The band gap of lead-europium-telluride (Pb_{1-x} Eu_x Te) was determined from room temperature optical absorption measurements and increases as dE_g/dx = 3.5 eV for x < 0.044. Eu atoms bond strongly to a PbTe surface during MBE growth and have a small diffusion coefficient (<1 x 10^{-16} cm^2/sec at 370°C). The lattice constant of Pb_{1-x} Eu_x Te is a nonlinear function of composition, and lattice-matched growth of Pb_{1-x} Eu_x Se_{1-y} Te on PbTe is demonstrated. Preliminary studies of the electrical properties of Pb_{1-x} Eu_x Te indicate compensation of n-type (Bi) and p-type (Te) dopants. These results indicate that Pb_{1-x} Eu_x Se_{1-y} Te may be useful for obtaining diode lasers which emit at wavelengths shorter than those available from Pb_{1-x} Sn_x Te.

Key words: lead-salt, diffusion, lattice-matched, compensation, quaternary.

Introduction

The usefulness of lead-salt diode lasers and detectors would be enhanced if their wavelength coverage could be extended and their operating temperature increased. In the telluride system, Pb_{1-x} Sn_x Te is useful for long wavelength
Cadmium, germanium, and manganese are potentially useful for shorter wavelength devices since they increase the band gap of PbTe. We have recently reviewed some of the problems associated with the use of these alloys, and shown that ytterbium (Yb) increases the band gap of PbTe \(1\). However, Yb acts as a donor under certain conditions, making it difficult to use it to make shorter wavelength lasers. Europium (Eu) is also potentially useful for increasing the band gap of PbTe, since EuTe has the face centered cubic crystal structure and a band gap (actually 4f level-conduction band edge separation) of 2.0 eV \(2\). The lattice constant of EuTe is 6.585 Å \(3\), whereas that of PbTe is 6.460 Å. All previous studies of Pb\(_{1-x}\)Eu\(_x\)Te assumed that the lattice constant was a linear function of \(x\) and used lattice constant measurements to determine the composition \(4-6\). We have now shown that this assumption is not correct, and have studied some of the properties of Pb\(_{1-x}\)Eu\(_x\)Te which are of interest for diode laser applications.

**Experimental Techniques**

The films for this study were grown in a molecular beam epitaxy (MBE) system \(7\) which had a base vacuum of \(10^{-10}\) Pa \(10^{-6}\) Torr) and which maintained a vacuum of \(10^{-7}\) Pa during deposition. The samples could be transferred to an analysis chamber immediately after growth for Auger analysis without exposure to air. A load lock mechanism permitted sample introduction without breaking vacuum in the growth chamber. Other aspects of the system have been described previously \(8,9\).

The Eu used for this study \(10\) was 99.99% pure excluding nonmetallic impurities. The major nonmetallic impurities (in ppm) were H \(1500\), O \(470\), C \(110\), Cl \(30\), and N \(22\). Of these, all except hydrogen form stable compounds with Eu which do not evaporate at the temperature of the Eu source oven \(180-240°C\). The hydrogen is believed to outgas from the Eu source material the first time it is heated in vacuum. The metallic impurities with vapor pressures similar to Eu were Ca \(28\) ppm, Sr \(5\), Mg \(4\), Li \(3\), and Tm \(2\). PbTe, PbSe, Te, Bi\(_2\)Te\(_3\) (n-dopant), Tl\(_2\)Te (p-dopant), and Eu were used as source materials for MBE growth. The films were grown on fresh \(111\) cleavage faces of epitaxial grade BaF\(_2\) \(11\), which are often used for PbTe.