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# Layered Structure GaSe as a Thermal Lattice Mismatch Buffer Layer in the GaAs/SiHeteroepitaxial System

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In this paper we propose the use of layered structure GaSe as a thermal and lattice mismatch buffer layer for the growth of high quality GaAs on Si and present preliminary results of GaAs grown on ultra thin GaSe films on As passivated Si(111) substrates by MBE.

INTRODUCTION: GaSe is a layered structure semiconductor which has been studied in recent years in connection with van der Waals epitaxy [1]. In van der Waals epitaxy, there are no strong covalent or metallic bonds between the epilayer and the substrate. Instead, the epitaxial orientation of the growing film is established by weak van der Walls forces. Van der Waals epitaxy applies only in cases where both 1) the substrate surface has no dangling bonds (such as passivated semiconductor surfaces) and 2) the epilayer has a crystal structure which has no dangling bonds (such as layered structure materials). Since the film and the substrate are held together by weak van der Waals forces, the epitaxial quality is not sensitive to either lattice mismatch or thermal expansion mismatch between the epilayer and the substrate.

As was shown by Tachikawa et. al. [2], even when the growth conditions for GaAs on Si are optimized such that the defect density is $\sim 10^4/cm^2$ at the growth temperature, defect densities of $\sim 10^6/cm^2$ are introduced by the stresses of thermal expansion mismatch when the substrate is cooled to room temperature. As illustrated in Fig. 1, we propose using a thin layer of layered structure GaSe as a thermal and lattice mismatch buffer layer between GaAs and Si. First, the Si substrate should be passivated. (Passivation of Si using H and As have been widely studied.[3,4]) Then growth of GaSe on the passivated Si substrate is achieved by van der Waals epitaxy[1]. Until now, there have been no reports of epitaxial growth of zinc-blende on layered structure materials [5]. Here, we report for the first time, GaAs grown on ultra-thin epitaxial GaSe films grown on passivated Si(111) substrates.

EXPERIMENTAL DETAILS AND RESULTS GaSe: Arsenic passivated Si(111) substrates were prepared by ex-situ cleaning in HF followed by in-situ high temperature annealing (1100°C, 45 min.) After this treatment the substrates showed a 7x7 surface reconstruction. As passivation was achieved by heating the substrate to 800°C in the presence of an As flux. Then GaSe was grown on the surface at 400°C with a Se/Ga flux ratio (BEP) of around 1:1 to 2:1. The Ga was supplied at a rate of about 4 ML/min for 2 minutes. Growth was interrupted after 1 minute to photograph the RHEED pattern. During growth, the RHEED pattern gradually changed, indicating a somewhat smoother surface as GaSe growth proceeds. After growth, AES indicated the presence of both Ga and Se on the surface, (as well as a weak silicon signal from the substrate). Fig. 2 is a plan view TEM diffraction pattern of this film. The brightest spots correspond to the Si substrate's (220) reflections plus the epitaxial GaSe's (1120) spots. The weak spots correspond to the GaSe (1100) reflections (Indicated by arrows in Fig. 2). This indicates that under these conditions, GaSe grows epitaxially with the c-axis parallel to the Si(111) surface and the (1120) axis parallel to the substrate's (220).

GaAs/GaSe: GaAs was grown on a GaSe film on an As-passivated Si(111) substrate. The GaSe was grown as in the previous case, except that growth interruptions were more frequent, every 15 seconds, or roughly once per monolayer of growth, for a total of 4 monolayers of growth. The film was annealed briefly at 500°C and an additional growth of 4 monolayers at 500°C did not change the RHEED pattern significantly. GaAs growth was done at 300°C, at a rate of about 1 ML/sec for 2 minutes. The RHEED pattern of the film showed that while portions of the film are epitaxially aligned with the substrate, there was a significant amount of polycrystalline material in the as deposited state. The amount of polycrystalline material decreased as the sample was annealed, and after about 5 minutes at 700°C, there was no sign of polycrystalline material in the RHEED pattern. Fig. 3 is a plan-view diffraction pattern of this film. The bright spots are the (220) spots of the Si substrate and the GaAs. The GaAs spots appear with 6 fold symmetry about the Si (220) spots due to double diffraction. The weak GaSe (1100) spots are barely visible and are indicated by arrows in Fig. 3. There is also a barely visible GaAs (111) polycrystalline diffraction ring* which indicates that some misoriented GaAs grains remain imbedded in the epitaxial film. Since the polycrystalline grains were not visible by RHEED after annealing, the misoriented grains are most likely located near the GaAs/GaSe interface.

