Extended Abstracts of the 1996 International Conference on Solid State Devices and Materials, Yokohama, 1996, pp. 224-226

Initial Stage of GaN MBE Growth Studied by Ion Scattering and Recoiling Spectrometry

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The growth mechanism of initial stage of GaN MBE growth on SiC have been studied by ISARS(Ion Scattering And Recoiling Spectrometry). From the results of ISARS measurement, the size of island and the lattice relaxation process in the initial growth stage of GaN on the 6H-SiC substrate strongly relate to the growth temperature. In the ISARS spectra, neither recoiling nitrogen nor scattering ions from N atoms are observed from stable GaN surface after the growth. Coupling above with the results of angular-resolved XPS and RHEED measurements, the stable toplayer of GaN surface may be a Ga-terminated plane.

Gallium nitride (GaN) is one of the most promising materials for electronic and optoelectronic devices[1,2]. The immediate need for a lattice-matched substrate for GaN has been somewhat alleviated by the use of GaN growth on silicon carbide (SiC) substrate. Owing to a large lattice misfit in this system, growth mode is very complicated, crystalline quality depend critically on the initial growth mechanism and surface structure. We present here a study about the growth mechanism of initial stage of GaN MBE growth on SiC using the ISARS(Ion Scattering And Recoiling Spectrometry).

The MBE-ISARS system is shown schematically in Figure 1. This system consists of two sets of time-of-flight(TOF) energy analyzers for low energy ion scattering[3-5] and low energy recoiling measurements[6] with a conventional MBE system. It is highly sensitive to the atomic structure of topmost layers and suitable for discussing the growth mechanism. Details of this system have been described elsewhere[6].

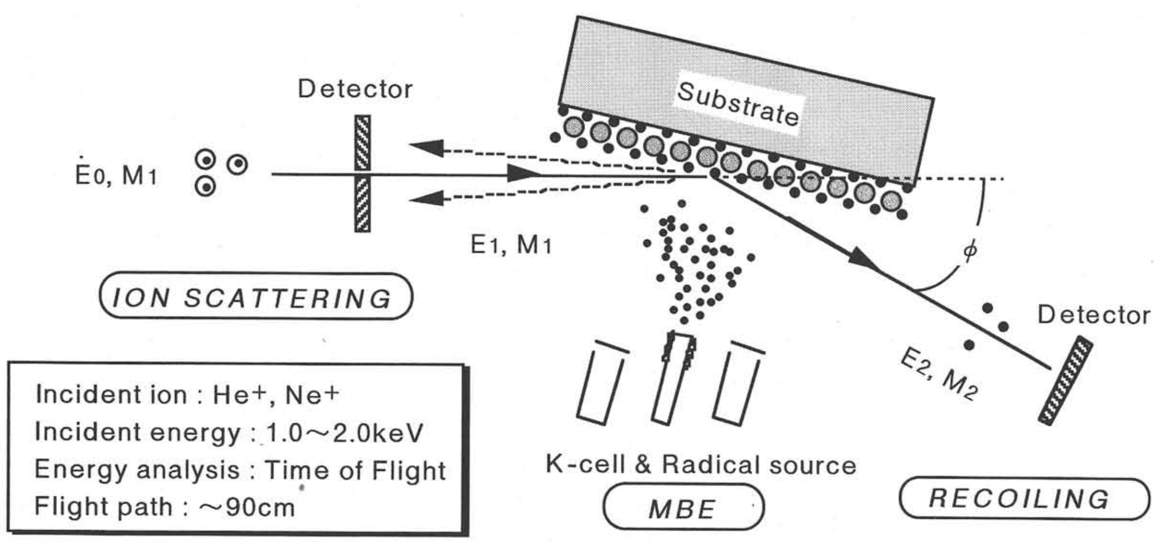

Figure 1. Schematics of MBE-ISARS apparatus.

Figure 2 shows the [0001]-aligned TOF(time-of-flight) spectra of SiC surface and GaN epilayer surface at several growth temperature(Tg). For the Tg=800℃, only Ga atoms can be seen in the spectra, while both Ga and Si signals were observed in Tg=650℃. Assuming the large size of island growth at lower Tg, this is quite natural because the Si atoms are visible to the primary ions in the spaces among the GaN islands. Figure 3 shows the [0001]-aligned scattering intensity from Ga atoms as a function of GaN epilayer thickness. The difference of these plots is corresponding to the difference of the lattice relaxation process. A change of slope at 10ML thickness for Tg=800℃ is caused by the transition from the island growth to the lattice relaxation. For the Tg=650℃, the scattering intensity increase monotonically with the thickness up to 25ML.

