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Natural Anthocyanin-Sensitized DSSCs with Optimized TiO_2/Nb_2O_5 Photoanode Architecture

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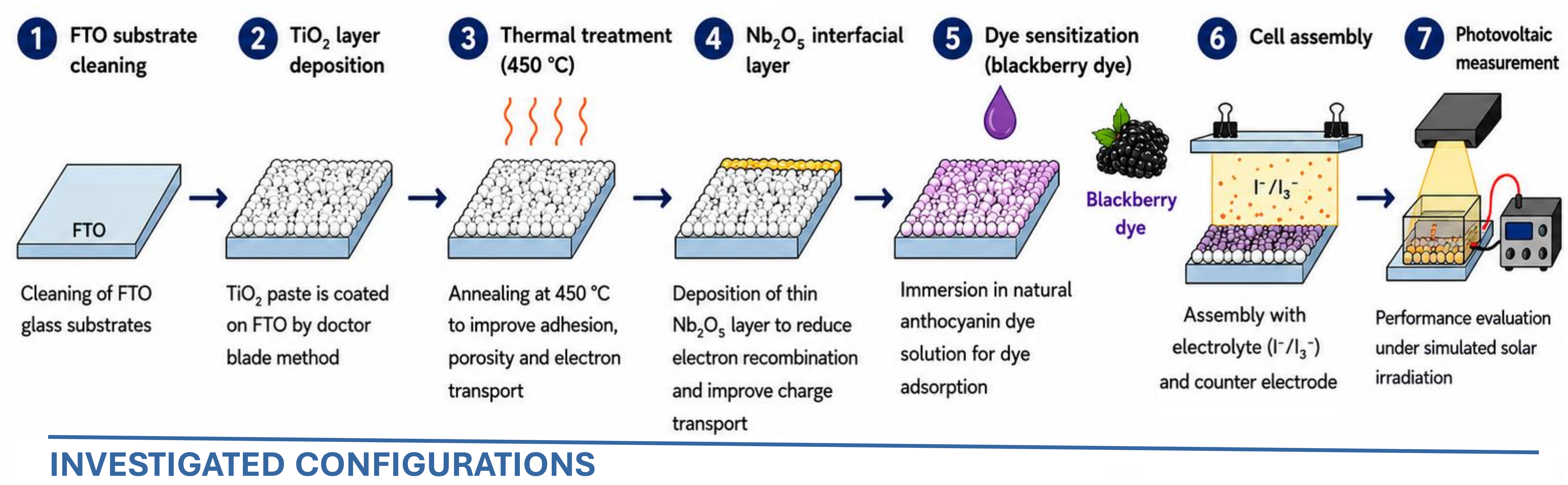
INTRODUCTION & AIM

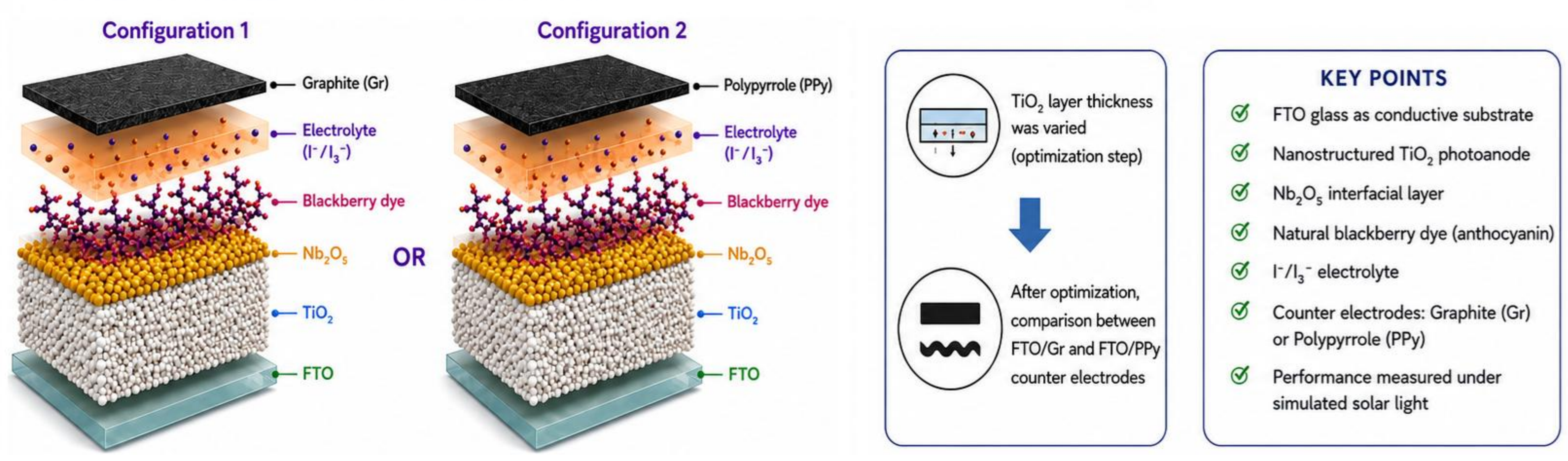
- Dye-sensitized solar cells (DSSCs) are a promising low-cost and environmentally friendly alternative to conventional silicon solar cells.
- Natural anthocyanin dyes are attractive sensitizers due to their abundance, biodegradability, and non-toxic nature.
- The performance of DSSCs strongly depends on the photoanode architecture, particularly the TiO_2 layer and interfacial charge-transfer layers.
- This work investigates the effect of TiO_2 thickness and an Nb_2O_5 interfacial layer on DSSC performance using blackberry-derived anthocyanin dye.
- After photoanode optimization, graphite (FTO/Gr) and polypyrrole (FTO/PPy) counter electrodes were compared under simulated solar irradiation.

