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Characterization of Misfit Dislocations at Heterovalent II-VI/III-V Interfaces

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Semiconductor superlattices and heterostructures have provided major breakthroughs in the optoelectronics industry, including the development of devices such as light-emitting diodes, quantum-well infrared photodetectors, and quantum cascade lasers [1]. Heterostructures introduce changes in material properties, such as abrupt changes in band-gap energy, which may be exploited for optoelectronic devices. However, they also introduce the possibility of strain becoming built-in to the device structure due to lattice mismatch between the constituent layers. Heterovalent structures exist for which the lattices of both layers are closely matched, thereby reducing misfit dislocation density and built-in strain, but at the cost of introducing valence mismatch. Previous investigations have analyzed the structural properties of II-VI materials grown on III-V substrates, including misfit dislocation densities and residual strain [2]. This current work focuses on characterizing the atomic-scale structure of misfit dislocation cores in heterovalent II-VI/III-V systems. This study was made on 2.4-μm-thick ZnTe epilayers grown on either GaAs or InP substrates using molecular beam epitaxy. A Nova 200 NanoLab dual-beam system was used to prepare TEM cross-section samples using an initial ion-beam energy of 30 keV, and amorphized material was removed from the front and back surfaces at 5 keV. Finally, a Gatan PIPS2 operated at 100 eV was used to polish away the remaining amorphized surface layers. A Philips CM200-FEG high-resolution TEM, operated at 200 keV, was used for initial imaging, and atomic-resolution images were taken with a probe-corrected JEOL ARM200F STEM at 200 keV.

Figure 1 (a) is a large-angle bright-field (LABF) STEM image of a representative Lomer dislocation at a ZnTe/GaAs interface, and Fig. 1 (b) is the corresponding high-angle annular-dark-field (HAADF) STEM image. Individual atomic columns are not well resolved at the interface, but it is still possible to identify the approximate location of Ga-As and Zn-Te atomic columns. A Burgers circuit is drawn around the dislocation in both images, with the resulting Burgers vector indicated by the arrows. The inset in Fig. 1 (a) is an enlargement of the defect area, with the approximate locations of atomic columns marked by yellow dots for GaAs and red dots for ZnTe. Comparison with the inset in Fig. 1 (b), where the ZnTe pairs are marked by dark blue dots, shows strong agreement. The 5- and 7-member rings common to Lomer dislocations are marked in both insets by white lines [3]. Most of the interfacial defects investigated matched the structure found in Fig. 1, but alternative defect structures were also observed. Figure 2 shows another Lomer dislocation located at the same interface and represented in the same way as shown in Fig 1, but with a different atomic structure. Further observations are still required to confirm that these structural defects are intrinsic to the interface, and not due to sample preparation or electron-beam irradiation effects [4].

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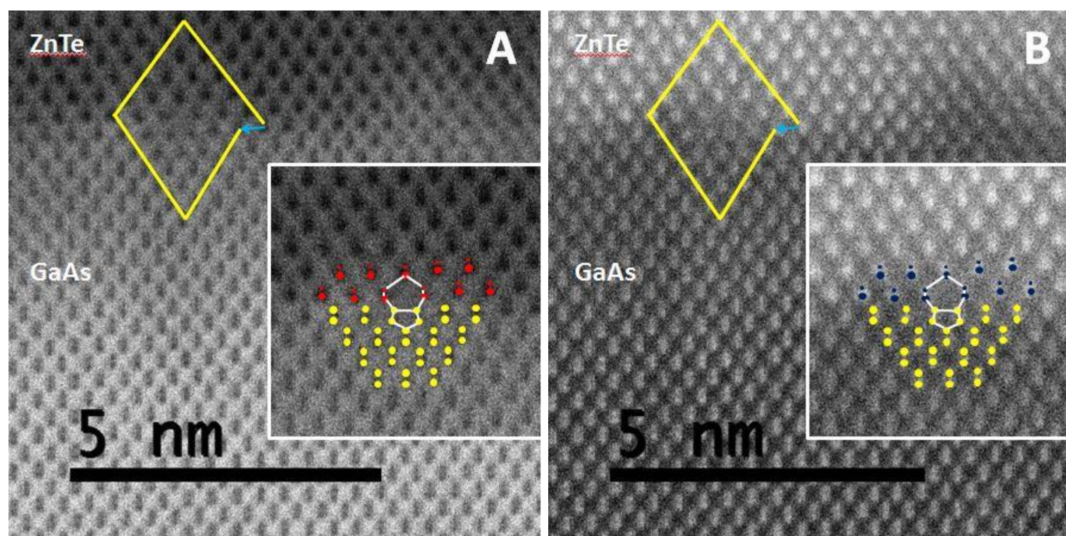

Figure 1. STEM images of individual Lomer dislocation at ZnTe-GaAs interface: (a) LABF image, and (b) HAADF image with Burgers Circuit shown in yellow, and projected Burgers vector shown in light blue. Insets show the region of the dislocation core, and the approximate locations of atomic columns are shown with colored dots. In both (a) and (b), Ga-As pairs are represented by yellow dots. Zn-Te pairs are represented by red dots in (a) and by dark blue dots in (b). The 5- and 7-member rings associated with a Lomer dislocation are shown with white lines.

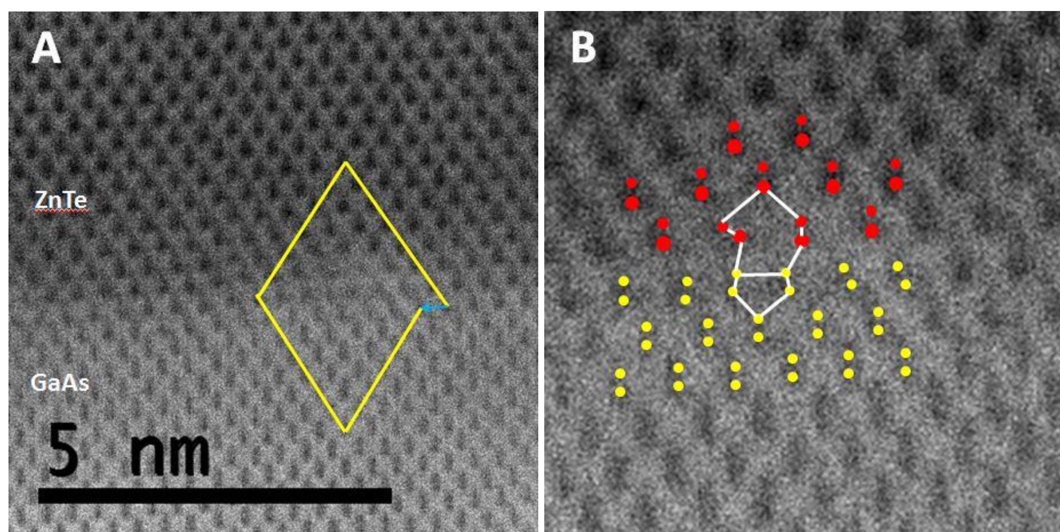

Figure 2. (a) LABF STEM image of individual Lomer dislocation at ZnTe-GaAs interface. Burgers Circuit shown in yellow and projected Burgers vector shown in light blue. (b) Enlarged view of the dislocation core region shows the approximate locations of atomic columns with colored dots. Ga and As are not distinguished and are represented by yellow dots. Zn and Te are also not distinguished from each other, and are represented by red dots. The 5- and 7-member rings associated with a Lomer dislocation are shown with white lines.

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