[1] K.Ueno, H.Abe, K. Saiki and A. Koma, Japn. J. Appl. Phys., 30(8a), L13 52, (1991).
[2] M. Tachikawa and H. Mori, Appl. Phys. Lett., 56(22) 2225, (1990).
[3] For example, see J.J. Boland, Surface Science, 224, 1, (1991).
[4] R.D. Brigans, Crit. Rev. in Solid State and Mater. Sciences, 17(4), 353, (1992).
[5] Recently growth of polycrystalline InSb on polycrystalline GaSe grown on glass substrates has been reported. H.Takei and T. Hariu, presented at the Japan Applied Physical Society Meeting, Spring 1992. Poster 30a-SZA-17 (In Japanese).
* The diameter of the GaAs (111) ring is almost the same as the GaSe (1100) spots indicated by arrows in the Fig.3.

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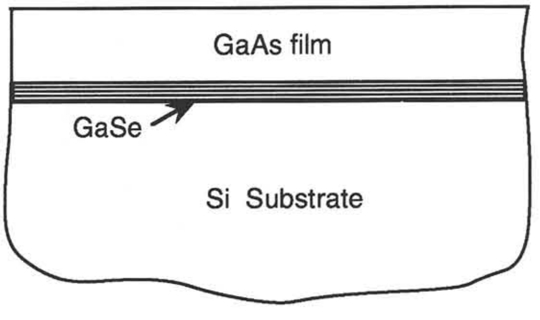


Figure 1. GaSe Layered structure material as a thermal and lattice mismatch buffer layer in GaAs on Si.

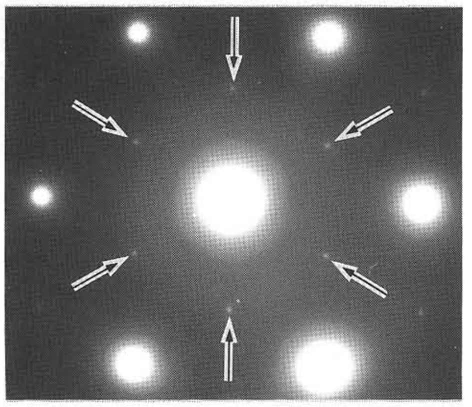

Figure 2. TEM plan-view diffraction pattern of a GaSe film grown on an As-passivated Si(111) substrate. The bright spots are the combined diffraction of the Si substrate (220) spots and the GaSe (1120) spots. Indicated by arrows in the figure are the weaker GaSe (1100) spots.

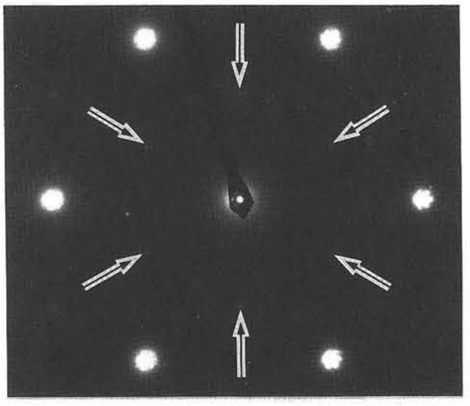

Figure 3. TEM plan-view diffraction pattern of a GaAs film grown on an ultra-thin GaSe film on an As-passivated Si(111) substrate. The bright spots are the combined diffraction of the Si substrate and GaAs (220) spots. Arrows indicate the weak GaSe (1100) spots and the GaAs (111) diffraction ring.