2026 S.T. Yau High School Science Award (Asia)

Research Report

The Team

Registration Number: Chem-159

Name of team member: Wit Kulvutiroj
School: Kamnoetvidya Science Academy
City, Country: Rayong, Thailand

Name of team member: Pornpawit Pruetarat
School: Kamnoetvidya Science Academy
City, Country: Rayong, Thailand

Name of supervising teacher: Yutichai Mueanngern Pradipasena
Job Title: Chemistry Kamnoetvidya Science Academy
School: Kamnoetvidya Science Academy
City, Country: Rayong, Thailand

Title of Research Report

Photoresponsive Modulation of CO_2 Reduction Activity via Metavanadate-Doped Chitosan/PVA Nanofibres on Copper Electrodes

Date

August 16, 2026

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Photoresponsive Modulation of CO_2 Reduction Activity via Metavanadate-Doped Chitosan/PVA Nanofibres on Copper Electrodes

Wit Kulvutiroj, Pornpawit Pruetarat

Abstract

The electrochemical carbon dioxide reduction reaction (CO_2RR) on copper-based catalysts is severely constrained by competitive hydrogen evolution (HER) and the poor aqueous solubility of CO_2. While engineering hydrophobic microenvironments can alleviate mass-transport limitations, static architectures lack the stimulus-induced structural and electronic reconfiguration prior to electrochemical operation required to adapt to complex tri-phasic reaction interfaces. Herein, we report a stimuli-responsive microenvironment achieved by directly electrospinning a vanadium-doped chitosan/polyvinyl alcohol (PVA) nanofiber network onto a copper substrate. In the dark state, vanadium incorporation was associated with a contracted fibrous morphology and a more oxidized Cu surface. However, *ex situ* visible light irradiation acts as a modification trigger prior to electrochemical operation. Irradiation was accompanied by the reduction of vanadium centers and expansion of the polymer network into a highly porous morphology proposed to facilitate CO_2 retention near the electrode surface. Concurrently, the irradiated surface exhibited an increased contribution from lower-valence Cu species together with an increased V^{4+} fraction. When operated at -0.801 V vs. RHE, the irradiated electrode, combining the altered Cu–V surface chemistry with the expanded polymer morphology, exhibited a 4.4-fold increase in average cathodic current density (4.83 mA/cm^2) compared to bare Cu (1.10 mA/cm^2). Furthermore, the absolute formate concentration was enhanced 4.5-fold (from 18.0 μM to 80.7 μM). This work provides a novel approach for utilizing photonic stimuli to alter both macroscopic mass transport and sub-nanometer electronic architectures for advanced electrocatalysis.

Keywords: Electrochemical CO_2 Reduction, Stimuli-Responsive Microenvironment, Copper Catalysis, Photochemical Activation, Nanofiber Network

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Acknowledgement

This research project was successfully completed due to the profound kindness and support of Dr. Yutichai Mueanngern Pradipasena, our project advisor, who provided invaluable guidance, directed our methodology, helped correct flaws, and offered continuous encouragement throughout the entire research process.

We extend our deep gratitude to Teacher Natthaputthiya Klayporsri, our chemistry laboratory instructor, for her meticulous guidance on utilizing laboratory equipment and her consistent supervision during our experiments. We also owe a special thanks to Dr. Min Medhisuwakul for his expert advice and hands-on assistance in constructing the custom gravity-fed electrospinning apparatus, as well as to Dr. Prasongporn Ruangpirasiri for providing crucial recommendations regarding the electrochemical testing protocols and product quantification.

Furthermore, we are highly indebted to the Vidyasirimedhi Institute of Science and Technology (VISTEC) for granting us access to their advanced analytical instruments. Their courtesy and essential technical consultations on electrochemistry significantly contributed to the completeness, accuracy, and reliability of our experimental results. Finally, we thank all the teachers and involved personnel whose support made this endeavor possible.

Declaration of AI Usage: In accordance with the competition guidelines, we declare the use of AI tools in this research report. ChatGPT-5.6 was utilized during the final drafting and language-editing stage of the report on one occasion in August 2026, in a single chat session, primarily to assist in English language refinement and grammar correction. The AI was used to review the wording of the existing manuscript and identify potential overstatements or insufficiently hedged scientific language; no new experimental results, data, or scientific claims were generated from the AI output. No AI was used to generate data, alter scientific findings, or formulate the core methodology. All AI-assisted outputs were reviewed and verified by the student researchers, and the scientific content and final wording were determined by the student researchers under the supervision of the supervising teacher.

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2. perform the research work ourselves and thus truly understand the content of the work.
3. observe the common standard of academic integrity adopted by most journals and degree theses.
4. have declared all the assistance and contribution we have received from any personnel, agency, institution, etc. for the research work.
5. have truthfully disclosed all AI tool usage in the research report and obtained prior approval from supervising teachers. All supporting documentation has been submitted as required. We hereby affirm that no improper use of AI has occurred at any stage of the research process.
6. undertake to avoid getting in touch with assessment panel members in a way that may lead to direct or indirect conflict of interest.
7. undertake to avoid any interaction with assessment panel members that would undermine the neutrality of the panel member and fairness of the assessment process.
8. observe the safety regulations of the venue(s) where we conduct the experiment(s), if applicable.
9. observe all rules and regulations of the competition.
10. agree that the decision of YHSA(Asia) is final in all matters related to the competition.

