



## Room Temperature Epitaxial Growth of InGaN and its Application to Solar Cells

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**Abstract** – We have developed a room temperature epitaxial growth technique for InGaN by the use of pulsed excitation deposition (PXD) and investigated its application to solar cells. We have found that reduction in growth temperature helps to suppress the phase separation reactions of InGaN and introduction of misfit-dislocations because thermal energy is necessary for diffusion of the atoms and rearranging of the chemical bonds. We have also performed device simulation of GaN/InGaN/GaN solar cells fabricated on various substrates using device simulator based on a self-consistent solution of the Schrodinger equation, the Poisson equation, and the current continuity equation. We have confirmed that the InGaN film grown on the ZnO substrate by this technique is appropriate for fabrication of a solar cell with a high conversion efficiency.

Recently, solar cells based on group III nitrides have attracted much attention because optical properties of InGaN alloys match the solar spectrum quite well. [1-4] However, the nitride solar cells suffer from the phase separation reactions during the growth of thick InGaN with high In concentrations which is necessary to make the film absorb a large amount of sunlight. The use of room temperature growth technique by the pulsed excitation deposition (PXD) should help to suppress the phase separation reactions because thermal energy is necessary for diffusion of atoms during the phase separation. [5] In fact, we have successfully grown a 500 nm thick  $\text{In}_{0.28}\text{Ga}_{0.82}\text{N}$  film on an atomically flat ZnO substrate [6-17] by the PXD low temperature growth technique and found that the phase separation was not serious in this film in spite of the large thickness and the high In concentration. We have also found that the lattice relaxation associated with the introduction of misfit-dislocations was suppressed by the reduction in growth temperature. These phenomena can be attributed to the lack of thermal energy which is necessary to overcome the activation energies for the phase separation and the introduction of misfit-dislocations. These results indicate that the use of the PXD low temperature growth technique is quite attractive for the growth of thick InGaN films with high In concentrations. We have also investigated characteristics of GaN/InGaN/GaN solar cells fabricated on various substrates using device simulator based on a self-consistent solution of the Schrodinger equation, the Poisson equation, and the current continuity equation. Although the conversion efficiencies for the heterostructures on the ZnO substrates are noticeably smaller compared with those on the GaN substrates at In compositions lower than 18%, the difference in the conversion efficiency becomes negligibly small at high In compositions. This phenomenon can be explained by the change in the polarity of strain for the InGaN films grown on the ZnO substrates that could suppresses or promote the separation of electron-hole pairs generated in the layer. It should be noted that the crystal growth of InGaN films with high In composition on GaN substrates encounters difficulty due to the large strain in InGaN films. Therefore, the use of ZnO substrates and PXD, which enables us to prepare thick high quality InGaN films with high In concentrations, is advantageous in fabrication of high conversion efficiency nitride solar cells.

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