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Effects of Inductively Coupled Plasma Hydrogen on Long-Wavelength Infrared HgCdTe Photodiodes

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Bulk passivation of semiconductors with hydrogen continues to be investigated for its potential to improve device performance. In this work, hydrogen-only inductively coupled plasma (ICP) was used to incorporate hydrogen into long-wavelength infrared HgCdTe photodiodes grown by molecular-beam epitaxy. Fully fabricated devices exposed to ICP showed statistically significant increases in zero-bias impedance values, improved uniformity, and decreased dark currents. HgCdTe photodiodes on Si substrates passivated with amorphous ZnS exhibited reductions in shunt currents, whereas devices on CdZnTe substrates passivated with polycrystalline CdTe exhibited reduced surface leakage, suggesting that hydrogen passivates defects in bulk HgCdTe and in CdTe.

Key words: Mercury cadmium telluride (HgCdTe), molecular beam epitaxy (MBE), long-wavelength infrared (LWIR), inductively coupled plasma (ICP), hydrogen, passivation, silicon

INTRODUCTION

Interest in hydrogen passivation of bulk $Hg_{1-x}Cd_xTe$ has increased over the last decade due to the recognized potential of HgCdTe grown on CdTe/Si substrates to be fabricated into large-format detector arrays and the need to mitigate the effects of threading dislocations inherent to this material system. Lattice and thermal mismatches arising from the use of Si substrates limit detector applications[1] since they give rise to states in the bandgap that create diode leakage currents[2] and act as Shockley–Read–Hall recombination centers.[3] Attachment of hydrogen to the dangling bond results in bonding and antibonding states whose separation exceeds the narrow bandgap of long-wavelength infrared (LWIR) HgCdTe. The bonding states are in the valence band and no longer electrically active, while the unoccupied antibonding states are in the conduction band and are also electrically inactive.[4]

Early research employed electrochemical methods to introduce hydrogen into $Hg_{0.5}Cd_{0.5}Te$.[5,6] Mercury-vacancy-doped HgCdTe was investigated by Jung et al.,[7] who reached the conclusion that electron cyclotron resonance (ECR) plasma hydrogenation is effective in passivating surface trap states, whereas Kim et al.[8] concluded that hydrogen's only role is to passivate mercury vacancies. Some studies have found that hydrogenation improves the quality of HgCdTe/passivant interfaces.[9] While dislocations are thought to decrease the minority-carrier lifetimes[10,11] and carrier mobilities[12] of HgCdTe, it is interesting to note the report[13] of HgCdTe/CdTe/Si layers with lifetimes comparable to those grown on CdZnTe, even though their dislocation densities are greater. Carmody et al. [13] conjecture that this may be a consequence of not all dislocations being active as recombination centers. The reproducibility of these results and the lifetime uniformity over the wafer areas are not clear. Note that Carmody et al. observe a drop in

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