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Optimization of hydrothermally grown ZnO nanorods on flexible fabric using finite element simulation and single precursor for wearable nanogenerator
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Abstract
The increasing demand for wearable technology has underscored the need for sustainable energy sources, leading to the development of wearable nanogenerators on flexible fabric. Piezoelectric nanogenerators based on ZnO nanorods provide a promising solution to power wearable devices through body movements. The hydrothermal method was chosen for the synthesis of ZnO nanorod due to its simplicity and effectiveness in achieving uniform ZnO nanorod growth on fabric substrates. However, most studies utilized double precursor solution for two steps hydrothermal process. Limited previous work studied on finite element analysis to predict the aspect ratio, and the output voltage generated for the optimization before proceeding to the fabrication. Hence, this study aims to optimize the hydrothermal growth of ZnO nanorods on a flexible conductive fabric substrate using hexamethylenetetramine (HMTA) as a single precursor. Finite element simulation was conducted for single nanorod and device level to investigate the effect of aspect ratio (the ratio of the length to the diameter) towards the output voltage. Finite element simulation result showed that, as the aspect ratio of a single nanorod increases, the output voltage increases accordingly. The simulation results showed the simulated output voltage generates 25 μV for 8000 nm nanorod length when 500nN input force is applied. Employing a single precursor solution in the synthesis of ZnO nanorods not only enhances the uniformity of the nanoparticles but also simplifies the overall synthesis process. The impact of growth duration on nanorod distribution was examined, revealing that Sample S3, grown for 2 h, demonstrated uniform distribution and an optimal aspect ratio of 16. X-ray diffraction confirmed the formation of the wurtzite structure with a peak at 34.57°, indicating preferred growth along the c-axis. The fabricated ZnO nanogenerator, evaluated under various finger-bending angles, produced an average output voltage of 41.96 mV at an 80° bend. The measured result is comparable to the finite elmeent analysis result where the measured output voltage generated 41.96 mV which is lower compared to simulated output voltage at the same aspect ratio. These findings highlight the potential of optimizing ZnO nanorod growth using finite element simulations and a single precursor to enhance the performance and efficiency of flexible wearable piezoelectric nanogenerators.

Index Keywords
Crystallites, Enameling, Hard facing, Hydrothermal synthesis, Layered manufacturing, Metal nanoparticles, Nanoclay, Nanorods, Zinc Selenide, ZnO nanoparticles; Aspect-ratio, Fabric substrate, Finite elements simulation, Nanogenerators, Nanorod growth, Optimisations, Output voltages, Piezoelectric nanogenerator, Single precursors, ZnO nanorod; Aspect ratio

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