be very critical to realize the control of band offsets as theoretically predicted.

Si (0~1 ML) and AlAs (30 Å) layers were grown on As-stabilized and Ga-stabilized (100) (denoted by (100)Ga and (100)As, respectively), (110), and (311)A oriented GaAs substrates by molecular beam epitaxy. Apparent VBO, (ΔE_v), was evaluated by in-situ XPS measurements [3]. ΔE_v decreases monotonously by ~0.4 eV when d increases from 0 to ~0.5 ML and saturates at ΔE_v ~0 eV, almost independent of the orientation.

The results for the (100)As interface agree well with the results in [2] as well as with the theoretical prediction when $d \leq 0.5$ ML. However, the experimental results for the (100)Ga, (110) and (311)A orientations disagree with the theoretical prediction: theoretically the VBO should increase for the (100)Ga and remain unchanged for the (110) orientation, while the experimental data decreased monotonously until d = 0.5 ML as being the same as in the (100) orientation. This disagreement shows that the interface dipole is not effectively formed by the Si layer insertion. This change in ΔE_v can rather be explained by the band bending in the AlAs overgrown layer caused by ionized Si-donors which should be independent of the crystal orientation.

In order to clarify why the interface dipole is not formed in our samples, we calculated by the tight binding method the interface dipole potential formed by Si layers in the following two structures; One consists of Si layers which fully occupy an As layer and a Ga layer at an AlAs/GaAs interface (ideal case) and the other consists of Si atoms distributed in an interface group-III site and two As sites next to the interface (diffused-Si case). It is found that the interface dipole potential is ~1.6 eV for the ideal case and only ~0.2 eV for the diffused-Si case, showing that a precise site control of Si atoms is essential to form an ideal interface dipole and to change the band offset.

We also formed a GaAs/AlAs (311)A heterostructure with a p-type Si-doped GaAs layer and a Si δ-doped (n-type) layer to show a possibility to control a band offset, while suppressing a band bending. We have obtained an evidence of the band-offset change. The details will be presented at the conference.

[1] A. MuÒos et al. Phys. Rev. B 41, 2976 (1990).
[2] L. Sorba et al. Phys. Rev. B 43, 2450 (1991).
[3] Y. Hashimoto et al. Proc. ICPS (1992); Proc. Int. Symp. GaAs Related Compounds (1992).

Thursday, June 24, 1993, AM

Session F1: SiGe Electrical and Optical Properties

Room: Engineering II Conference Room
Session Chairman: Y.H. Xie, AT& T Bell Labortaries, 600 Mountian Ave., Murry Hill, NJ 07174
Co-Chairman:. Meyerson, J. Watson Research Center, Post Office Box 218, Yorktown Heights, NY 10598

8:20 AM, F1+
Effect of Alloy Scattering on Low Temperature Mobilities of Two-dimensional Holes and Electrons in Si/$Si_{1-x}Ge_x$ Heterstructures: V. VENKATARAMAN, C. W. Liu and J. C. Sturm Dept. of Electrical Engineering, Princeton University, Princeton, NJ 08544

There has been great interest recently in the study of two-dimensional electron and hole systems in Si/$Si_{1-x}Ge_x$ modulation doped heterostructures. Although electron mobilities in strained Si have surpassed 100,000 $cm^2/V \cdot s$, the best hole mobilities in strained $Si_{1-x}Ge_x$ reported so far are below 7000 $cm^2/V \cdot s$. Previous workers have attributed the low mobility of holes to either coulombic scattering from ionized impurities, higher effective masses, or interface scattering due to poor sample quality. However these mechanisms do not explain the big order of magnitude difference in electron and hole mobilities of similar samples. In this paper, we experimentally show that this difference is due to the fundamental effect of alloy scattering in the $Si_{1-x}Ge_x$ and establish the first determination of the strength of the $Si_{1-x}Ge_x$ alloy scattering potential in a 2-D system.

