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Work function and AC operating gas-sensitive films based on quaternary chalcogenides

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Abstract

A study of quaternary alloys of As–S–Ge–Te was performed in order to assess their use in future gas sensors operating at room temperature. To elucidate the effect of tellurium, the quaternary compositions $As_2Te_{13}Ge_8S_3$ and $As_2Te_{130}Ge_8S_3$, with increasing concentration of Te have been considered along with pure tellurium films. SEM, AFM, and X-ray analysis have shown that the nature of the films was predominantly amorphous. To overcome the sensing disadvantage of DC chalcogenide-based sensors due to small signal/noise ratio, gas-sensing measurements were performed using both potential difference (Kelvin probe) and AC methods. The work-function measurements showed that the amorphous chalcogenides in question are suitable materials for the detection of small concentrations of NO_2. The sensing mechanism of NO_2 is explained by "strong" chemisorptions via interaction of adsorbed species with lone-pair electrons, which form the upper part of the valence band of chalcogenide semiconductors. The chemisorption of NO_2 molecules results in increases in both work-function change $\Delta\Phi>0$ and electrical conductivity $\Delta\sigma>0$ because of the additional charging of the surface and band bending. The impedance spectra, being strongly influenced by gaseous environment, depend on material composition and film microstructure. The frequency-dependent impedance sensitivity to nitrogen dioxide denotes the competitive influence of carrier transport via states of allowed bands, hopping between localized states in the extended band tails and tunneling (variable-range hopping) between localized states close to the Fermi level. Impedance sensitivity, being maximal for amorphous $As_2Te_{13}Ge_8S_3$, is assumed to be controlled by competition of these charge-transport mechanisms.