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Life cycle assessment of facile microwave-assisted zinc oxide (ZnO) nanostructures

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ABSTRACT:

The life cycle assessment of several zinc oxide (ZnO) nanostructures, fabricated by a facile microwave technique, is presented. Key synthesis parameters such as annealing temperature, varied from 90 °C to 220 °C, and microwave power, varied from 110 W to 710 W, are assessed. The effect of these parameters on both the structural characteristics and the environmental sustainability of the nanostructures is examined. The nanostructures were characterized by means of X-ray diffraction (XRD), focused ion beam scanning electron microscopy (FIB-SEM), ultraviolet–visible spectroscopy (UV–Vis), Photoluminescence (PL) and Brunauer–Emmett–Teller (BET) analysis. Crystalline size was found to be 22.40 nm at 110 W microwave power, 24.83 nm at 310 W, and 24.01 nm at 710 W. Microwave power and synthesis temperature were both directly proportional to the surface area. At 110 W the surface area was 10.44 m^2/g, at 310 W 12.88 m^2/g, and at 710 W 14.60 m^2/g; while it was found to be 11.64 m^2/g at 150 °C and 18.09 m^2/g at 220 °C. Based on these, a life cycle analysis (LCA) of the produced ZnO nanoparticles was carried out, using the ZnO surface area (1 m^2/g) as the functional unit. It was found that the main environmental weaknesses identified during the production process were; (a) the use of ethanol for purifying the produced nanomaterials and (b) the electricity consumption for the ZnO calcination, provided by South Africa's fossil-fuel dependent electricity source. When the effect of the key synthesis parameters on environmental sustainability was examined it was found that an increase of either microwave power (from 110 to 710 W) or synthesis

temperatures (from 90 to 220 °C), results in higher sustainability, with the environmental footprint reduced by 27% and 41%, respectively. Through a sensitivity analysis, it was observed that an electricity mix based on renewable energy could improve the environmental sustainability of the nanoparticles by 25%.