenzene, complicating the coating process.

Effect of solvents on carbon electrodes

Table 2 : Comparison of device performance with different carbon electrode conditions

Conditions	PCE (%)	Voc (V)	FF (%)	Jsc (mA/cm^2)
Carbon + CB	11.36	1.07	60.1	17.81
Carbon + sorbitol	N/A	N/A	N/A	N/A
Carbon + CB + PGMEA	9.97	1.04	58.13	16.48

Solvent additive

- Reduced the evaporation rate.
- No significant improvement in solar cell performance was observed.

The comparison between developed and traditional carbon electrodes

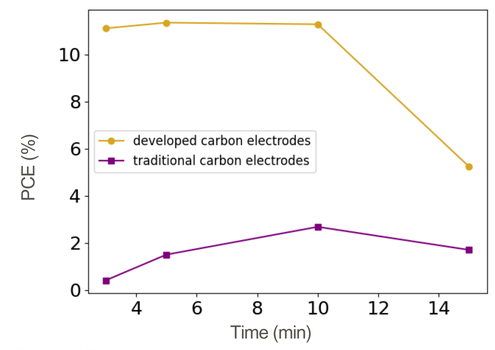


Fig 4 : PCE comparison of traditional and developed carbon electrodes.

- Using the developed carbon electrode achieved higher efficiency than the traditional carbon electrode in all conditions.

Conclusions

- The optimal carbon preparation through thermal annealing under vacuum is 60 °C for 5 min.
- The incorporation of solvent additives successfully suppressed the solvent evaporation rate. However, the performance of solar cell device unimprovable due to a reduction in electrical conductivity.
- Process 3 is identified as the optimal condition, achieving a maximum PCE of 11.36%, which is a viable pathway for improving the efficiency and stability of perovskite solar cells in future developments.

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