We understand and agree that failure to honor the above commitments may lead to disqualification from the competition and/or removal of award, if applicable; that any unethical deeds, if found, will be disclosed to the school principal of the team member(s) and relevant parties if deemed necessary; and that the decision of YHSA(Asia) is final and no appeal will be accepted.

Wit K.

Name of team member: Wit Kulvutiroj

Pornpawit P.

Name of team member: Pornpawit Pruetarat

Name of supervising teacher: Yutichai Mueanngern Pradipasena

Noted and endorsed by

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Name of school principal: Prof. Boonchoat Paosawatyanyong, Kamnoetvidya Science Academy

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1. Introduction

The electrochemical carbon dioxide reduction reaction (CO_2RR) has emerged as a promising strategy for recycling carbon dioxide into valuable products, including fuels such as ethanol, carbon monoxide, formate, and various chemical precursors [1]. While copper (Cu) is widely investigated as a benchmark electrocatalyst due to its unique ability to stabilize diverse intermediate species, the efficiency and selectivity of bare Cu electrocatalysts in aqueous environments are heavily constrained [2]. Two fundamental bottlenecks hinder optimal performance: the low solubility of CO_2 in aqueous electrolytes and the thermodynamically favorable, highly competitive hydrogen evolution reaction (HER), which often dominates the catalytic interface and reduces product yield [3].

To circumvent these limitations, recent advancements in electrocatalysis have shifted focus from solely altering the atomic composition of the catalyst to modifying the local microenvironment above the active sites [4]. An effective strategy involves depositing hydrophobic layers—such as polytetrafluoroethylene (PTFE) or specific polymers—over the Cu surface [5], [6]. These layers repel liquid water while maintaining a high affinity for CO_2, successfully forming a robust gas-liquid-solid triple-phase boundary that concentrates the reactant gas at the active sites. Despite their utility, these conventional microenvironments are fundamentally static, which presents an inherent dilemma under operational conditions [7]. A permanently fixed hydrophobic matrix cannot adapt to the dynamically evolving tri-phasic interface. Excessively restrictive layers often introduce high electrical resistance and impede the desorption and outward diffusion of local liquid products, leading to kinetic poisoning. Conversely, prolonged cathodic operation can cause structural degradation or wetting of the polymer, leading to eventual electrolyte flooding and a resurgence of competitive HER [8]. Therefore, the development of stimuli-responsive microenvironments capable of stimulus-induced structural and electronic reconfiguration prior to electrochemical operation remains a critical frontier [9].

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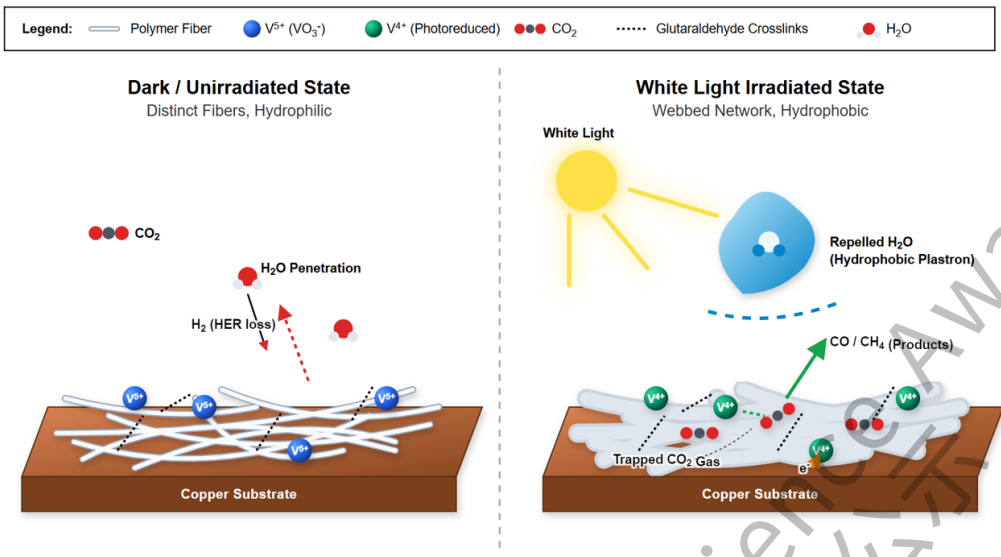


Figure 1: Detailed mechanistic schematic demonstrating the transition from isolated, hydrophilic fibers in the dark state (left) to an expanded, hydrophobic webbed network in the light state (right) proposed to facilitate CO_2 retention and Cu–V interfacial interactions.

We selected visible light as an external stimulus for inducing these changes, drawing on the ability of transition metal-polymer coordination complexes to undergo structural transitions upon photon absorption [10], [11]. In this study, we report the fabrication of a photo-responsive microenvironment comprising a vanadium-doped chitosan/polyvinyl alcohol (PVA) nanofiber network electrospun directly onto a Cu electrode. As illustrated in Figure 1, we find that *ex situ* visible-light irradiation produces substantial changes in the morphology and surface oxidation-state distribution of the vanadium-doped Cu electrode. We propose that these changes may produce an expanded porous microenvironment and a proposed Cu^0/Cu^+–V^{4+} interfacial structure that contribute to the enhanced electrochemical response. By decoupling the initial modification from the electrochemical operation, we prepare the electrode in its irradiated state prior to applying a cathodic bias.

