Effect of Sodium Citrate Concentration on SnO_2 -GQDs Composite Quantum Dots Synthesized via a Two-Step Electrochemical Route

FACULTY OF SCIENCE
CHIANG MAI UNIVERSITY

Abstract

This study reports a two-step electrochemical synthesis of SnO_2 -GQDs nanocomposite nanomaterials. By fixing KCl at 0.06 M and varying sodium citrate 0.01–0.04 M, the optical properties were effectively tuned. Results showed an expanded bandgap of 4.34–4.46 eV due to quantum confinement in sub-5 nm particles. The composite system exhibited significant PL quenching at 326 and 374 nm, confirming efficient charge transfer via a Type-II junction.
DLS analysis further revealed that citrate concentration and pH are critical for controlling hydrodynamic size and colloidal stability. These findings showcase the high potential of the synthesized nanocomposite as an efficient electron transport layer (ETL) for high-performance perovskite solar cells.

Authors

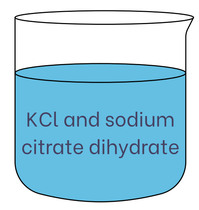
Tharathep Kawthaisong
Department of Physics and Materials Science

Advisors

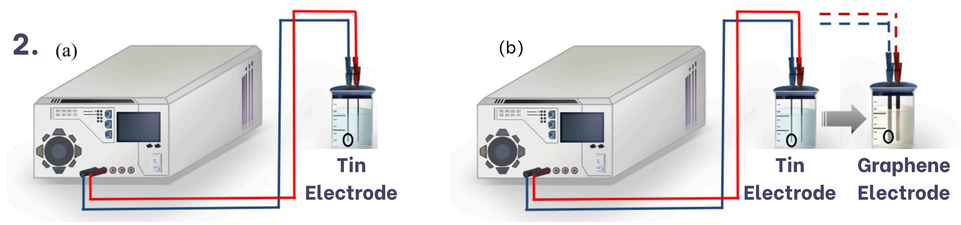
Asst. Prof. Dr. Sukrit Sucharitakul

Methods

1.



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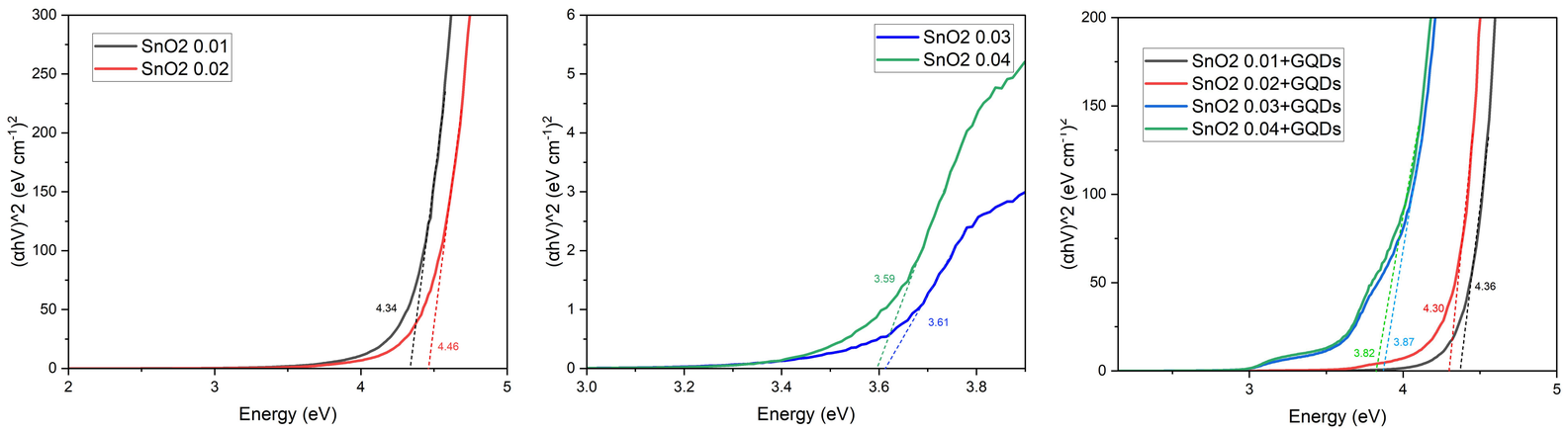


Two-Step Electrochemical Synthesis

The SnO_2 -GQDs nanocomposite was prepared using a dual-stage electrochemical process at 12V:
(a) SnO_2 QDs: Synthesis using a Tin Oxide electrode 1h in 0.06 M KCl electrolyte with varied Sodium Citrate (0.01–0.04 M).
(b) Nanocomposite: Secondary electrolysis using a Graphite electrode 1h to exfoliate and integrate GQDs into the SnO_2 solution.

