Strain Stability of IV - VI Compound Semiconductor

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$Pb_{1-x}Eu_xTe$ alloys are important for the fabrication of devices involving PbTe/EuTe superlattice and PbTe/$Pb_{1-x}Eu_xSe_yTe_{1-y}$ heterostructure. [1] However, spinodal decomposition was observed on $Pb_{1-x}Eu_xTe$ ($0.41 < x < 0.51$) films grown on BaF_2 substrate at 573 K. [2] The directions of decomposition are <111> and <1-10>, where the elastic energy is relative minimum. In this work, we have shown that the $Pb_{1-x}Eu_xTe$ films grown on BaF_2 substrate with PbTe buffer layer are stable, and the stability of $Pb_{1-x}Eu_xTe$ film is explained in terms of elastic starin energy between $Pb_{1-x}Eu_xTe$ film and PbTe buffer layer. The critical temperature is calculated and TEM data are presented.

$Pb_{1-x}Eu_xTe$ film was grown on BaF_2 substrate with PbTe buffer layer at 573 K using MBE. TEM samples were prepared by mechanical grinding subsequent ion milling using argon gas at liquid nitrogen temperature. During the first stage of ion milling, the energy of the ions was 3 keV with a glancing angle of 15 degrees and during the later stage of the process, even lower energy, 2.5 keV with approximately 12 degree of glancing angle was used to minimized the damage induced by ion milling and to obtain wider thin area.

In the case of $Pb_{1-x}Eu_xTe$ film, the strain energy due to the compositional fluctuation in the $Pb_{1-x}Eu_xTe$ film is too small to stabilize the solution. [3] Furthermore, the interface between $Pb_{1-x}Eu_xTe$ film and BaF_2 is incoherent (semicoherent), the free energy due to the strain between the $Pb_{1-x}Eu_xTe$ and BaF_2 substrate is negligible. Therefore,

there is no appreciable coherent strain to stabilize the $Pb_{1-x}Eu_xTe$ films grown on BaF_2 substrate. However, when a $Pb_{1-x}Eu_xTe$ film is grown on PbTe buffer layer, the lattice mismatch of ~ 1.3 % between the $Pb_{1-x}Eu_xTe$ film and the buffer layer is accommodated by strain. Thus, for the $Pb_{1-x}Eu_xTe$ system, the coherent strain between the film and buffer layer is expected to lower the decomposition temperature and stabilize the solid solution. We have calculated the strain energy energy between the $Pb_{1-x}Eu_xTe$ film and PbTe buffer layer using two methods. One method was previously reported by Flynn [4] and the other one by Nahory. [5] The critical temperatures calculated by both methods are lower than both the growth temperature and room temperature. We have grown the $Pb_{1-x}Eu_xTe$ alloy on BaF2 substrate with a PbTe buffer layer at 573 K and observed using TEM. There was no evidence for spinodal decomposition in lattice image and diffraction pattern. Therefore, the $Pb_{1-x}Eu_xTe$ alloy becomes stable when a PbTe buffer layer is grown prior to the growth of the $Pb_{1-x}Eu_xTe$ layer.

References

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