Extended Abstracts of the 2001 International Conference on Solid State Devices and Materials, Tokyo, 2001, pp. 366–367

E-6-6

Strong Photoluminescence and Low Surface State Densities on Clean and Silicon Deposited (001) Surfaces of GaAs with (4x6) Reconstruction

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1. Introduction

As compared with silicon, surfaces of GaAs and related compounds are difficult to control due to presence of high densities of surface states which pin the Fermi level, and cause various unfavorable related phenomena. A silicon interface control layer (Si ICL)-based passivation method [1,2] has been found considerably effective for reducing the surface state density. So far, the effectiveness of this method has been investigated on (2x4) and c(4x4) reconstructed As-rich (001) surfaces of GaAs[2], and no systematic attempt on Ga-rich (001) surfaces has been made.

The purpose of this paper is to investigate the effectiveness of the Si ICL-based passivation process on the (4x6) reconstructed Ga-rich (001) GaAs surface. The result showed strong photoluminescence and large reduction of surface state density on the (4x6) surface as compared with As-rich surfaces.

2. Experimental

All experiments were carried out in a UHV-based multi-chamber system shown in **Fig.1**, containing MBE chamber, UHV PL chamber, UHV STM chamber, UHV contactless C-V chamber and XPS chamber. Three kinds of GaAs (001) surfaces with different surface reconstructions of (4x6), c(4x4) and (2x4) patterns were prepared in the MBE chamber after growth of the fresh GaAs layers. Si ICL was grown up to 1 nm by MBE at 300°C in the MBE chamber. Properties of clean and Si-deposited surfaces were investigated by UHV STM, XPS, UHV PL and UHV contactless C-V measurements without breaking the UHV condition. In the contactless C-V method[3], a narrow parallel UHV gap (300-400 nm) was maintained between the top field electrode and the sample surface, and it allowed MIS assessment of free surfaces.

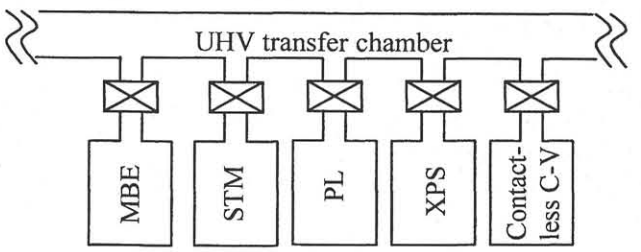


Fig. 1. A UHV multi-chamber system.

3. Results and Discussion

Figure 2 shows examples of the observed RHEED patterns on the (4x6) reconstructed surface. The pattern changed from a well-defined (4x6) pattern to a (2x1) pattern after deposition of 0.2 nm Si and eventually to a (1x1) pattern, indicating that crystalline order is maintained during and after Si ICL deposition.

STM study of the (4x6) surface showed presence of predominant Ga-rich (4x6)-reconstructed areas with characteristic micro-structures including Ga-droplets which were mixed with As-stablized areas, as shown in **Fig.3(a)**. The result is in agreement with the observation and the microscopic modeling by Xue et al[4]. The STM image taken after deposition of 1 nm Si is shown in **Fig.3(b)**. Initial

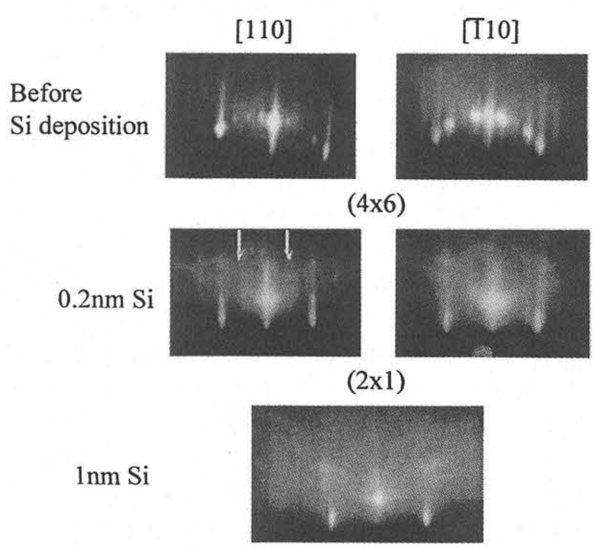
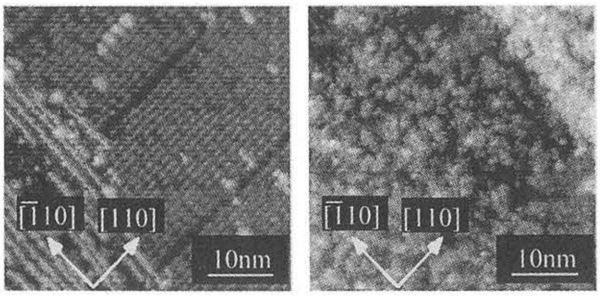


Fig. 2. RHEED patterns on (4x6) surface before and after Si ICL deposition.