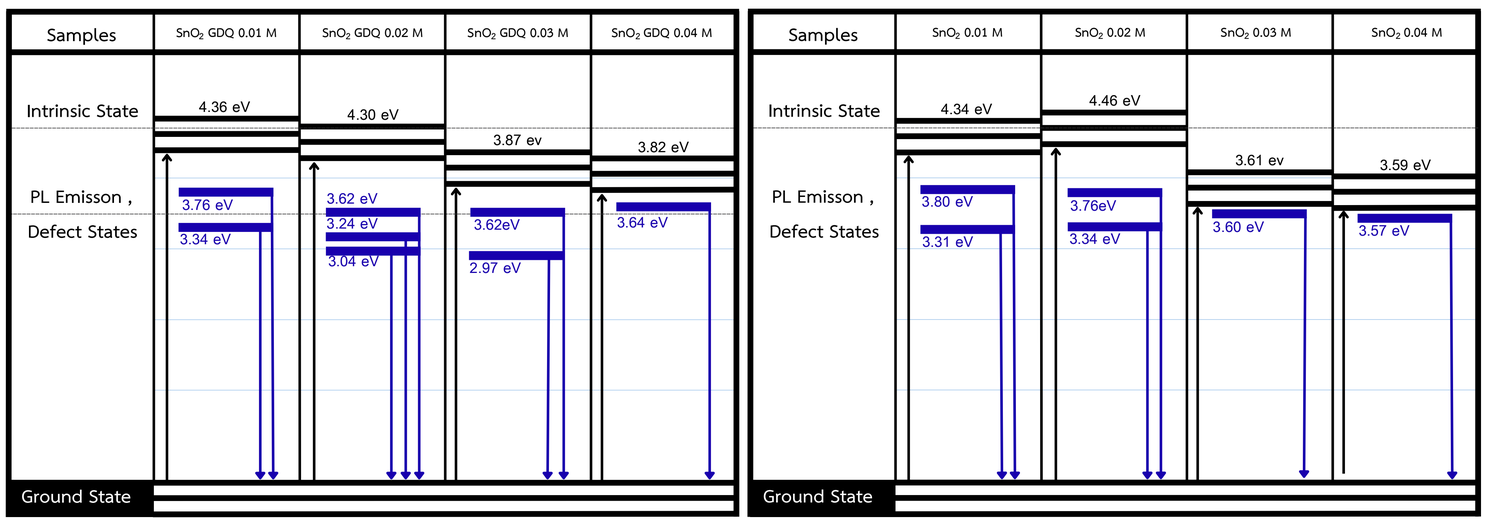
Results and Discussion

1.Optical Band Gap Analysis via Tauc Plots



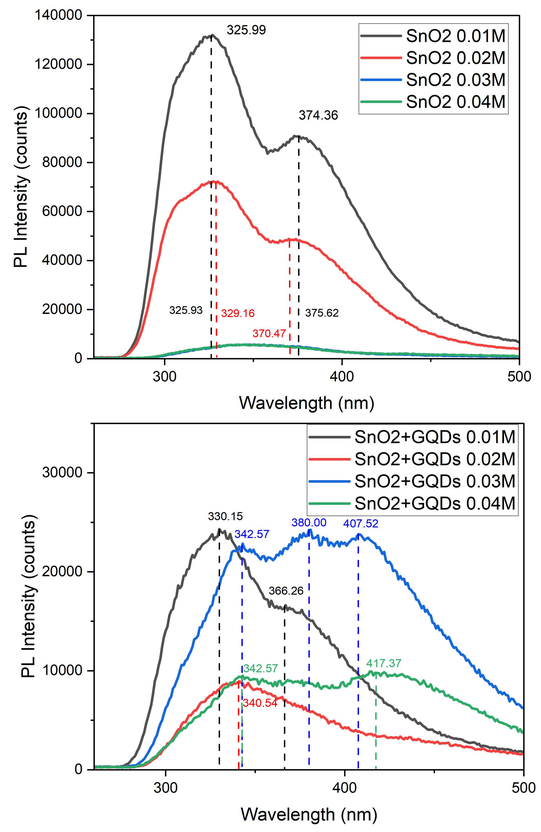
The optical band gap (Eg)exhibits a clear concentration-dependent shift, ranging from 3.59 eV to 4.46 eV, indicating the tunability of SnO_2 electronic structure via GQD doping.

3.Energy Level Diagram



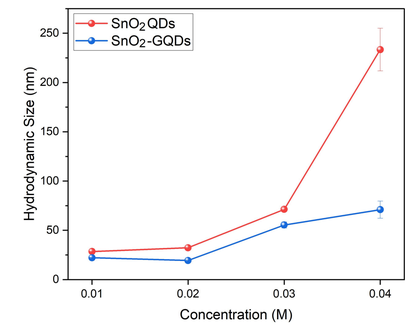
The proposed energy level diagram illustrates the electronic transitions and the presence of defect-induced sub-band states, which correlate with the observed PL emissions.

2.PL Emission Properties



By effectively suppressing radiative recombination, the hybrid structure facilitates superior charge separation and mobility.

4.Hydrodynamic Size



- SnO_2QDs (Red): Significant aggregation observed, size reaching 235 nm
- SnO_2-GQDs (Blue): Maintains stable, sub-75 nm size across all conditions

Conclusion

- Synthesis: SnO_2 -GQDs nanocomposites were successfully synthesized via a two-step electrochemical route. Sodium citrate concentration 0.01–0.04 M was found critical for controlling particle growth and colloidal stability.
- Optical Properties: The quantum dots exhibited a significant blue-shift, with an optical bandgap (Eg) expanded to 4.34–4.46 eV. This confirms the quantum confinement effect in sub-5 nm particles.
- Charge Dynamics: The composite system showed significant PL quenching at 326 and 374 nm compared to pure SnO_2 . This provides strong evidence of efficient charge transfer at the Type-II junction interface.
- Application: Due to its wide bandgap and superior charge-separation efficiency, this nanocomposite is a highly promising candidate for the electron transport layer (ETL) in high-performance perovskite solar cells (PSCs).