Visible-light-activated Antibacterial Coatings Incorporating Modified TiO_2 Nanoparticles For Safer Indoor Healthcare Environments

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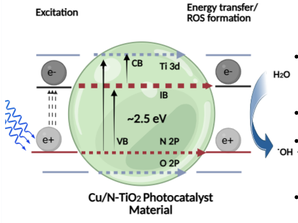
Introduction

- Hospital-acquired infections (HAIs) remain a serious healthcare challenge due to bacterial contamination on indoor surfaces
- Conventional wall coatings do not actively eliminate pathogens
  - *Staphylococcus aureus*
  - *Escherichia coli*
- TiO_2 nanoparticles are well-known photocatalytic antimicrobial materials, but pure TiO_2 is mainly activated under UV light



Cu/N-TiO_2 Photocatalyst Material

- Cu/N co-doping introduces intermediate energy states within the TiO_2 band structure
- Nitrogen (N 2p) raises the valence band energy level
- Copper (Cu 3d) creates acceptor states below the conduction band
- Reduced band gap enables visible-light activation of TiO_2

Objective: To develop visible-light-activated antibacterial acrylic coatings incorporating Cu/N co-doped TiO_2 nanoparticles for safer indoor healthcare environments

Methodology

***STEP 1** - Synthesis of Cu/N Co-doped TiO_2 Nanoparticles*

Preparation of Titanium Precursor Solution | Preparation of Dopant Solution | Add dopant solution to Ti precursor solution | Wash with deionized water by centrifuging

***STEP 2** - Incorporation of Modified Nanoparticles into Biocide-Free Paint*

Adding nanoparticles to PVP solution | Suspension added to acrylic base paint and sonicated | Paint batches made with 1%, 3%, 6%, 12% nanoparticle loadings

Results & Discussion

1. UV-Vis DRS

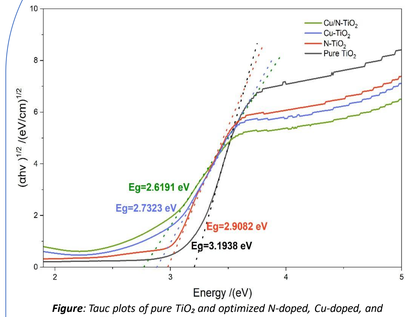


***Figure**: Tauc plots of pure TiO_2 and optimized N-doped, Cu-doped, and co-doped TiO_2*

2. XRD

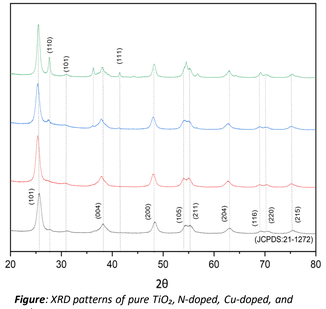


***Figure**: XRD patterns of pure TiO_2, N-doped, Cu-doped, and Cu/N co-doped TiO_2 sample*

2. SEM images

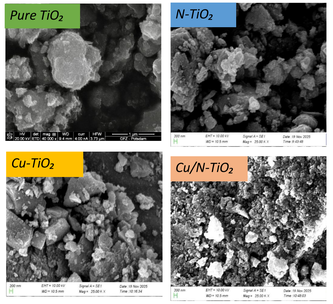
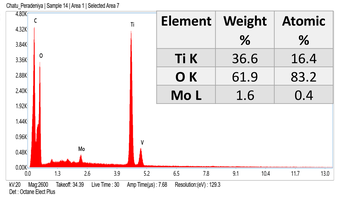


***Figure**: SEM images of pure, N-doped , Cu-doped and Cu/N co-doped TiO_2 nanoparticles*

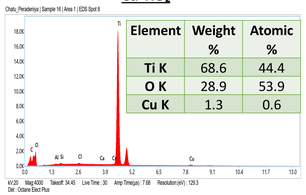
3. EDX analysis

Pure TiO_2



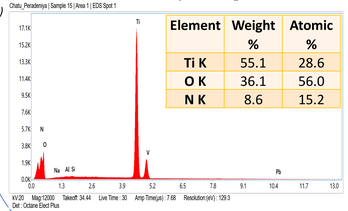
Element	Weight %	Atomic %
Ti K	36.6	16.4
O K	61.9	83.2
Mo L	1.6	0.4