2. Methodology

2.1. Materials and Synthesis of the Polymeric Microenvironment

A spinnable composite polymer ink was formulated by preparing a 7% weight-by-volume (w/v) solution in a solvent mixture of glacial acetic acid and deionized water (7:3 volumetric ratio). Chitosan and PVA were blended in an optimized 3:7 volume ratio. The dynamic microenvironment was fabricated utilizing a custom gravity-fed electrospinning apparatus. A pristine Cu foil (cleaned via sonication in ethanol and dilute HCl) was utilized as the ground collector, positioned 14 cm from a 22G stainless steel spinneret. Electrospinning was conducted at an applied potential of 12 kV for 30 minutes to deposit

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a uniform 3D nanofiber web. The chitosan-PVA nanofibers (CPNs) were crosslinked by immersion in a 3% glutaraldehyde solution for 20 minutes. Vanadium was integrated into the polymer matrix by immersing the crosslinked electrode in a 0.1 M $NaVO_3$ solution for 2 minutes, followed by drying in ambient air.

2.2. Photochemical Activation

To modify the interface and isolate the photo-induced structural changes from the electrochemical reaction, the modified electrodes underwent *ex situ* light irradiation. The electrodes were exposed to a 1000 W white light source for 3 hours under ambient conditions prior to electrochemical testing. A control sample set was synthesized in an identical manner but kept strictly in the dark.

2.3. Physicochemical and Computational Characterization

Morphological transitions were assessed using a Scanning Electron Microscope (SEM) and a Transmission Electron Microscope (TEM), both equipped with Energy Dispersive X-Ray Spectroscopy (EDS). Quantitative analysis of fiber diameter and macroscopic porosity was conducted using ImageJ. Fourier Transform Infrared (FTIR) spectroscopy evaluated chemical crosslinking and metavanadate incorporation. Oxidation states were determined via X-ray Photoelectron Spectroscopy (XPS). Density Functional Theory (DFT) calculations were performed using the ORCA software package to evaluate the proposed coordination geometry utilizing the B3LYP exchange-correlation functional.

2.4. Electrochemical CO_2RR Evaluation and Product Quantification

Electrochemical reduction was performed in an H-type electrolytic cell using a standard three-electrode setup. The modified Cu substrate served as the working electrode, paired with a Pt wire counter electrode and an Ag/AgCl reference electrode, in a 0.1 M $KHCO_3$ aqueous electrolyte. The catholyte was continuously purged with high-purity CO_2 gas (20 sccm). Cyclic Voltammetry (CV) was recorded at a scan rate of 50 mV/s. Steady-state operational stability and product generation were evaluated via chronoamperometry (CA) at -0.801 V vs. RHE for 3 hours. Liquid products were quantified utilizing Nuclear Magnetic Resonance spectroscopy (^{1}H-NMR) with dimethyl sulfoxide (DMSO) as a stable internal standard.

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3. Results and Discussion

3.1. Morphological and Structural Evolution of the Microenvironment

The synthesis of the electrode was validated via FTIR spectroscopy (Figure 2). Following glutaraldehyde immersion, a peak emerged at ∼1640 cm^{-1}, corresponding to the C=N imine linkage, supporting the successful crosslinking process of glutaraldehyde with chitosan polymers [12]. Upon vanadium doping, a new characteristic vibrational band appeared at ∼950 cm^{-1}, corresponding to V=O stretching, supporting the presence of vanadium-containing species in the matrix.

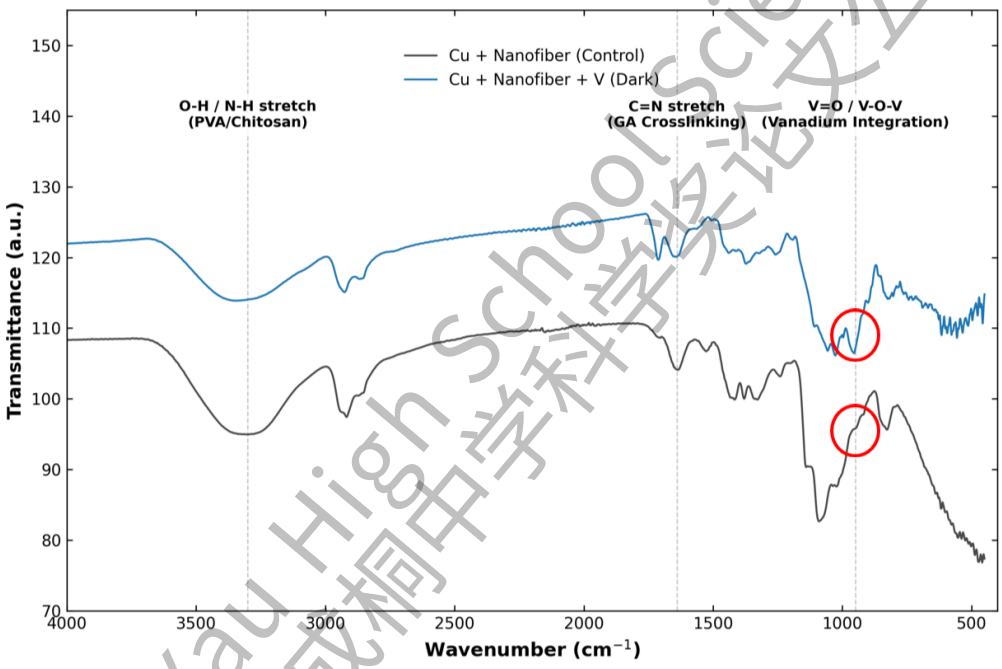


Figure 2: FTIR spectra for copper substrates with nanofibers deposited via electrospinning, pre- and post-vanadium soaking. The spectrum verifies the presence of vanadium in the material matrix.

