ABSTRACT

The growth and characterization of Gallium Antimonide (GaSb), a III-V compound semiconductor, has become a focal point of research in recent years because of the potential advantages of its use in high speed electronic devices as a substrate material, due to its narrow and direct band gap and its lattice parameter closely matching with the other binary compound semiconductors. This research work focuses on the growth and characterization of both bulk crystals and thin films of GaSb. Subsequently, based on this material, both bulk crystal and thin films have been used for the fabrication of different devices and their electrical characterization. The experimental results have been then compared and validated by TCAD software. SILVACO-TCAD, the state-of-the-art simulation software available for academic purposes has been used for this study. From the point of view of developing devices, this work shows the importance of the metal-semiconductor, semiconductor-semiconductor and metal-oxide-semiconductor interfaces. Thus, experimental and simulation work have been conducted accordingly and a correlation has been proposed between the experimental data and theoretical calculations.

Bulk GaSb crystals have been successfully grown by the Thermo Vertical Directional Solidification (TVDS) technique exclusively designed in our lab, without using a seed crystal, inside a vacuum-sealed conical-tip quartz ampoule which has been indigenously designed and fabricated in our laboratory. The structural characterizations was verified by anX-ray diffraction (XRD) study, which shows that the synthesized sample of bulk GaSb has face-centered cubic (zinc blende) structure with a lattice parameter of 6.092 Å. The surface morphology of the sliced bulk GaSb was studied by Scanning Electron Microscopy (SEM). Similarly, Raman spectroscopy shows peaks at about 221cm^{-1} and 238cm^{-1}and assigns the degree of crystallinity of the GaSb sample. GaSb thin film (with Ga and Sb in a 1:1 stoichiometric ratio) on a glass substrate was successfully deposited by the Thermal Evaporation method, taking bulk GaSb sample as a source material. From the structural, morphological and electrical properties studied of the bulk crystal and thin film of GaSb, it has been ascertained that the quality of the grown crystal is good enough to be used for device fabrication. Using the material synthesized, three devices were fabricated or simulated on the basis of the type of interface formed by different materials with GaSb—interfaces with conductors (Au/*n*-GaSb Schottky diode), interfaces between two different semiconductors (*n*-ZnO/*p*-GaSb heterojunction diode) and finally interfaces with insulators (Au/high-K/*n*-GaSb MOSCAP). First of all, the interface properties of an Au/*n*-GaSb Schottky diode were investigated both experimentally and using a simulation model. Interface properties like ideality factor and barrier heights were found to be 2.1 and 0.48eV for the fabricated Schottky contact, whereas for the simulated structure they were 1.4 and 0.56eV respectively. Both properties showed strong temperature dependence. The second interface investigated was of a heterostructure formed by taking *n*-type ZnO (wide band-gap) and *p*-type GaSb (narrow band-gap) on a glass substrate was fabricated. The Sol-gel method followed by the novel technique of Chemically Wet and Dry (CWD) process was used to coat a ZnO semiconductor film on the GaSb film. From the I-V characteristic of the heterostructure, the ideality factor and barrier height were computed and found to be 4.7 and 0.61eV respectively. Finally, due to the limitations of the infrastructure at our facility, the oxide-semiconductor interface could not be fabricated and was studied by simulation using the SILVACO TCAD software.

The novel part of this research was the fabrication and characterization of the *n*-ZnO/*p*-GaSb heterojunction diode. The study of structural and morphological properties of ZnO thin film over GaSb demonstrates that strain plays a vital role in altering the lattice constant of GaSb when trying to provide better sticking conditions at the ZnO-GaSb interface so that optical devices can be designed using *n*-ZnO/*p*-GaSb heterostructure. Thus an extensive study is needed in the direction of developing a better *n*-ZnO/*p*-GaSb heterojunction diode and experimentally fabricating a Metal-Oxide-Semiconductor Capacitor (MOSCAP) in context of IC applications.

Keywords: GaSb, Thermo Vertical Directional Solidification (TVDS), Thermal Evaporation, ZnO, Sol-Gel, Chemically Wet and Dry (CWD), Schottky diode, *n*-ZnO/*p*-GaSb heterojunction diode, MOSCAP, TCAD.