Materials Science and Engineering Doctoral Defense

Study of CdTe/MgxCd1-xTe Double Heterostructures and Its Application in High Efficiency Solar Cells and in Luminescence Refrigeration

School for Engineering of Matter, Transport and Energy

Xinhao Zhao

Advisor: Yong-Hang Zhang

abstract

CdTe/MgxCd1-xTe double heterostructures (DHs) have been grown on lattice-matched InSb (001) substrates using Molecular Beam Epitaxy. The MgxCd1-xTe layers, which have a wider bandgap and type-I band edge alignment with CdTe, provide sufficient carrier confinement to CdTe, so that the optical properties of CdTe can be studied. The DH samples show very strong Photoluminescence (PL) intensity, long carrier lifetimes (up to 3.6 μs) and low effective interface recombination velocity at the CdTe/MgxCd1-xTe heterointerface (~1 cm/s), indicating the high material quality. Indium has been attempted as an n-type dopant in CdTe and it is found that the carriers are 100% ionized in the doping range of 1×1016 cm-3 to 1×1018 cm-3, and that the PL intensity is strongest at 1×1017 cm-3 doping concentration. With decent doping levels, long minority carrier lifetime, and almost perfect surface passivation by the MgxCd1-xTe layer, the CdTe/MgxCd1-xTe DHs are applied to high efficiency CdTe solar cells. Monocrystalline CdTe solar cells with efficiency of 17.0% and a record breaking open circuit voltage of 1.096 V have been demonstrated in our group.

With such a great material quality, luminescence refrigeration can be potentially realized in CdTe/MgxCd1-xTe DHs. Both external luminescence quantum efficiency and excitation-dependent PL measurement show that the best quality samples are almost 100% dominated by radiative recombination, and calculation shows that the internal quantum efficiency can be as high as 99.7% at the optimal injection level (1017 cm-3). External luminescence quantum efficiency of over 98% can be realized with the proper design of optical structures.

Mg0.13Cd0.87Te (1.7 eV), also with high material quality, has been proposed as a current matching cell to Si (1.1 eV) solar cells, which could potentially enable a tandem solar cell with high efficiency and thus lower the electricity cost. The properties of Mg0.13Cd0.87Te/Mg0.5Cd0.5Te DHs and solar cells have been investigated. It is found that carrier lifetime is as long as 0.56 μs and the external luminescence quantum efficiency is as high as 1.2% under one sun illumination. A solar cell with 11.2% efficiency and open circuit voltage of 1.176 V is demonstrated

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