Assuming the lattice relaxation as the large size of island growth, only near-surface atoms of relaxed islands contribute to the spectral peaks.

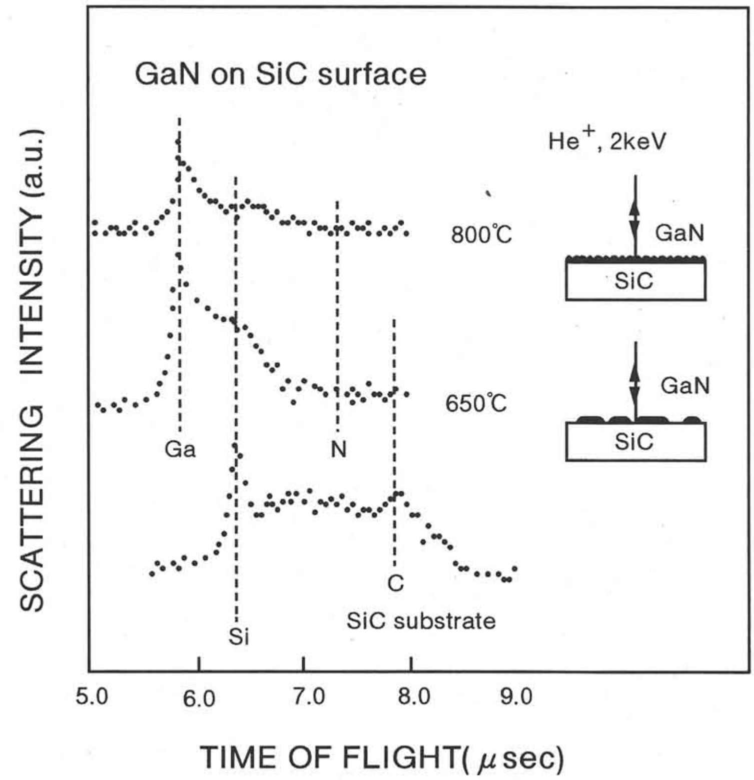

Figure 2. TOF spectra of GaN on SiC MBE grown surface at several growth temperature.

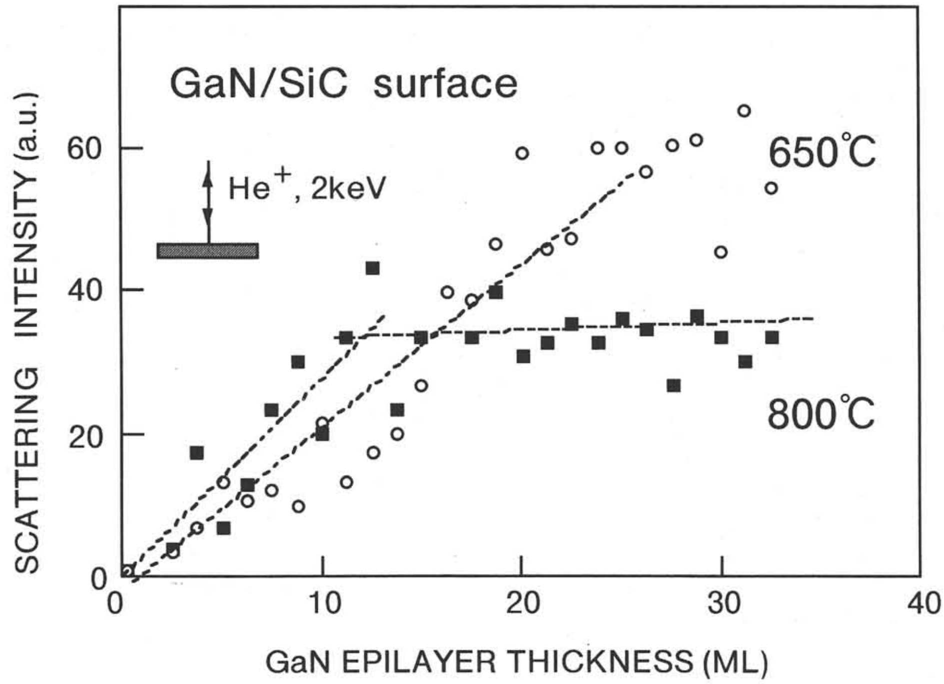

Figure 3. The [0001]-aligned scattering intensity from Ga atoms as a function of GaN epilayer thickness.

