METALORGANIC VAPOR PHASE EPITAXIAL GROWTH OF (211)B CADMIUM TELLURIDE

by

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ABSTRACT

Mercury cadmium telluride ($Hg_{1-x}Cd_xTe$) is the material of choice for high performance infrared detectors used in night vision military applications. Epitaxial growth of $Hg_{1-x}Cd_xTe$ can be carried out on lattice-matched $Cd_{1-x}Zn_xTe$ substrates. But there are several advantages to using silicon substrates – larger size, less expensive, monolithic integration with the detector electronics. The 19% lattice mismatch between the Si substrate and the $Hg_{1-x}Cd_xTe$ film forms misfit dislocations at the strained interface, which give rise to threading dislocations (TDs). The TDs act as efficient recombination centers and reduce the minority carrier lifetime. CdTe buffer layers have been used in the hetero-epitaxy of $Hg_{1-x}Cd_xTe$ on Si, to reduce the TD density to approximately $10^6 cm^{-2}$. The TD density needs to be reduced by another order of magnitude for high performance IR detectors. (211)B is the preferred orientation for molecular beam epitaxy (MBE) of $Hg_{1-x}Cd_xTe$. Hence there is a requirement for high-quality (211)B CdTe buffer layers on Si. In this study, we have investigated the use of different techniques during the metal organic vapor phase epitaxy (MOVPE) of (211)B CdTe on Si substrates, in order to reduce the TD density.

The first part of this study used MBE grown (211)B CdTe/Si substrates. The goal here was to reduce the TD density in the CdTe film from the mid-$10^6 cm^{-2}$ range to the mid-$10^5 cm^{-2}$ range or lower. The various MOVPE process parameters were first optimized for homo-epitaxial growth of (211)B CdTe. Next, epitaxial lateral overgrowth (ELO) using a silicon nitride mask was carried out. A systematic study of the anisotropy during ELO was conducted, in order to maximize the efficiency of the ELO process. Conventional ELO consists of growth windows, which are a few microns wide. Nano-patterned ELO has been shown to offer several advantages in other material systems and was studied here for the first time for the CdTe/Si hetero-epitaxial substrates using MOVPE. The key challenges to the ELO process were the high growth temperatures required (leading to deterioration of the surface morphology) and the high vertical growth rates (compared with the lateral growth rates) for the (211)B orientation.

The challenges faced during the ELO process motivated us to investigate direct MOVPE growth of CdTe on (211) Si substrates. One of the key challenges during direct MOVPE growth on Si substrates is the pre-growth removal of surface oxide. This is

usually achieved using a high-temperature anneal step (≈ 900^{o}C), but the Si substrate has been observed to be susceptible to etching by residual Te from the reactor parts. This problem has been solved by first growing a Ge film on the Si substrate (using GeH_4 precursor). GeH_4 has been shown to be effective in etching Si oxides at lower temperatures and this eliminates the need for the high-temperature pre-growth anneal step. The Ge / Si films are exposed to an arsenic flux during cool-down to CdTe growth temperatures. The As exposure was found to be critical in obtaining the B face (211) CdTe films and also reduce the twinning in the grown CdTe films. Finally, an intermediate ZnTe layer (between Ge and CdTe) has been found to be very effective in improving the surface morphology of the grown CdTe films. Thick (5-8µm) (211)B CdTe layers were grown on the Si substrates using the Ge and ZnTe interfacial layers. Cyclic annealing was used to improve the crystal quality of grown CdTe films. This is the first demonstration of direct MOVPE growth of (211)B CdTe on (211) Si substrates without the requirement of a high-temperature pre-growth anneal step. The x-ray diffraction (XRD) (422) peak rocking curve full-width at half-maximum (FWHM) of 85 arc-secs for a 8µm thick film obtained in this study is the best reported for MOVPE CdTe on (211) Si substrates.