

Evaluation of manganese distribution in ferromagnetic (Ga,Mn)N semiconductor by convergent electron beam diffraction study

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Systematic transmission electron microscopy (TEM) study combined with convergent beam electron diffraction (CBED) technique was performed to determine the change in lattice parameter of epitaxial Mn doped GaN films with low Mn contents (0.06 ~ 0.5 at.%) grown by plasma-enhanced molecular beam epitaxy (PEMBE). Secondary ion mass spectroscopy (SIMS) reveals that the Mn profiles for the films are uniform throughout the entire thickness range of 0.7 ~ 1.0 μm with no appreciable segregation. CBED is well known to be very powerful technique in characterization of material as well as widely used in evaluating the lattice parameter change in GaN epitaxial grown layer with various kinds of substrate material and processes. Comparison between observed and calculated HOLZ line distribution clearly indicates the expansion of lattice parameter of Mn doped GaN films. The lattice parameter for the Mn doped GaN is found to be $a = 0.31865$ nm, larger than those for the metal organic chemical vapor deposition (MOCVD)-grown GaN used as a substrate and Mn-undoped GaN grown on MOCVD GaN, reflecting the expansion of a due to Mn ion substitution for Ga ion in the wurtzite $(\text{Ga}_x\text{Mn}_{1-x})\text{N}$ structure. Lattice parameter measurement is believed to give useful information on the crystalline quality of $(\text{Ga}_x\text{Mn}_{1-x})\text{N}$ structure grown by PEMBE.

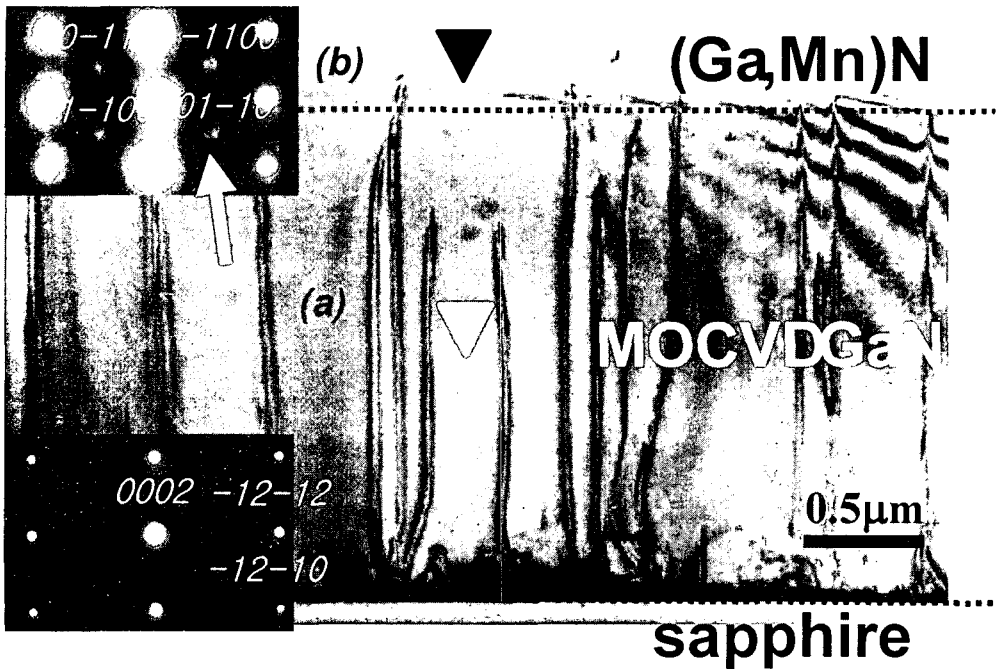


Fig. 1. (a) Cross-sectional TEM image of (Ga,Mn)N (upper) grown on MOCVD GaN (lower) circle. Selected area diffraction (SAD) pattern from (GaMn)N shows additional diffraction spots (indexed by italic) indicating the twin spots of $(01\bar{1}2)$ twinning in the $[01\bar{1}0]$ matrix. SAD pattern from lower MOCVD GaN on zone axis $B=[10\bar{1}0]$ shows no additional spots.

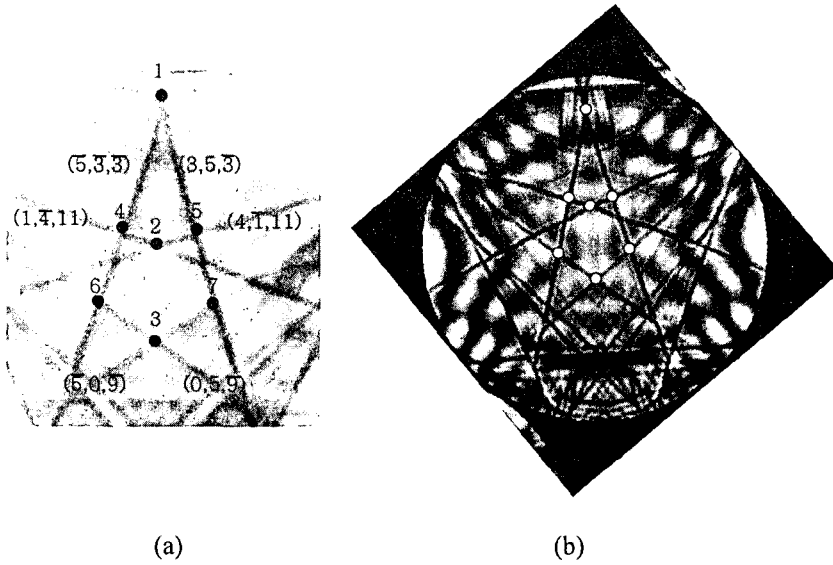


Fig. 2. Comparison of observed and simulated GaN $[\bar{2}201]$ HOLZ patterns, (a) experimental pattern with indexed HOLZ lines used, (b) simulated HOLZ pattern from dynamic simulation method.

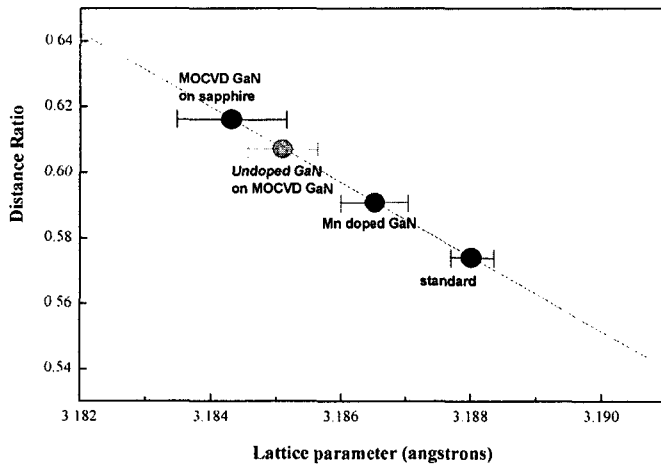


Fig. 3. Distance ratios measured from the HOLZ patterns and corresponding lattice parameters of various GaN samples.