A Digital and Portable Integrated Apparatus for Dynamic Monitoring and Highly Efficient Catalysis of Trace Formaldehyde Using Fe-Based TiO2 Single-nanoparticle Photocatalyst

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Recognizing formaldehyde’s significant health risks and prevalence in the environment, particularly the indoors, this study presents a cost-effective and size-flexible integrated system for real-time monitoring and efficient catalysis of trace formaldehyde using a novel Fe-TiO2 photocatalyst. The single-nanoparticle photocatalyst was synthesized via hydrothermal reaction and high-temperature calcination. Morphological characterization through TEM, SEM, EDS, and spectral characterization through XPS, XRD, UV-Vis confirmed high surface-area-to-volume ratio, crystallinity, and uniformity, enhancing the material’s catalytic and electrochemical reactivity. The modified electrochemical sensors demonstrated high electroconductivity and sensitivity to low formaldehyde concentrations, with a detection limit of 10?7M. Compared to other catalysts, the Fe-TiO? nanocomposite exhibits superior photocatalytic performance, achieving 80.0% formaldehyde reduction in 6 hours and 89.2% in 18 hours, outperforming TiO2, Fe-MOF, Cu-MOF, and Co-MOF. Stability tests over three runs showed consistent performance with minor efficiency decreases, highlighting its reliability for long-term use. By integrating detection and remediation into one apparatus, this study offers a digital, portable solution for indoor air quality management with real-time monitoring and efficient catalysis. This approach overcomes traditional method limitations, expanding applications in residential and commercial settings.

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