METHOD

DSSC FABRICATION PROCESS



INVESTIGATED CONFIGURATIONS



RESULTS & DISCUSSION

SURFACE AND CROSS-SECTION MORPHOLOGY

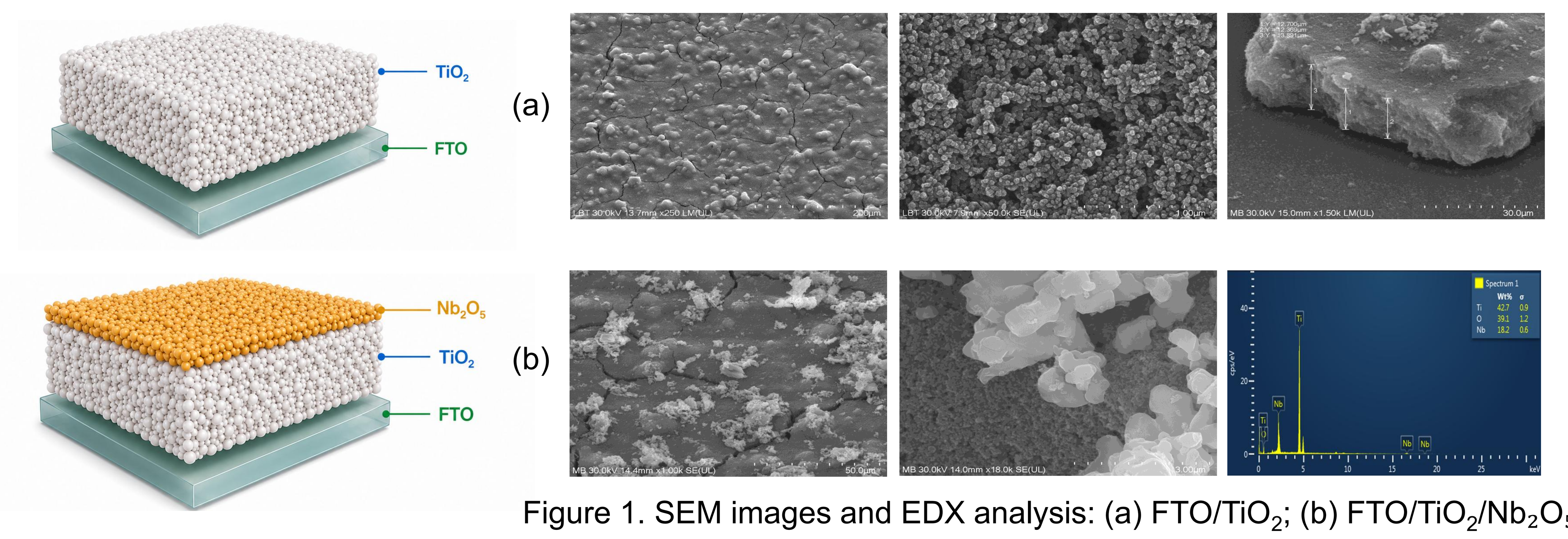


Figure 1. SEM images and EDX analysis: (a) FTO/TiO_2; (b) FTO/TiO_2/Nb_2O_5

- SEM images show a dense and uniform TiO_2 film (~12 μm thick) with a high surface area for dye adsorption.
- Nb_2O_5 surface agglomerates enhance light scattering and confirm successful photoanode modification.
- EDX analysis confirms the presence of niobium, indicating successful electrode functionalization.

