

Abstract

Thin films of Cr_2O_3 and Cu-doped Cr_2O_3 (1–4% Cu) were successfully synthesized using the spray pyrolysis technique by spraying a 0.2 M precursor solution onto preheated ($\sim 400^\circ\text{C}$) soda lime glass substrates. XRD analysis confirmed the polycrystalline rhombohedral structure of the films, with crystallite size decreasing and lattice strain increasing as the Cu/Cr ratio increased, as estimated by the Williamson-Hall method. The films exhibited porous, rough surface morphology, transitioning from spherical to rice-like grains with higher Cu content. Raman spectroscopy confirmed vibrational modes associated with E_g and A_{1g} symmetries of Cr–O bonding, while UV–Vis analysis revealed a decrease in optical band gap from 2.92 eV to 2.6 eV with increasing Cu doping. Optical properties such as extinction coefficient, refractive index, dielectric constants, and optical conductivity were also enhanced, with refractive index dispersion analyzed via the Wemple–DiDomenico model. Electrical resistivity decreased significantly from $\sim 1000 \Omega\cdot\text{cm}$ to $33 \Omega\cdot\text{cm}$, with 4% Cu-doped films showing the best figure of merit ($4.66 \text{ M}\Omega^{-1}$). Surface contact angle measurements indicated reduced surface energy, and Vickers hardness reached a maximum of 903 HV for films with 2% Cu. Antibacterial tests against gram-positive (Bacillus subtilis, Bacillus meurellus) and gram-negative (E. coli, Acetobacter rhizophherensis) bacteria demonstrated that higher Cu content enhanced antibacterial activity, especially under UVA light, establishing a strong correlation between structural, optical, morphological and biological properties of the films. The thin film with 1.5% Cu/Cr ratio shows the highest photocatalytic efficiency, with a rate constant of $10.81 \times 10^{-3} \text{ min}^{-1}$ for methylene blue degradation under sunlight. Furthermore, the electrochemical analysis of spray deposited Cr_2O_3 and 2, 4% Cu doped Cr_2O_3 electrodes showed pseudo capacitive behavior.