Morphological analysis via SEM (Figure 3) quantified the structural impact of vanadium integration. The unmodified CPN nanofibers (Figure 3A) exhibited a uniform architecture with an average diameter of ∼174 nm and a macroscopic porosity of 13.0%. However, when doped with vanadium in the dark state (Figure 3B), the fibers contracted, shrinking the average diameter to ∼107 nm and resulting in a macroscopic porosity of 38.6%. Subsequent SEM-EDS characterization (Figure 3C) confirmed a homogeneous spatial distribution of V within these constricted fibers.

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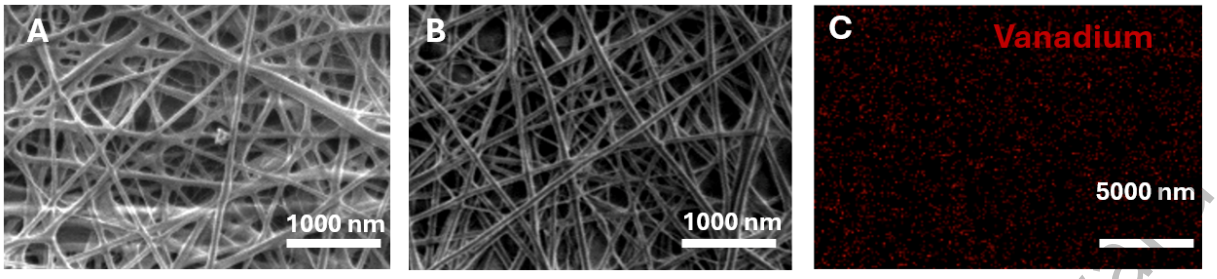


Figure 3: (A) Electrospun chitosan-PVA nanofibers (CPN). (B) Electrospun chitosan-PVA nanofibers following vanadium soaking in dark state (CPN-V). (C) Corresponding SEM-EDS mapping indicating the presence of vanadium in the nanofibers.

Following *ex situ* white light irradiation, the morphology was substantially altered, as observed in the TEM imagery (Figure 4). The previously constricted network expanded, adopting a highly porous, webbed morphology (Figure 4D-E). Furthermore, localized V-rich aggregations were observed within the expanded fiber matrix, mapped via TEM-EDS (Figure 4F). Together with the XPS evidence, these observations are consistent with photo-induced redistribution and reduction of vanadium species.

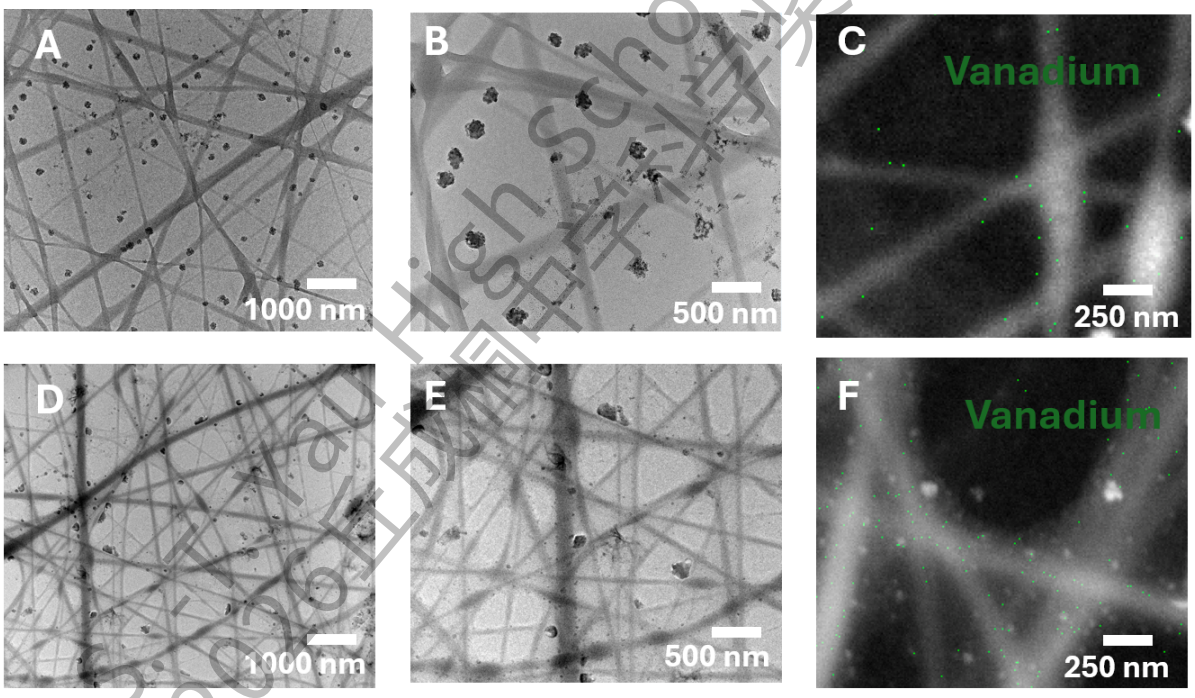


Figure 4: (A-B) Electrospun vanadium-soaked chitosan-PVA nanofibers (CPN-V) on TEM grids in the dark state. (C) Corresponding EDS mapping. (D-E) Corresponding images for vanadium-soaked and irradiated chitosan-PVA-nanofibers (CPN-VR). (F) Corresponding EDS mapping showing localized clustering.