Figure 4 shows the azimuthal angle scans of Ga peak under the surface shadowing condition[4] at the Tg=650℃ and 800℃, respectively. Intensity variations with a six-fold symmetry based on shadowing and focusing effects are clearly observed in the figure of Tg=800 ℃. The difference in the symmetry between Tg=650℃ and 800℃ is attributed to the difference of the crystalline quality due to the lattice relaxation process. An important thing is that the size of island in the initial growth stage of GaN on the hexagonal structure of 6H-SiC substrate strongly depends on the Tg. Both azimuthal profiles consist of only Ga signals from GaN surface, and N atom signal is not seen in the Figure 2. On the contrary, in the recoiling spectra during GaN growth, recoiling N atoms can be observed from the surface. Neither recoiling nitrogen nor scattering ions from N atoms are observed from stable GaN surface after the growth. Coupling above with the results of angular-resolved XPS and RHEED measurements, the stable toplayer of GaN surface may be a Ga-terminated plane. It is thus suggested that Ga atoms occupy a position that is not deep within the surface.

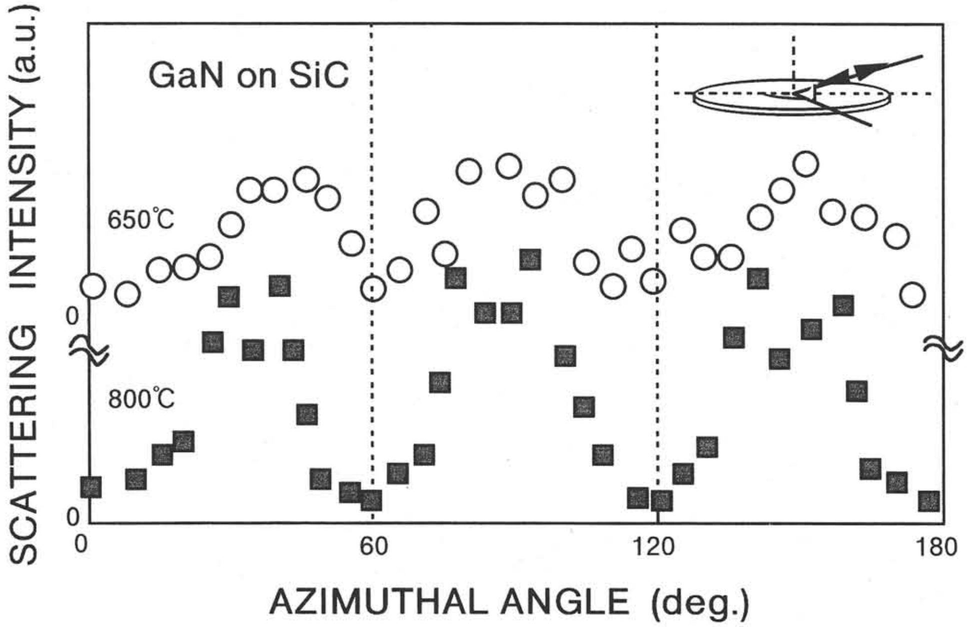

Figure 4. The azimuthal-angle scans of scattering intensity from Ga atoms.

In summary, we have applied ISARS to the study of the growth mechanism of initial stage of GaN MBE growth on SiC. Ion scattering measurements in the initial growth stage indicate that the lattice relaxation process strongly depend on the Tg and the growth mechanism of island. Results from ISARS, angular-resolved XPS, and RHEED measurements suggest that the stable toplayer of GaN surface after growth may be a Ga-terminated plane. On the contrary, during GaN MBE growth, recoiling N atoms can be observed from the substitutional site on surface. Further study is necessary to clarify the transition of stable surface structure and the microscopic growth mechanism.

Authors thanks Drs. K. Hatada and S. Ohnaka for continuous encouragements and also thanks Drs. Y. Ban and A. Ishibashi for their useful discussions.

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