ABSTRACT

Decreasing the dimensions of structures to nano-scale are known to open up a whole new realm of fascinating properties, primarily due to the enhanced surface area to volume ratio and changes in the density of states and bandgap.

The present study encompasses the optimisation of the synthesis and growth of group IV-alloy and core shell nanoparticles using the Integrated gas phase deposition setup involving the use of a Differential Mobility Analyser (DMA) for controlled size selection by electrical mobility manipulation. In-depth study of their structural, morphological and compositional properties using HRTEM, XRD and XPS and of their optical properties using PL, Raman and UV-Vis spectroscopy provide a deeper insight into the physics of defects and O-vacancies.

The versatility of this synthesis technique allowed us to play with the stoichiometries of tin (oxide), nanoparticles and analyse the different modes of incorporation of Carbon into these nanoaprticle lattices. The gas sensing properties of SnO$_2$, SnO$_2$:C alloy, SnO and C@ SnO core-shell nanoparticles towards two reducing gases : H$_2$ and ethanol, helped in exploring the selectivity of these two structures at lower operational temperatures. The study of their defects and optical properties provided a deeper insight into the gas sensing mechanism behind.

Group IV compounds are shown to have large calculated phonon gaps and small electronic band gap (Eg), as well as several other advantages, sufficient to block Klemen’s decay. The optimisation of the growth and synthesis of the SiSn nanoparticle system using the integrated gas phase deposition setup was carried out in this direction. SiSn stands out as one of the main candidates for a Hot Carrier Absorber (HCA) material and the DFT studies carried out, further probed the phonon spectra of this system providing a proof of principle study for its application towards HCSCs.

The optimisation and growth of Au and Au@silica nanoparticle system using the integrated
gas phase deposition setup was also studied. In-depth study of the structural and optical properties of these nanostructures helped in understanding the plasmonic properties of naive Au nanoparticles and the effect of forming multiple core-shell satellite structures with the most popular silica. Comparison of the experimentally observed spectra with the theoretically observed electric field distributions in the nano-composite core-shell structures using FDTD calculations provided a panoramic view and understanding. These Au decorated silica nanoparticles were further interacted with human genomic DNA to understand the shifts in LSPR post DNA interaction, thus exploring the bioanalytical technique for routine characterization of molecular recognition events at a solid interface using the UV-Vis spectroscopy. The study of I-V properties of these structures embedded in a SiO$_2$ matrix showed improved resistive switching that was ‘forming free’. The concept of stable bipolar switching explained by the filamentary and electromigration theory of vacancies and defects helped in suggesting the suitability of the candidature of the synthesised nano-composite thin film structures for application in memory devices like ReRAMs.