Vapor Growth of Alloy-Type Semiconductor Crystals

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The advantages of vapor phase techniques are very useful for the growth of high-quality $Hg_{1-x}Cd_xTe$ bulk crystals and epitaxial layers. Because of the greatly different vapor pressures of the constituents of $Hg_{1-x}Cd_xTe$, the chemical vapor transport method is employed, allowing the use of a single source material of predetermined composition in a closed container. This technique is particularly suitable for crystal growth under space flight conditions.

Extensive ground-based studies of the bulk growth and heteroepitaxy of $Hg_{1-x}Cd_xTe$ on CdTe by CVT revealed the sensitivity of this complex, ternary, alloy-type growth system to possibly even minute convective effects under vertical, stabilizing conditions. They also demonstrated the inherent transient properties of this heterojunction system. The influences of the initial compositional and structural microhomogeneity on the electrical properties of layers are observed. These observations strongly suggested measurable effects of microgravity on vapor phase crystal growth of this material. The growth of $Hg_{1-x}Cd_xTe$ epitaxial layers by chemical vapor transport on (100) CdTe during the First United States Microgravity Laboratory (USML-1) (6.4 and 8.1 hr growth) mission showed significant improvements in the crystallinity of the substrate/layer interface, of the epitaxial layer and of the surface morphology relative to ground samples. These observations indicated the effects of residual convective flow at or near the interface on crystal growth on ground. The morphological improvements of the space-grown layers are reflected in the considerably increased carrier mobilities.

In order to further elucidate the effects of fluid flow on deposition and layer growth during the transient period of this system, the Second United States Microgravity Laboratory (USML-2) mission experiments were performed for shorter growth periods (1.5 and 2.5 hr growth). This required further ground-based experiments concerning the necessary temperature-time-line conditions. The emphasis in these studies was on the observation of microgravity effects on layer growth under transient, non-steady-state conditions. The objectives included the observation of the coalescence of three-dimensional islands to two-dimensional layers, measurements of the compositional and structural uniformity, and of the electrical properties of the islands and layers grown in microgravity. The USML-1 and USML-2 experiments and ground-based studies represent the first investigations of transient crystal growth properties under normal and reduced gravity conditions.

The comparative analysis of the ground and USML-2 results showed significant differences. The as-grown surface morphology of the islands and epitaxial layer obtained in microgravity is considerably flatter relative to ground specimens. The compositional microuniformity (IR mapping) and the single crystallinity (etching, X-ray diffraction rocking curves) of the islands and epitaxial layer grown in space are measurably enhanced. These improvements yield carrier mobilities of the materials deposited under microgravity conditions which are greater by a factor of two than those of ground specimens. The significantly improved crystallinity of the space-grown substrate/layer interface relative to that of ground samples shows that any annealing effects during longer growth times (USML-1 experiments) are small.

The combined observations of the USML-1 and USML-2 experiments demonstrate the effects of even small convective flows on the growth processes of this multi-component, multi-reaction, low pressure, solid-vapor transport system. The morphological investigations of the substrate-layer interfaces (heterojunctions) strongly suggest that the formation and propagation of defects is influenced by gravity-related processes during the very initial period of deposition. The combined results show the effects of microgravity on the chemical and structural homogeneity during the transient period. These findings are of general importance for heteroepitaxial growth, independent of the particular growth method employed.