Defect Generation in CVT Grown $Hg_{1-x}Cd_xTe$ Epitaxial Layers Under Normal and Reduced Gravity Conditions

H. Wiedemeier and Y.R. Ge
Department of Chemistry
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

In order to optimize the infrared detector properties of the alloy-type semiconductor $Hg_{1-x}Cd_xTe$ in electronic devices, a high degree of compositional and structural microhomogeneity of the single crystals of this material is required. Therefore, a better understanding of the crystal growth properties and ultimate control of the defect formation are of basic scientific importance and of technological significance.

Earlier ground-based studies of the epitaxial growth of $Hg_{1-x}Cd_xTe$ on (100) CdTe substrates by chemical vapor transport demonstrated the effects of gravity-driven convection on the growth morphology and crystallinity of this material. These observations suggested that epitaxial layers of improved microhomogeneity could be grown under reduced gravity conditions.

The combined results of our First United States Microgravity Laboratory (USML-1) and Second United States Microgravity Laboratory (USML-2) experiments confirmed the above expectations and yielded $Hg_{1-x}Cd_xTe$ epitaxial layers on CdTe of significantly improved compositional and structural microhomogeneity and electrical properties relative to ground test samples. They also confirmed the considerably lower dislocation density of the $Hg_{1-x}Cd_xTe$/CdTe layer/substrate interfaces of the layers and islands. The time dependence of the morphological evolution of the growing layer and the coalescence of islands to layer reveal the inherent transient growth properties of this heterojunction system under normal and reduced gravity conditions. The combined observations show the influence of gravity-related phenomena on fluid flow at or near the growth interface.

The present investigation is concerned with the further elucidation of fluid flow interactions with deposition and growth processes. It is generally known that the compositional and structural uniformity of single crystalline layers are affected by the crystallographic orientation (off-orientation) and surface quality of the substrates, by the growth rate and temperature, and by annealing. The combined influences of these parameters on crystal growth and quality are most likely interrelated, yielding a rather complex mechanism of defect formation. The decoupling of the various origins of defect formation and their control represent major challenges in the field of crystal growth.

As a step towards these goals, new research under this project is concerned with the investigation of substrate orientation (misorientation) effects on epitaxial growth of $Hg_{1-x}Cd_xTe$ layers on CdTe. Emphasis in these studies is on the morphological evolution of the growing layers during the transient growth period of this heterojunction system. In order to correlate the results of the present investigations with those of previous epitaxial growth of $Hg_{1-x}Cd_xTe$ on (100) CdTe on ground and in microgravity, the same temperature profile, source material composition, and transport agent pressure are used.

Therefore, the effects of substrate misorientation on $Hg_{1-x}Cd_xTe$ epitaxial film growth by chemical vapor transport are being studied, for the first time, using a transient growth technique. For this purpose, (100) CdTe substrates with a misorientation of 3° towards [011] and growth periods of different duration are employed. The morphological evolution of the $Hg_{1-x}Cd_xTe$ films deposited on the vicinal CdTe substrates shows a transition from three-dimensional islands to two-

dimensional layer growth. This trend is similar to that observed for films deposited on (100) CdTe substrates. However, there are distinct differences in the details of the surface morphology between the epitaxial growth on the vicinal and on (100) CdTe substrates. These differences include the edge morphology of individual islands, and, in particular, the formation of a long-range terrace structure of the films grown on the vicinal CdTe substrates. The formation of the terraces is related to corresponding morphological developments at the layer/substrate interface as reflected by the {011} cross-sections of this system. The pronounced terrace morphology is a direct result of the substrate misorientation, and approaches the planar surface structure of the films grown on regular (100) CdTe substrates after an extended growth time and layer thickness. In addition to the above, small differences of the surface composition and of the growth rate relative to those observed for the growth on regular (100) substrates reveal the influences of the 3° misorientation of the (100) CdTe substrates on the heteroepitaxial growth of $Hg_{1-x}Cd_xTe$. The combined results show that the interface kinetics are not fixed in the transient regime and that they are coupled to the vapor mass transport processes.

In order to further elucidate the effects of vicinal (100) CdTe faces on epitaxial growth and defect formation, investigations are in progress employing CdTe substrates with smaller misorientations than 3° from the (100) crystallographic orientation. The objectives of these studies are to correlate the morphological observations with the step density on the substrate surface, which, in turn, can be related to the degree of misorientation.

As part of the systematic investigation of the effects of substrate orientation on epitaxial growth, the transient properties of $Hg_{1-x}Cd_xTe$ film growth on (111)B CdTe substrates are being studied under vertical stabilizing and destabilizing orientations of the density gradient with respect to the gravity vector. Although the (111)B CdTe face is crystallographically quite different from the (100) and vicinal (100) faces, results to date indicate similar transient behavior of the epitaxial growth on these faces. Present data reveal measurable effects of small convective flow disturbances on the growth morphology and defect formation of this heterojunction system.

The combined results of this investigation will provide quantitative experimental data useful for the decoupling of the interactions of gravity-driven convection with surface related phenomena.