ABSTRACT

Textile and dyeing industries generate liquid waste containing various contaminants, particularly synthetic dyes, which pose significant threats to aquatic ecosystems and environmental quality. Malachite green, a triphenylmethane synthetic dye, is of particular concern due to its persistent, toxic, and potentially carcinogenic nature. Photoelectrocatalysis, a combined approach integrating electrolysis and photocatalysis, represents a promising method for organic compound wastewater treatment owing to its ability to generate highly reactive radical species with superior efficiency. The effectiveness of this method is critically dependent on the performance of the photoactive electrode material, necessitating the development of electrodes with enhanced photocatalytic activity and energy efficiency. Accordingly, this study aims to synthesize CuO-doped ZnO thin film anodes on graphite plate substrates via the sol–gel method employing a dip-coating technique, and to investigate the effect of CuO incorporation on the photoelectrocatalytic effectiveness of ZnO in decolorizing malachite green dye.

In this study, thin film anode electrodes were synthesized with varying CuO compositions, namely ZnO/Graphite and CuO–ZnO/Graphite (%CuO = 1, 3, 5). Photoelectrocatalytic activity was evaluated through the application of photoelectrocatalysis using the synthesized anodes and a graphite cathode in a 20 ppm malachite green solution. The reaction was conducted in a closed reactor equipped with a 15 W UV-C lamp and an applied external potential of 2 V, determined based on the inflection point of the measured current–voltage curve.

The study successfully produced ZnO/Graphite and CuO–ZnO/Graphite thin film anodes synthesized via the sol–gel method with the planned CuO content variations. Photoelectrocatalytic application demonstrated that CuO dopant addition significantly enhanced the decolorization percentage of malachite green dye. The electrode exhibiting the best photoelectrocatalytic performance was the 3% CuO–ZnO/Graphite variant, achieving an improvement in decolorization from 79.047% for ZnO/Graphite to 93.519% for 3% CuO–ZnO/Graphite. The optical band gap of CuO-doped ZnO decreased progressively with increasing doping percentage. The results confirm that CuO incorporation enhances the photoelectrocatalytic performance of ZnO in the dye decolorization process up to an optimal concentration threshold.

Keywords: *Malachite green, photoelectrocatalysis, ZnO, CuO doping, thin film electrode, sol-gel, decolorization*