3.2. Photo-induced Interfacial Electronic Restructuring

To elucidate the chemical nature underlying the observed structural expansion and metallic nucleation, high-resolution XPS was performed (Figure 5). Quantitative data from the

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non-irradiated sample revealed a high-valency dominance, with V^{5+} accounting for 59.35% and V^{4+} for 40.65% of the vanadium species. Furthermore, the non-irradiated Cu $2p_{3/2}$ spectrum displayed distinct, prominent shake-up satellite peaks located between 940 and 945 eV. These satellites are characteristic of a highly oxidized state (Cu^{2+}), consistent with an oxidized Cu surface that may be less favorable for CO_2 reduction under the tested conditions.

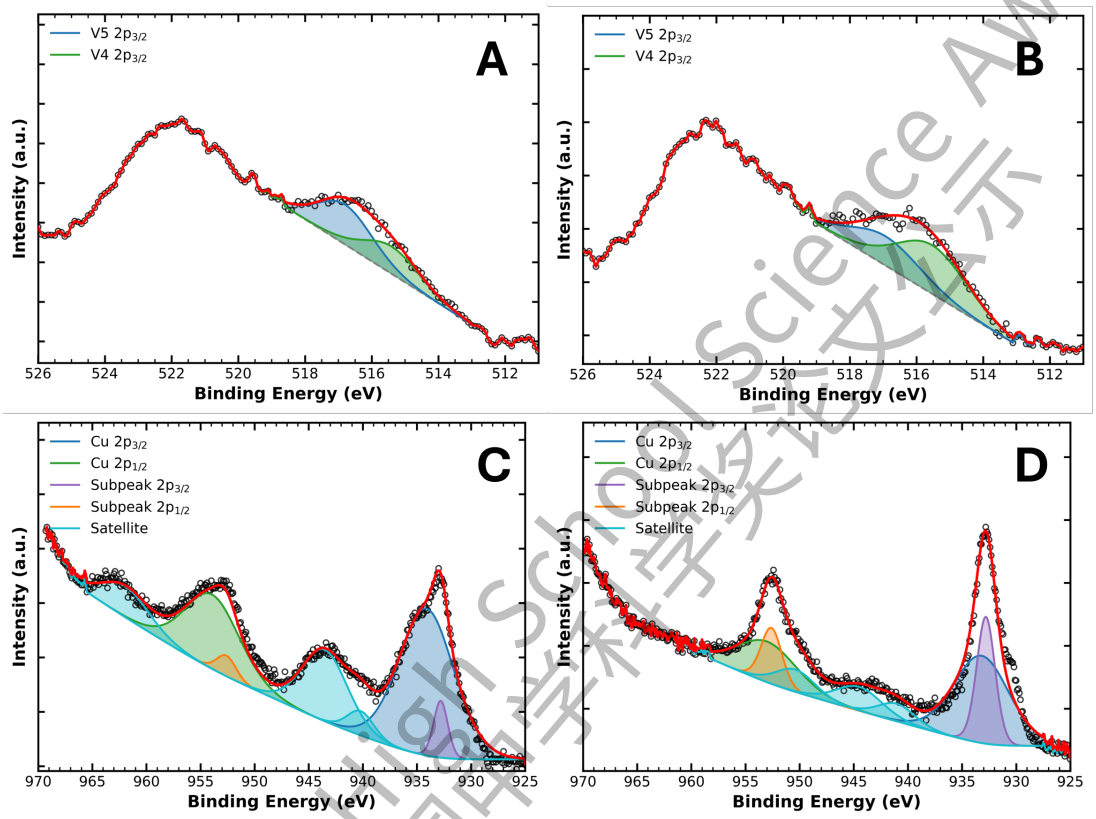


Figure 5: High-resolution XPS spectra of the V 2p and Cu 2p core levels for the non-irradiated (dark) and light-irradiated samples. (A) V 2p spectrum in the dark state, showing a dominance of the high-valency V^{5+} species. (B) V 2p spectrum following *ex situ* white light irradiation, illustrating partial photo-reduction and a proportional shift toward V^{4+}. (C) Cu 2p spectrum of the underlying substrate in the dark state, exhibiting prominent Cu^{2+} shake-up satellite peaks (cyan shading). (D) Cu 2p spectrum after white light irradiation, demonstrating a significant attenuation of the Cu^{2+} satellites and a narrowing of the primary peaks, suggesting a shift toward lower-valency copper species (Cu^{+}/Cu^{0}).

Following *ex situ* light irradiation, the XPS spectra showed substantial changes in the surface oxidation-state distribution. The V 2p signal shifted to a lower binding energy, shifting the composition significantly to 62.43% V^{4+} (and 37.57% V^{5+}), indicating strong photo-reduction. Concurrently, the Cu^{2+} shake-up satellites were significantly attenuated, and the primary peaks narrowed. This suggests a proportional shift toward lower-valency, closed-shell $3d^{10}$ states (Cu^{0}/Cu^{+}) and supports the formation of a putatively active Cu–V interfacial structure.