Cu-TiO_2



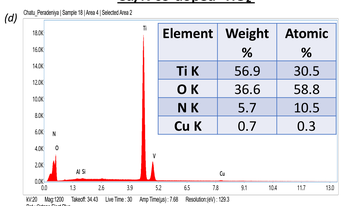
Element	Weight %	Atomic %
Ti K	68.6	44.4
O K	28.9	53.9
Cu K	1.3	0.6

N doped -TiO_2



Element	Weight %	Atomic %
Ti K	55.1	28.6
O K	36.1	56.0
N K	8.6	15.2

Cu/N co-doped -TiO_2



Element	Weight %	Atomic %
Ti K	56.9	30.5
O K	36.6	58.8
N K	5.7	10.5
Cu K	0.7	0.3

***Figure**: EDS spectra and elemental composition of (a) pure, (b) N-doped, (c) Cu-doped, and (d) Cu/N co-doped TiO_2 samples*

4. TGA analysis

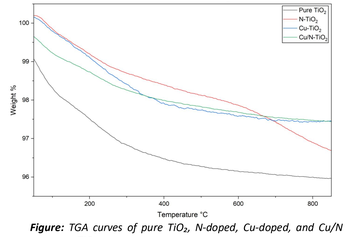


***Figure**: TGA curves of pure TiO_2, N-doped, Cu-doped, and Cu/N co-doped TiO_2 samples*

5. FTIR analysis

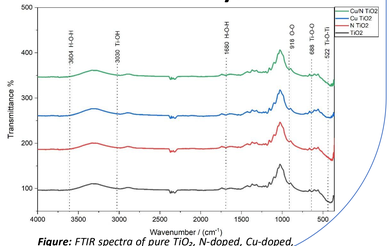


***Figure**: FTIR spectra of pure TiO_2, N-doped, Cu-doped, and Cu/N co-doped TiO_2 samples*

Antimicrobial Testing

Gram-positive bacteria- *Staphylococcus aureus*

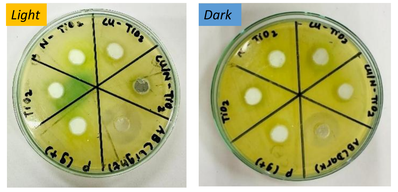


***Figure:** Staphylococcus aureus culture in light dark conditions*

Plate Section	Dark cond Avg. value /(mm)	Dark cond Avg. value /(mm)
Paint Only	10	11
Pure TiO_2	10	10
N-TiO_2	12	11
Cu-TiO_2	15	12
Cu/N- TiO_2	16	13

Gram-negative bacteria- *Escherichia coli*

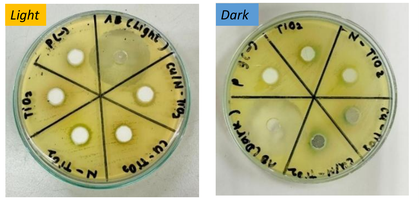


***Figure:** Escherichia coli culture in light dark conditions*

Plate Section	Light cond. Avg value /(mm)	Dark cond. Avg value /(mm)
Paint Only	11	11
Pure TiO_2	11	11
N-TiO_2	13	11
Cu-TiO_2	14	13
Cu/N-TiO_2	14	13

Conclusions

- **Among all samples Cu/N co-doped TiO_2 showed the most favorable band gap (2.6 eV), structural properties, and photocatalytic and antimicrobial performance**
- Acrylic paints with 12 wt% loading, Cu/N-TiO_2 paints exhibited, light-enhanced antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*

References

1. Mathew, S., Ganguly, P., Rhatigan, S., Kumaravel, V., Byrne, C., Hinder, S. J., Bartlett, J., Nolan, M., & Pillai, S. C. (2018). *Cu-Doped TiO_2: Visible light assisted photocatalytic antimicrobial activity*. Applied Sciences, 8(11).
2. Banerjee, S., Pillai, S. C., Falaras, P., O'Shea, K. E., Byrne, J. A., & Dionysiou, D. D. (2014). *New insights into the mechanism of visible light photocatalysis*. Journal of Physical Chemistry Letters, 5(15), 2543–2554.
3. Krishnan, S., Karim, A. V., & Shriwastav, A. (2022). *Visible light responsive Cu-N/TiO_2 nanoparticles for the photocatalytic degradation of bisphenol A*. Water Science and Technology, 86(6), 1527–1539.