

Optical, Electrical, and Gas Sensing Properties of ZnO Dielectric Films on Black Silicon Substrates

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Abstract: This work reports a detailed study of the optical, electrical, and gas sensing properties of ZnO dielectric films deposited on black silicon (b-Si) substrates. The b-Si surface was fabricated using reactive ion etching (RIE), enabling the formation of dense, high-aspect-ratio nanostructures that provide strong light trapping and a significantly increased effective surface area. ZnO dielectric films were deposited onto the nanostructured b-Si substrates using the sol–gel method, ensuring good film uniformity and conformal coverage of the textured surface. Optical characterization revealed a pronounced reduction in surface reflectance and enhanced optical absorption over a broad spectral range compared to planar silicon, resulting from the combined effects of the b-Si nanostructure and the ZnO coating. Electrical measurements demonstrated stable dielectric behavior, low leakage currents, and well-defined capacitance–voltage characteristics, indicating high-quality ZnO films and a stable ZnO/b-Si interface. Gas sensing experiments showed a strong, reversible, and reproducible response to nitrogen dioxide (NO₂) at relatively low operating temperatures. The enhanced sensing performance is attributed to the high specific surface area of the RIE-fabricated b-Si, efficient adsorption of NO₂ molecules on the ZnO surface, and effective charge transfer across the ZnO/b-Si heterojunction. These results demonstrate the strong synergistic effect between sol–gel-derived ZnO dielectric films and nanostructured substrate, highlighting the potential of ZnO/b-Si structures for low-power NO₂ gas sensors as well as multifunctional optoelectronic and environmental monitoring applications.

Keywords: Black silicon, Dielectric films, ZnO, Heterojunction, Properties