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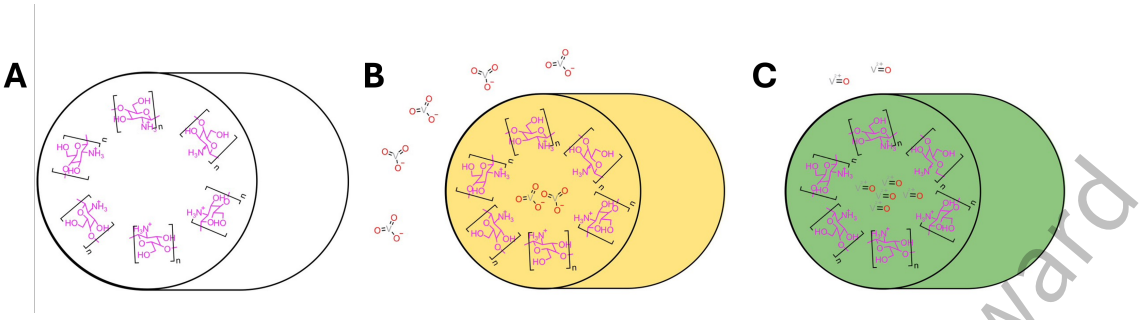


Figure 6: Proposed sub-nanometer coordination geometry. (A) Base polymer matrix. (B) Nanofibers interacting diffusely with V^{5+} in the dark state. (C) Photoreduction of vanadium to a 4+ oxidation state increases binding affinity, yielding localized crosslinking nodes that allow the broader matrix to relax.

These electronic data, supported by DFT calculations, allow us to propose a physical mechanism (Figure 6). In the non-irradiated state (Figure 6B), the V^{5+} state exhibits a relatively weak interaction energy (-28.17 kcal/mol) and a longer coordination distance (4.310 Å) with the matrix. We propose that photo-induced charge transfer, potentially involving ligand-to-metal charge transfer (LMCT), contributes to the observed increase in V^{4+} (Figure 6C). The stronger calculated V^{4+}–matrix interaction (-47.95 kcal/mol) is consistent with increased local coordination and may contribute to the observed redistribution of the polymer network and formation of the expanded morphology.

3.3. Electrocatalytic CO_2RR Performance and Product Yield

Initial electrochemical behavior was assessed using cyclic voltammetry (CV) (**Figure 7**). The CV sweeps demonstrated a marked increase in cathodic current density and an earlier onset potential for the irradiated Cu-CPN-V electrode compared to all controls, indicating enhanced cathodic current response under the tested conditions.

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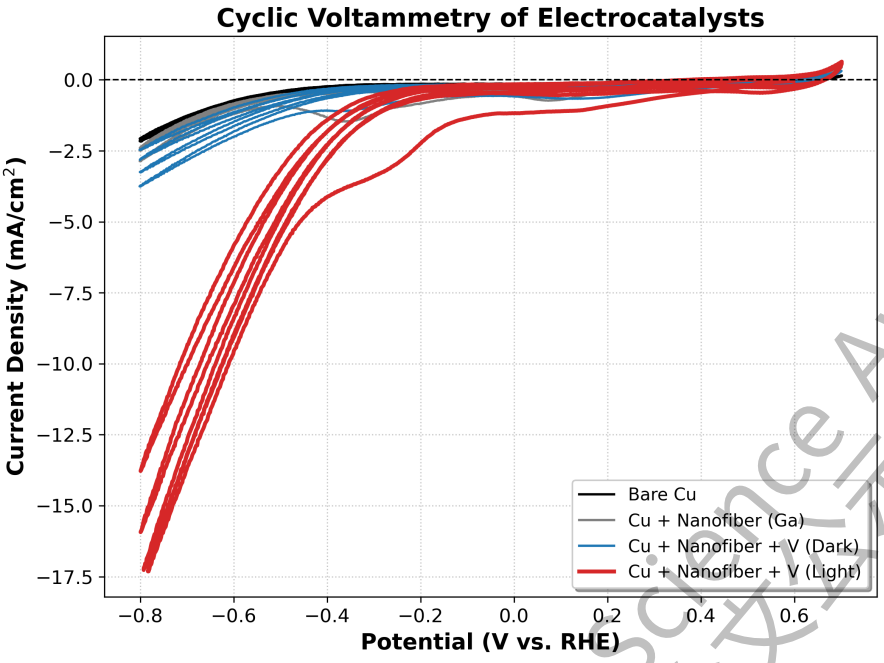


Figure 7: Cyclic voltammograms for bare Cu, Cu with nanofibers, Cu with nanofibers with vanadium (dark), and Cu with nanofibers with vanadium following white light irradiation.

The steady-state performance evaluation was then performed via chronoamperometry (Figure 8) at -0.801 V vs. RHE for 3 hours. The bare Cu foil achieved an average current density of only 1.10 ± 0.01 mA/cm^2. Integrating the unmodified base nanofiber increased the current density to 2.82 ± 0.03 mA/cm^2, indicating that incorporation of the unmodified nanofiber layer increased the measured cathodic current under the tested conditions. However, for the V-doped non-irradiated electrode, performance plummeted to 1.26 ± 0.03 mA/cm^2, which may indicate that the contracted network restricts mass transport and may increase susceptibility to aqueous flooding. Conversely, upon light irradiation, the system maintained a relatively stable average current density of 4.83 ± 0.32 mA/cm^2, a 4.4-fold increase over bare Cu.

