Enhancement of Photocatalytic Activity of ZnO Nanoparticles via Non-Thermal Plasma

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Zinc oxide (ZnO) nanoparticles were synthesized via the sol-gel method using zinc nitrate and citric acid precursors. The dried gel was calcined at 500°C to produce crystalline ZnO nanoparticles. Despite its advantages such as chemical stability, non-toxicity, and strong UV absorption, the practical application of ZnO in photocatalysis is often limited by relatively wide bandgap and high recombination rate of photogenerated electron–hole pairs. These drawbacks significantly reduce its photocatalytic efficiency under UV or solar irradiation. To enhance their photocatalytic performance, the nanoparticles were treated with non-thermal plasma (NTP) for varying durations (2 and 6 minutes).

NTP is a partially ionized gas where energetic electrons exist at much higher temperatures (1–10 eV) than ions and neutral gas species, which remain near room temperature. It contains reactive components such as electrons, ions, radicals (e.g., •OH, •O), reactive oxygen species (ROS) and reactive nitrogen species (RNS), which can strongly interact with material surfaces without significant thermal damage. These properties make NTP highly effective for surface modification and photocatalytic enhancement [1,2]. The structural properties of the plasma-treated ZnO nanoparticles were investigated using X-ray diffraction (XRD). The analysis confirmed the presence of a hexagonal wurtzite crystal structure in all samples. NTP treatment resulted in sharper and more intense diffraction peaks, suggesting improved crystallinity and enhanced crystal quality. Optical properties were examined using UV–Visible spectroscopy. As shown in Figure1(a), NTP-treated ZnO nanoparticles exhibited enhanced absorption in the UV region (300–800 nm), indicating better light harvesting. Figure 1(b) presents the Tauc's plots, which showed a reduction in the optical bandgap from ~3.15 eV (pristine) to ~3.10 eV (plasma-treated), suggesting the formation of oxygen vacancies or surface states beneficial for photocatalysis[3].

Photocatalytic activity was evaluated via degradation of methylene blue (MB) dye under UV irradiation. Plasma-treated ZnO samples showed significantly improved degradation efficiency, with the 2-minute treated sample achieving the highest activity and faster reaction kinetics. These results demonstrate that non-thermal plasma treatment effectively enhances the photocatalytic behavior of ZnO nanostructures by modifying their surface and electronic properties.

References

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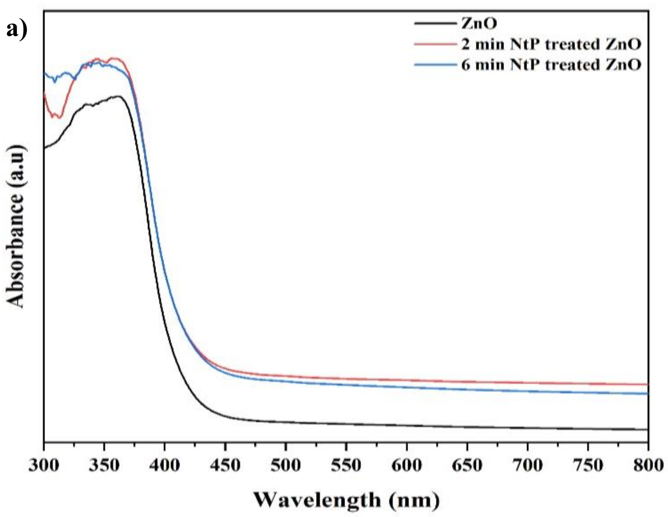

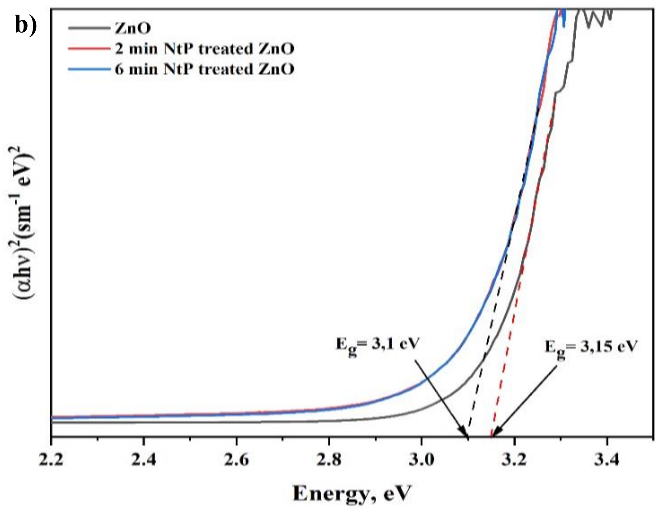

Figure1: (a) UV–Visible absorption spectra and (b) Tauc's plot of of pristine and Non thermal Plasma treated ZnO nanoparticles