Both n-type modulation doped structures (on relaxed $Si_{0.65}Ge_{0.35}$ substrates) and p-type modulation doped structures (on silicon substrates) were fabricated using rapid thermal chemical vapor deposition. The germanium concentration in the channel was varied from 0 to 20% while fixing the other parameters of the structure. Temperature dependent Hall measurements confirm the presence of a degenerate two-dimensional carrier system in all samples. The electron mobilities at 10 K were determined to be 15000, 3000 and 2500 $cm^2/V \cdot s$ for 0, 12 and 20% germanium channels, respectively. The strong decrease of the low temperature mobility with increasing germanium concentration in the channel clearly proves the strong effect of alloy scattering. Despite slightly lower in-plane effective masses, the electron mobilities are, however, lower than hole mobilities for the same germanium concentration because of the extra effect of strong intervalley scattering caused by the alloy disorder (an effect unique to electrons). By fitting the mobilities measured to the correct expression for alloy scattering in two-dimensional systems, we obtain an effective scattering potential of 0.55 eV. Using this value, we show that maximum hole mobilities in $Si_{1-x}Ge_x$ channels cannot exceed,10,000 and 6000 $cm^2/V.s$ for x=0.1 and 0.2 respectively, consistent with our data and other published results, (6000 and 3500 $cm^2/V.s$ for electrons).

8:40 AM, F2+
Velocity-Field Characteristics and Alloy Scattering in $Si_{1-x}Ge_x$: S-H. Li, J. Hinckley, J. Singh and P. BHATTACHARYA Department of Electrical Engineering and and Computer Science, The University of Michigan, Ann Arbor, MI 48109-2122

$Si_{1-x}Ge_x$ alloys and SiGe/Si heterostructures are currently of immense interest due to the potentially useful electron and optical properties and compatibility with existing Si technology. The built-in strain in pseudomorphic alloys alters the bandstructure and carrier transport properties. No report on the experimental determination of the high-field transport in these alloys has been made. We will describe our work on the theoretical and experimental determination of the velocity-field characteristics in relaxed and coherently strained n- and p-type $Si_{1-x}Ge_x$ ($0.1 \leq x \leq 1.0$). The alloy scattering potential in the material has also been estimated.

Relaxed (1-2μm thick) and coherently strained $Si_{1-x}Ge_x$/Si heterojunctions were grown on (001) Si substrates by molecular beam epitaxy using gaseous disilane and solid Ge as sources. The undoped SiGe was n- type and p-type doping was achieved with solid B. The velocity-field characteristics at room temperature were obtained from pulsed current-voltage measurements on planar H-devices. The velocity increases monotonically with Ge content for the same applied field. As an example, in relaxed $Si_{0.7}Ge_{0.3}$, the electron velocity is 5×10^6 cm/s and in coherently strained $Si_{0.87}Ge_{0.13}$ at 3kV/cm the in-plane hole velocity is ~ 2×10^6 cm/s at 3 kV/cm.

A Monte Carlo calculation is carried out to study the effect of alloying and strain on the velocity-field relations of electrons and holes in the strained and relaxed SiGe alloys. The hole transport involves (a) the use of a (6 x 6) k·p formalism to identify the bandstructure of the alloy valence band with inclusion of the deformation potential theory, and (b) a Monte Carlo calculation retaining the anisotropic nature of the valence band. The electron transport uses an anisotropic conduction band where the valley degeneracies are affected by the strain in the system. The theoretical work is compared with the experiments to identify the role of alloy scattering. An alloy scattering potential of 0.2 eV for the holes and 0.5 eV for electrons is found to provide a good agreement with the experiments.

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9:00 AM, F3
Luminescence Characterization of Gas-Source-Grown Strained $Si_{1-x}Ge_x$/Si Quantum Wells: S. FUKATSU, H. Sunamura, N. Usami, Y. Kato and Y. Shiraki Research Center for Advanced Science and Technology (RCAST), The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153, Japan

Luminescence characterization of strained $Si_{1-x}Ge_x$/Si quantum wells (QWs) grown by gas source Si molecular beam epitaxy (Si MBE) is presented.

It is addressed that the selection of appropriate growth temperature,