Development of ZnO Nanoparticle-Based Voltage Sensor Using Copper Oxide Nanofluids via Large-Area Printing Technology

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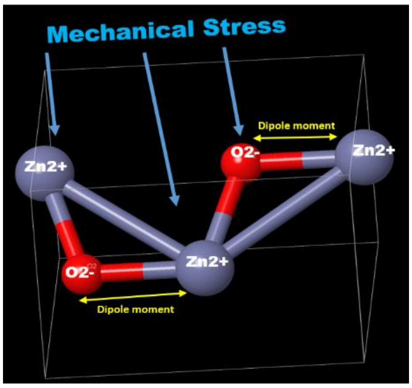

Unlike nanoparticles, bulk forms of zinc oxide lack the surface characteristics and interactions needed for optimal adhesion and synergistic effects. This is because bulk materials have larger particle sizes and less surface area, making it harder to form strong bonds with substrates. ZnO is a prime candidate for voltage sensors due to its unique properties, such as high piezoelectric coefficients, wide band gap, and excellent semiconducting characteristics. These properties make ZnO well-suited for voltage sensing applications, where precise and sensitive detection of electrical signals is essential. The calculated piezoelectric coefficient is 45.6 pm/V, based on a Debye-Scherrer radius of 14.15 nm. SEM analysis shows an average ZnO nanoparticle radius of 16 nm, resulting in a d33 value of 35.65 pm/V. The observed d33 value of 35.65 pm/V as per the morphological analysis of SEM suggests that the nanoparticles have a well-defined crystalline structure and are capable of efficiently converting mechanical energy into electrical energy, making them highly suitable for applications in piezoelectric sensors and devices. The Impedance Nyquist plot analysis yielded a slope of 0.4198, providing insight into the electrical characteristics of the ZnO nanoparticles. The adhesion tests reveal 7:6 ZnO: Ethylene glycol has uniform dispersion and accurate deposition; this ratio was utilized for preparing ZnO nanoparticle paste for large-area screen printing which resulted in closely packed ZnO nanoparticle deposition with a uniform conducting path suitable for a fluid flow induced voltage sensor. The proposed ZnO voltage sensor was successfully tested which gave 0.9 mV due to capillary action and unimpeded CuO nanofluid flow and 0.45 mV from pure capillary action of CuO nanofluid, the authors of this work are engaged in ongoing research on ZnO related voltage sensors and nanofluids.

The authors would like to highlight several key findings. SEM analysis shows agglomerated ZnO nanoparticles having a mean diameter of 32.2 nm resulting in a d33 value of 35.65 pm/V, which suggests well-defined crystalline structure and capability of converting mechanical energy into electrical energy which is beneficial for piezoelectric sensing. The slope of the impedance analysis is 0.4198. The best adhesion was achieved with a ZnO to ethylene glycol in the ratio of 7:6, reaching a 4A standard in the X-cut adhesion test. The uniform dispersion of ZnO in the print is extremely beneficial for the ZnO voltage sensor due to its high-density fill factor, when tested the sensor measured 0.9 mV due to capillary action and unimpeded CuO nanofluid flow and 0.45mV from pure capillary action of CuO nanofluid.