Structural characterizations of defects and interfaces in the semiconductors using high voltage electron microscopy

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Recently, the increasing miniaturization and large scale integration of devices lead the strong demand to establish the knowledge on the defect properties of both electronic and structural in a nanoscopic scale. At this moment, it is generally recognized that one of the key challenges is the lack of understanding of relationship between structural defects and electrical and optical properties of nanostructured semiconductors. Detailed understanding on structure of the defects and interfaces is thus of great importance, in order to have an understanding of crystal growth and the properties of crystal. In this talk, I shall demonstrate how various TEM techniques (high voltage electron microscopy(HVEM), image simulation, image processing, and quantitative analysis) for analysis be used to gain quantitative information of structural defects and interface in the nanostructured materials. Case studies will be presented in detail :

(1) New sources of stacking faults in bulk and thin film semiconductors
Atom positions and local structure around the central stacking fault of a Z-shape faulted dipole within deformed GaAs have been evaluated numerically through HVEM analysis. The stacking fault is found to generate large local displacements and exhibit a different structure from that of the well known intrinsic stacking fault of a dissociated dislocation considered so far. Secondly, by studying heteroepitaxial thin films, a new source of stacking fault due to tilting has been also observed in ZnO/LiTaO3 films. In this discovery, HVEM studies give us that the observed intrinsic stacking faults dominantly in an epitaxial film can be formed as a result of tilting of the lattices between films and substrate required to maintain a particular orientation relationship.

(2) Structural analysis of nano-interfacial layers and microstructural evidence on electrical properties in Ti/Ta/Al and Ta/Ti/Al ohmic contacts to AlGaN/GaN/sapphire
HVEM, optical diffractograms, and image computations confirmed that TiN(~10.0 nm) and

Ti_3AlN(~1.4 nm) interfacial layers form at the interface between the Ti layer and the $Al_{0.35}Ga_{0.65}N$ substrate by a solid state reaction. A model of the atomic configurations of the $Ti_3AlN/Al_{0.35}Ga_{0.65}N$ interface is proposed. The contact resistivity was also found to depend on the thickness of the AlGaN layer, interfacial phase, and interface roughness. The formation of interfacial phases by solid-state reactions with the metal layer appears to be essential for ohmic behavior on *n*-III-nitrides suggesting a tunneling contact mechanism.