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Ohmic-to-Schottky modification of ZnO-Metal contact modulated by film thickness

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The current study systematically explored the structure and charge transport characteristics at the junction between a Pt-Ir metal contact and transparent zinc oxide (ZnO) electrodes of varying film thicknesses. ZnO nanoparticles were synthesized through the coprecipitation method and dispersed in dichlorobenzene. Characterization of the nanoparticles involved X-ray diffraction, Raman spectroscopy, and UV-vis spectroscopy. The ZnO dispersions were spin-coated onto a conductive substrate to produce films comprising one, four, and eight layers. To investigate the films' nanoscale surface electrical properties and charge transport mechanisms, electrostatic force microscopy (EFM), Kelvin probe force microscopy (KPFM), and conducting atomic force microscopy (c-AFM) techniques were employed. The study examined the influence of grain boundaries (GBs) and thickness on films' electrical and optoelectronic properties. Variations in film thickness resulted in changes in the metal-semiconductor (M-S) contact type, transitioning from ohmic to rectifying with increasing layers. The modulation in the M-S contact type was primarily attributed to the presence of GBs during film formation. EFM measurements indicated charge trapping within the GB region, suggesting localized band-bending effects. KPFM measurements revealed slightly higher local work function values in the GB region across all samples, attributed to Fermi level shifts towards the conduction band induced by optically active states introduced by GBs. For single-layer films, semiconductor work functions exceeded those of the metal, suggesting the formation of ohmic contacts with no potential barrier to transport, as per Mott and Schottky theory. In contrast, four and eight-layer films exhibited lower work function values than the metal and thus typical rectifying behavior akin to Schottky diodes, governed by thermionic emission theory. The study underscored the influence of grain boundaries and film thickness on the optoelectronic and charge transport properties of conductive and transparent ZnO electrodes, emphasizing its significance in forming versatile M-S contacts crucial for diverse semiconductor applications.