FABRICATION AND CHARACTERIZATION OF HIGH PERFORMANCE GALLIUM ANTIMONIDE PHOTODIODES

By

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ABSTRACT

The antimonide based III-V compound semiconductors such as GaSb, InSb, GaInSb, GaInAsSb, AlGaSb cover a wide spectral range from ~0.1 to 1.58 eV, i.e., 0.8 to 10 μm. Also, detection of longer wavelengths between 8 to 14 μm is possible with antimonide based superlattices. This makes the antimonide based alloys attractive for infrared detector applications. Since the early 1970's, there have been continuous research activities in the antimonide based materials and devices, though not as rigorous as the other III-V compounds such as GaAs, InP or GaN. One of the reasons why antimonide based devices have still not matured is the high leakage currents in the devices resulting from poor quality of native oxides. To make the technology commercially viable, problems due to the poor surface needs to be solved. The objective of this research is to develop suitable surface passivation techniques and protective capping layers for GaSb based photodiode structures that would result in lower reverse leakage currents and higher reverse breakdown in the devices.

As a part of this research, a new low temperature chemical bath deposition technique for wider bandgap II-VI compounds such as CdS and ZnS has been developed. The effectiveness of these wider bandgap layers as passivating and capping layers on GaSb based diodes has been evaluated. In particular, we have studied the current transport properties of GaSb based Schottky photodiodes with an interfacial layer of CdS. We have found that the current transport in these structures is governed by the barriers at the CdS/GaSb interface with an effective series resistance from the bulk of the interfacial CdS layer. Space charge limited current in the interfacial layer gives rise to an increase in the forward turn-on voltages. These structures demonstrate excellent characteristics in the reverse bias region such as high breakdown voltages, low surface leakage current and good reverse current saturation. Significantly, rectifying junctions on p-GaSb have been achieved with barrier height as high as ~0.6 eV and breakdown voltages of ~4.5 V. Schottky diodes on n-GaSb with breakdown voltages as high as ~11 V have been obtained. The effect of different annealing conditions on the diode properties has been studied. Vacuum annealing is found to increase the breakdown voltage and reduce the reverse leakage significantly.

A new Zn diffusion technique from a low temperature chemical bath deposited ZnS layer has been developed to obtain high breakdown voltages. Junctions formed by this technique have breakdown voltages of ~18.5 V, low reverse leakage current (0.01 - 0.03 A/cm^2 at -3 V), excellent reverse current saturation and ideality factor of ~1.3. The high breakdown voltages obtained are due to the co-doping of zinc and sulfur from the ZnS film. Sulfur forms shallow and deep levels that compensate the *p*-doping of due to zinc. The non-linear relation of 1/R$_0$A versus P/A in these diodes indicates surface leakage is still the dominant leakage mechanism. CdS has been used to passivate the mesa photodiodes. After passivation, the 1/R$_0$A product reduces from 0.3 $\Omega^{-1}cm^{-2}$ to 0.02 $\Omega^{-1}cm^{-2}$ for a 150 μm diameter device. The 1/R$_0$A product is also independent of the diode dimension confirming effective passivation. ZnS surface passivation on the mesa walls is not effective and is found to increase the leakage current.

Planar diodes using SiN$_x$ as the mask and Zn diffused from ZnS were fabricated and compared with Zn diffusion from the vapor phase. The leakage current was found to be of the same magnitude indicating that the high surface Zn concentration during vapor phase diffusion is not a source for leakage. Rather the surface degradation due to ion bombardment during SiN$_x$ deposition leads to surface leakage (as observed in prior research).

The role of CdS based interfacial layers during the fabrication of planar GaSb *p-n* junction photodetectors using zinc diffusion process was studied. To overcome the damage caused by the PECVD process, we have fabricated planar photodetectors by suitably passivating and capping the GaSb surface by a wide band gap CdS film before the deposition of SiN$_x$. However, CdS diffuses into the GaSb substrate when subjected to long durations at high temperatures. Therefore a suitable scheme that does not diffuse and acts as a passivation/masking layer is required to successfully realize high performance planar diodes in the future.