Superlattice structures, properties, and application to quantum-well lasers in PbSnTeSe and PbEuTeSe systems

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$PbTe_{1-y}Se_y$-$Pb_{1-x}Sn_xTe$ superlattices (SLs) and PbTeEuTe short-period superlattices (SPSs) were prepared by hot wall epitaxy (HWE), and their structures and properties were investigated. Multiple quantum-well (MQW) lasers were also prepared using these SLs, and high temperature laser operations were observed. First, x-ray diffractions were measured for the $PbTe_{1-y}Se_y$-$Pb_{1-x}Sn_xTe$ SLs, and satellites in the x-ray diffraction patterns were analyzed. It was found that interdiffusion of Pb and Sn was very large even when the substrate temperature was very low (250°C), and that the diffusion decreases by shielding the substrate from the radiation of wall heater. Next, cyclotron resonance and optical properties of PbTe-$Pb_{0.78}Sn_{0.22}Te$ SLs, and Hall properties of PbTe-SnTe SLs were measured to determine the band offsets of the SLs.

It was found that the PbTe-$Pb_{0.78}Sn_{0.22}Te$ SL has a type-I′ structure where conduction-band edge of the $Pb_{0.78}Sn_{0.22}Te$ is about 60meV higher than of PbTe, and that the PbTe-SnTe superlattice has a type-II structure where valence band edge of the SnTe is higher than the conduction-band edge of PbTe. Even though $PbTe_{0.96}Se_{0.04}$-$Pb_{0.89}Sn_{0.11}$ Te SL has a type-I′ structure, $PbTe_{0.96}Se_{0.04}$-$Pb_{0.89}Sn_{0.11}$ Te MQW lasers were successfully prepared. The laser operated up to high temperature (204K), and showed anomalous properties in the output photon energy and threshold current at low temperature. These properties are explained in terms of the band bending due to acceptor doping in the Pb $Te_{0.96}Se_{0.04}$ layers. PbTe-EuTe SPSs were also prepared by HWE, and energy gaps were analyzed through optical transmission mesurement. Further, PbEuTeSe MQW lasers were prepared using the SPSs, and pulsed laser operation was observed up to 175 K.