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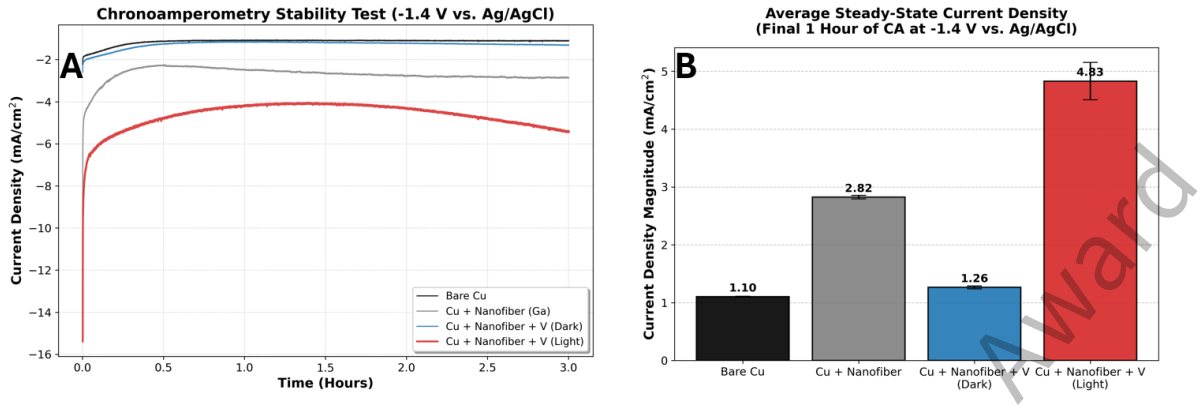


Figure 8: (A) Current density stability over 3 hours for bare Cu, Cu nanofiber samples, Cu nanofiber with vanadium, and Cu nanofiber with vanadium after white light irradiation. (B) The corresponding steady-state current density magnitudes summarized as bar plots.

Because macroscopic mass transport dictates local reactant concentrations, comparing current density with measured formate accumulation provides complementary information about the electrochemical response and formate production. Quantitative ^{1}H-NMR (Figure 9) revealed an absolute formate concentration of 80.7 μM for the irradiated sample, representing a 4.5-fold enhancement over the Cu baseline (18.0 μM). This similar fold increases in measured formate concentration are consistent with the current density observed under the tested conditions.

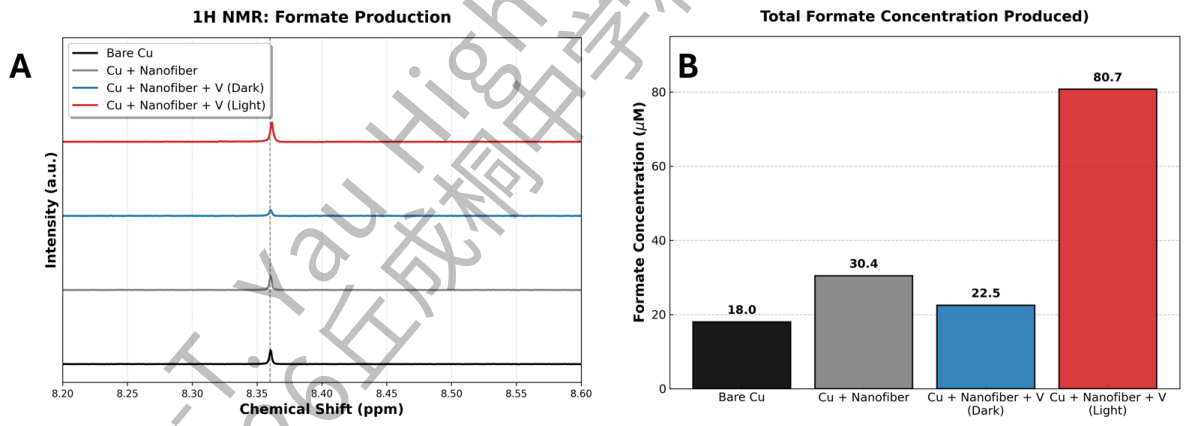


Figure 9: (A) ^{1}H-NMR spectra of bare Cu, Cu nanofiber samples, Cu nanofiber with vanadium, and Cu nanofiber with vanadium after white light irradiation. (B) Total formate concentration summarized as bar plots.

3.4. Proposed Dual-Phase Mechanistic Synergy

We propose that the observed enhancement arises from two potentially coupled effects involving microenvironmental structure and interfacial electronic structure. Macroscopically, the observed structural expansion may alter interfacial wetting and mass transport, potentially increasing local CO_2 availability near the electrode surface (see Figure 1).

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Microscopically, we propose that the irradiation-induced Cu–V interfacial structure may operate via a dual-site activation mechanism. We hypothesize that V^{4+} sites may provide Lewis-acidic interactions with oxygen-containing intermediates or CO_2, while the electron-rich Cu surface may provide an electron-donating site for CO_2 activation. We propose that such interfacial interactions may stabilize CO_2-derived intermediates such as *OCHO and thereby facilitate formate formation, which may contribute to the observed 4.5-fold increase in measured formate concentration.