PHOTOVOLTAIC CHARACTERIZATION AND OPTIMIZATION

Table 1. Photovoltaic performance of DSSCs under simulated solar irradiation
(a) TiO_2 Thickness optimization (Graphite CE)

TiO_2 (um)	Voc (V)	Jsc(mA/cm²)	FF (%)	PCE_{max} (%)
6	0.36	0.92	32.11	0.11
9	0.42	1.20	35.10	0.18
12	**0.44**	**1.19**	**41.18**	**0.22**

(b) Counter Electrode comparison (TiO_2 = 12 μm)

CE	Voc (V)	Jsc(mA/cm²)	FF (%)	PCE_{max} (%)
Gr	0.44	1.19	41.2	0.22
PPy	**0.39**	**3.15**	**46**	**0.57**

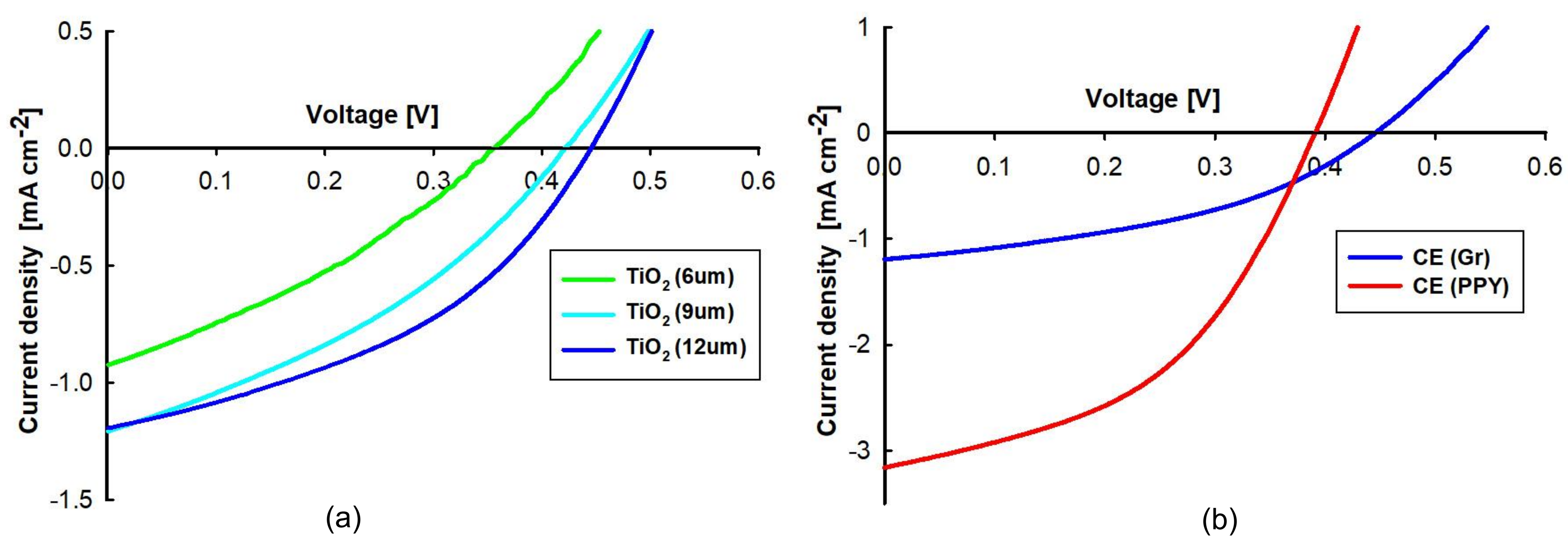


Figure 2. J–V characteristics of DSSCs under simulated solar irradiation: (a) effect of TiO_2 layer thickness (6, 9, and 12 μm); (b) comparison between graphite (FTO/Gr) and polypyrrole (FTO/PPy) counter electrodes

- TiO_2 thickness optimization (6 → 12 μm) enhanced light harvesting and charge collection efficiency.
- The DSSC with a graphite CE exhibited the best performance at 12 μm TiO_2 (Voc = 0.44 V, FF = 41.18%, PCE = 0.22%).
- Replacing graphite with PPy significantly improved the catalytic activity of the counter electrode, yielding the highest efficiency (PCE = 0.57%).

CONCLUSIONS

- SEM and EDX analyses confirmed the successful incorporation of Nb_2O_5 onto the TiO_2 photoanode surface, providing additional light-scattering sites that may contribute to improved light harvesting.
- In DSSCs based on FTO/TiO_2/Nb_2O_5/blackberry dye/electrolyte/CE, thicker TiO_2 photoanodes promoted improved photovoltaic output due to enhanced dye loading.
- The use of a PPy counter electrode instead of graphite reduced interfacial losses and markedly improved device performance, particularly Jsc and overall efficiency.

ACKNOWLEDGMENT

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