MBE Growth and Characterization of IV-VI Diluted Magnetic Semiconductors

A. Y. Ueta, E. Abramof, P. H. O. Rappl, P. Motisuke, C. Boschetti, H. Closs and I. N. Bandeira

Instituto Nacional de Pesquisas Espaciais – INPE. Laboratório Associado de Sensores e Materiais – LAS – CEP, 12201-970 – São José dos Campos

S. O. Ferreira

Depto. de Física, Universidade Federal de Viçosa, Viçosa - MG

Molecular beam epitaxy (MBE) of narrow gap IV-VI semiconductors, also known as lead salt compounds, has long been used for the fabrication of mid-infrared optoelectronic devices. The incorporation of a rare-earth element in such crystals is very useful to increase their energy gap. In particular, Eu is potentially useful in the case of PbTe, since EuTe has a band gap of 2.0 eV and the lattice mismatch between them is only 2.1%. Furthermore, both molecules crystallize in the same rock salt structure. The progress in the MBE growth of lead salt compounds and their pseudo-binary alloys not only has made possible the fabrication of mid-infrared devices, but also yields bulklike and quantum-well samples in which some basic phenomena can be studied. In particular, the diluted magnetic semiconductor $Pb_{1-x}Eu_xTe$ is of interest because of the exchange interaction between free carriers and the localized magnetic moments of the paramagnetic Eu^{2+} ions.

MBE growth and characterization of epitaxial layers of IV-VI compounds and their diluted magnetic semiconductors on BaF2 (111) substrates will be presented here. A series of PbEuTe/PbTe multi-quantum wells (MQW's) was also investigated and the main results of structural and optical measurements will be reported. The $Pb_{1-x}Eu_xTe$ barrier width was kept at approximately 500 Å with the Eu content at x~0.05-0.06 and the PbTe well width was varied from 23 to 206 Å. Detailed structural characterization was made by high-resolution x-ray diffraction using the triple axis configuration and optical transitions in PbEuTe/PbTe MQW's were systematically investigated as a function of well width and temperature. The MQW period, the thickness of individual barrier and well layers, and the buffer lattice constants were determined by measuring the $\Omega\backslash 2\theta$ scans of the (222) Bragg diffraction peak. The well-resolved satellite peak structure observed for all MQW samples indicated that very good thickness control and sharp interfaces were obtained. Reciprocal space maps were measured around the asymmetrical (224) lattice point and indicated that the MQW structure tended to the free-standing equilibrium condition. A broadening in Ω direction was observed for all samples, indicating that some relaxation took place along the 50 periods of MQW structure. The (222) $\Omega\backslash 2\theta$ spectra were calculated by dynamical theory of x-ray diffraction and compared to the measured ones, using the in-plane lattice constant as the main fitting parameter. The strain in the MQW structure was then determined for samples with different PbTe well widths. The strain in the PbTe well inside the MQW structure decreased monotonically from an almost fully strained layer to a 26% of strain relaxation as the PbTe well width increased from 23 to 206 Å. The strain value obtained with this procedure is averaged over the 50 periods that compose the MQW structure. The transmission spectra of the MQW samples were measured using a Fourier transform infrared spectrometer in the range from 800 to 4500 cm^{-1} at temperatures between 5 and 300K. The optical transitions were obtained by fitting the measured spectra using a transfer matrix method.