4. Conclusion

In conclusion, we have engineered a stimuli-responsive microenvironment that utilizes an *ex situ* photo-driven pre-treatment strategy to address potential mass-transport and interfacial chemical limitations associated with Cu-based CO_2RR. Exposing an electrospun, vanadium-doped chitosan/PVA network on an oxidized Cu substrate to visible light was accompanied by physical and electronic reconfigurations. Irradiation was accompanied by reduction of V centers, expansion of the polymer network into a highly porous morphology, and a shift of the Cu surface toward lower oxidation states. We propose that the change in V coordination contributes to this morphological relaxation, forming a proposed Cu^0/Cu^+–V^{4+} interfacial structure. Because the interface is prepared in the irradiated state before electrochemical testing, the observed electrochemical response reflects the combined effects of the pre-irradiated structure and the applied cathodic bias. Consequently, at -0.801 V vs. RHE, the photo-activated system exhibited a 4.4-fold increase in average current density (4.83 mA/cm^2) and a 4.5-fold enhancement in measured absolute formate production (80.7 μM). This work establishes a versatile new framework for utilizing external photon stimuli to modify electrocatalytic interfaces.

5. References

[1] Nitopi, S., Bertheussen, E., Scott, S. B., Liu, X., Engstfeld, A. K., Horch, S., ... & Chorkendorff, I. (2019). Progress and perspectives of electrochemical CO_2 reduction on copper in aqueous electrolyte. *Chemical Reviews*, 119(12), 7610-7672.

[2] Bagger, A., Ju, W., Varela, A. S., Strasser, P., & Rossmeisl, J. (2017). Electrochemical CO_2 reduction: a classification problem. *ChemPhysChem*, 18(22), 3266-3273.

[3] Lv, J. J., Jiao, M., Eid, K., Varma, R. S., & Lu, J. (2022). Microenvironment Engineering for the Electrocatalytic CO_2 Reduction Reaction. *Angewandte Chemie International Edition*, 61(39), e202207252.

[4] Liang, H. Q., Zhao, S., Yuan, Q., & Lu, J. (2021). Hydrophobic Copper Interfaces Boost Electroreduction of Carbon Dioxide to Ethylene in Water. *ACS Catalysis*, 11(15), 9584–9592.

2026 S.T. Yau High School Science Award 仅用于2026丘成桐中学科学奖公示

[5] Weng, Z., Jiang, J., Wu, Y., Wu, Z., Guo, X., Materna, K. L., ... & Wang, H. (2018). Electrochemical CO_2 reduction to hydrocarbons on a heterogeneous molecular Cu catalyst in aqueous solution. *Journal of the American Chemical Society*, 140(16), 5345-5349.

[6] Xing, Z., Hu, L., MacFarlane, D. R., & Feng, X. (2021). Enhancing carbon dioxide gas-diffusion electrolysis by creating a hydrophobic catalyst microenvironment. *Nature Communications*, 12(1), 136.

[7] Li, Z., Wang, Y., Chen, X., & Zhang, L. (2025). Revealing the Dynamic Microenvironment of the Ag/CeO_2 Surface for Robust Electrocatalytic CO_2 Reduction. *ACS Catalysis*, 15(17), 15019–15032.

[8] Zhao, T., Zhou, Z., Wang, X., & Cheng, F. (2025). Tailoring dual-hydrophobic microenvironment for tandem CO_2/CO feedstock to enhance CO_2 electroreduction on Cu-based catalysts. *Chemical Science*.

[9] Zhang, L., Zheng, C., Sun, X., & Han, B. (2025). Self-Adaptive Catalysts for CO_2 Electroreduction. *Journal of the American Chemical Society*, 147(25), 21267-21283.

[10] Sangsawang, P., et al. (2025). Bifunctional metavanadate promoted chitosan/cassava biopolymer films with photo-switchable wetting properties: unveiling the surface restructuring mechanism. *RSC Advances*, 15, 7758–7768.

[11] Zhang, N., Long, R., Gao, C., & Xiong, Y. (2020). Recent progress on advanced design for photoelectrocatalytic CO_2 reduction. *Joule*, 4(11), 2275-2310.

[12] Kildeeva, N. R., Perminov, P. A., Vladimirov, L. V., Novikov, V. V., & Mikhailov, S. N. (2009). About mechanism of chitosan cross-linking with glutaraldehyde. *Russian Journal of Bioorganic Chemistry*, 35(3), 360-369.

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Appendix A — AI Usage Record

The following record documents the use of ChatGPT-5.6 during the final drafting and language-editing stage of this research report.

ChatGPT-5.6 was used in a single chat session in August 2026 to review the existing manuscript for English language refinement, grammar correction, potential scientific overstatement, and insufficiently hedged scientific language. The purpose of the review was limited to evaluating the wording and scientific claims supported by the results already present in the manuscript. No additional experimental data or results were generated or incorporated from the AI interaction.

The complete relevant chat record is provided as a separate PDF attachment in the submission package for verification.

AI tool: ChatGPT-5.6
Date of use: August 2026
Frequency: One occasion; one chat session
Purpose: English language refinement, grammar correction, and identification of potential overstatement or insufficiently hedged scientific language in the existing manuscript
Scope: Review of the existing manuscript only; no generation of experimental data, modification of scientific findings, or formulation of the core methodology

The attached chat record contains the complete relevant interaction associated with this use of AI.

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