(a) (b)

Fig. 3. STM images from (4x6) surface (a) before and (b) after Si deposition.

pattern mixture disappeared, and uniform (1x1) Si coverage was observed.

In-situ XPS measurements confirmed Ga-rich nature of the (4x6) surface as well as As-rich nature of the (2x4) and c(4x4) surfaces. XPS band bending measurements indicated that Fermi level pinning was reduced on the (4x6) surface as compared with other surfaces, and that it was further reduced by Si ICL deposition.

The result of PL measurements at room temperature is summarized in **Fig.4.** The PL line shapes were the same, but the intensities were very different as summarized in **Table 1**. The PL intensity of (4x6) surface was the largest, and it further increased by Si ICL deposition indicating remarkable reduction of nonradiative surface recombination centers as compared with other surfaces.

UHV contactless C-V measurements at 500kHz revealed

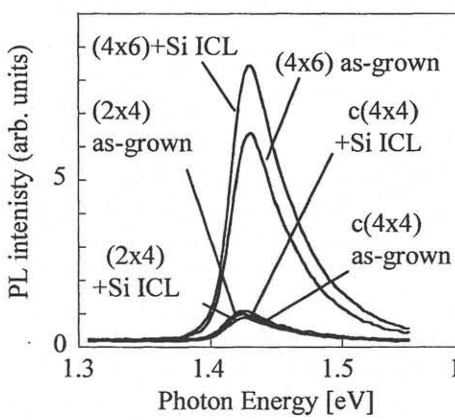
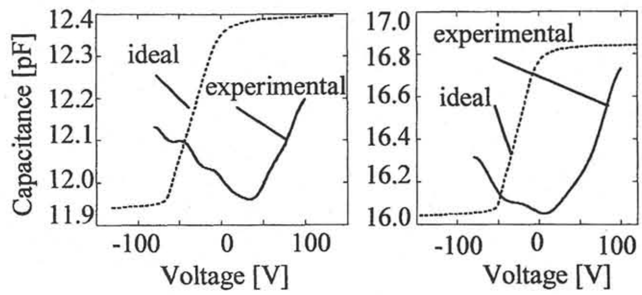


Fig. 4. PL spectra from GaAs surfaces.

Table. 1. Normalized PL intensity of GaAs surfaces.

	2x4	c(4x4)	(4x6)
GaAs as-grown	1	1	6.2
Si ICL	0.9	1.1	8.4



(a) (b)

Fig. 5 Contactless C-V curves on (4x6) surface (a) before and (b) after Si deposition.

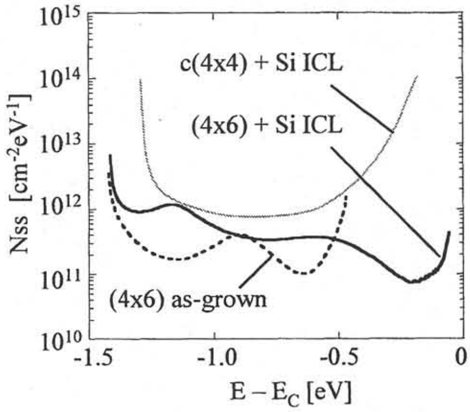


Fig. 6. Distributions of surface state density, Nss.

large capacitance change with bias both on the initial and Si deposited (4x6) surfaces, as shown in **Fig.5(a)** and **(b)**. **Figure 6** shows the distributions of surface state density (N_{ss}) calculated from measured UHV contactless C-V curves for (4x6) surface and Si-deposited (4x6) surface. For comparison, our previous best result obtained on Si deposited c(4x4)[2] is also shown. These two new surfaces gave very wide Nss distributions with low Nss values. The result is consistent with PL measurements. Thus, to our knowledge, Si deposited (4x6)-(001) surface is the best initial surface so far reported on GaAs surfaces except the vacuum cleaved (110) surface which is free of surface states.

4. Conclusion

Strong PL and low surface state density are obtained on clean Ga-rich (4x6) reconstructed GaAs (001) surfaces. They are further improved by deposition of Si ICL.

References

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