tude below the diffusion coefficient extrapolated from higher temperatures for C in bulk Si.

The analysis of Si/SiGeC superlattices is less straightforward since we have to account for two interdiffusion coefficients. For a Si/SiGe superlattice, analysis of x-ray diffraction after a 950°C anneal yields an interdiffusion coefficient consistent with what is expected for diffusion of Ge in bulk Si. However, the diffusion of Ge in Si/SiGeC is apparently enhanced over that observed in the Si/SiGe superlattices by approximately one order of magnitude. The movement of the zero order diffraction peak in SiGeC superlattices again indicates loss of substitutional carbon, at a rate equal to or somewhat less than that observed for Si/SiC superlattices.

4:10PM, H8+

Silicon Epitaxial Regrowth in RTCVD for Passivation of Reactive Ion Etched Si/SiGe/Si Microstructures: M. CARROLL, L.L. Lanzerotti; C.L. Chang and J.C. Sturm, Department of Electrical Engineering, Princeton University, Princeton, NJ 08540

Recently there has been a strong interest in fabricating pseudomorphic SiGe dots and wires inside silicon using two basic experimental approaches. First, a V-groove has been etched in the Si substrate, and it has been found that SiGe will first grow only in the bottom of the groove, which can then be followed by a silicon cap. This provides a structure with all the SiGe surfaces passivated by the wider band gap Si, but the composition of the V-groove is very difficult to control. Alternatively, one can grow planar Si/SiGe/Si structures, with arbitrary control, and then pattern them by etching into dots, wires, etc. This method unfortunately leaves the edges of the quantum wells exposed and damaged by etching, and hence the band-edge photoluminescence (PL) from the well, which is used to probe the SiGe properties, is quenched or replaced by defect PL. In this work we demonstrate for the first time the passivation of etched Si/SiGe/Si structures by epitaxial regrowth.

The original 2-D Si/SiGe/Si structures were grown by RTCVD between 600 and 700°C and exhibited strong well defined band-edge SiGe PL as grown. After patterning into wires and boxes by low energy RIE, the SiGe PL was completely quenched, due to both etch damage and the exposure of the edges of the quantum wells at the surface, which leads to rapid non-radiative surface recombination of carriers. High temperature annealing (to remove the damage) and surface passivation by oxidation was partially successful in restoring the SiGe PL. The most successful approach was to epitaxially regrow Si on the exposed vertical sidewalls. This completely confines carriers to the narrow bandgap SiGe away from the surfaces. This was successfully done using regrowth temperatures from 700-1000°C. At 1000°C, there was a slight (25meV) increase in the PL energies due to interdiffusion of the Si and the SiGe, but this was not observed for low T regrowth. For small structures, the SiGe PL in passivated structures per unit SiGe area was actually larger than in the as-grown un-etched structures, due to the fact that excitons could diffuse latterally from exposed Si areas to be collected into the SiGe quantum wells. 2-D numerical device modeling of the carrier motion will be presented to support this hypothesis. This work was supported by USAF, USAF AASERT program, ONR and Sandia National Labs.

4:30PM, H9

Influence of the Oxygen Content in SiGe on the Parameters of Si/SiGe Heterojunction Bipolar Transistors: D. KNOLL, D. Bolze, K.E. Ehwald, G. Fischer, B. Heinemann, D. Krüger, T. Morgenstem, E. Naumann, P. Schley, B. Tillack, D. Wolansky, Institute for Semiconductor Physics, Walter-Korsing-Str.2, 15230 Frankfurt (Oder), Germany

A high O content can lower the carrier lifetimes and reduces the B diffusion in epitaxial SiGe layers. We present now a comprehensive study about the influence of O on essential device parameters of $Si/Si_{1-x}Ge_x$ heterojunction bipolar transistors (HBTs), like maximum cut-off (f_T) and oscillation frequencies (f_{max}), base currents, low frequency noise, and pipe-yield. In particular, we show that it is possible to exploit the positive effect of reduced B diffusivity in O-rich layers, and at the same time, to outflank the influence of the low lifetimes.

We demonstrate both f_T and f_{max} of about 50 GHz with emitter widths of more then 1 µm by using a "halfgraded" Ge profile with x ~ 0.2 at the collector side of the base, and a B doping resulting in a pinched base resistance of ~ 5kΩ. This performance, however, is only reached for HBTs with O-rich ($[O]_{SIMS} > 10^{20}$ cm^{-3}) SiGe base layers. We doped our transistors after epitaxy by a set of low-dose As (low-doped emitter) and P implantations (low-doped collectors), respectively, to reduce the emitter transit time and to shift the onset of Kirk effect to higher currents. The HBT collector current characteristics and SIMS measurements show that the B diffusion is strongly enhanced in the SiGe layers with low O content ($[O]_{SIMS} > 10^{18}$ cm^{-3}) when the implantation have been applied. The result is the formation of conduction band barriers by B outdiffusion from SiGe degrading the dynamical performance of HBTs with low O content. We demonstrate that the contributions of all low-dose implantation steps to the enhancement of B diffusion are similar.

For recombination-influenced parameters like base currents and low-frequency noise, we show that an exact positioning of the emitter-base pn-junction to the hetero-junction is necessary for a sufficient behavior. Ideal base current characteristics and a low 1/f noise level, similar to that of SiGe-base transistors with lower O and Ge content, are shown to be also possible with high O and Ge content in the base when a slight B outdiffusion from SiGe occurs only at the emitter side of base.

Finally, we present data from large-area devices representing an active device area of more then 10^4 µm² and thus allowing a pipe-yield evaluation. With the O-rich layers a high wafer yield (~ 90 %) is shown to be attainable but a stronger scattering compared with the O-poor devices is observed.

4:50PM, H10

Compound Ge_xSi_{1-x} Structures: Novel Measurement Algorithm via Optical Reflectance Spectrometry: D. CONNELLY and K. Saraswat, Center for Integrated Systems, Stanford University, Stanford, CA 94305

In this work we present a rapid, non-destructive, low-cost method of using optical reflectance spectroscopy to extract the Ge profile of $Ge_x Si_{1-x}$ structures with depth-dependent x, or to measure oxides and other transparent films formed on such structures. The rapid measurement turnaround and wide availability of the measurement apparatus makes it an excellent candidate for statistical process control and rapid process verification of product wafers as well as primary calibration applications.

Optical reflectance spectrometry is commonly used to measure the thickness of insulating and semiconducting films using simple refractive models. Modeling of $Ge_x Si_{1-x}$ films requires a detailed specification of the refractive and absorptive dispersion over the measured wavelength range. Simple interpolation on the complex refractivity axes is inadequate; the spectra are peaked with the location, as well as the height, of the peaks alloy-dependent. Thus interpolation is done first in energy-wavenumber space to align the peaks via a linear transformation of the wavenumber axis as a function of Ge content. Then, interpolation in the complex refractive axes is done to match the specific Ge content.

The energy value of the peaks in the refractive and absorptive spectra of published $Ge_x Si_{1-x}$ films varies in a nicely linear fashion with x, allowing the use of a simple linear transformation to render the peaks independent of transformed energy z, and thus suitable for interpolation of the refractive and absorptive indexes. The reflection spectrum is then modeled by discretizing the modeled sample into sections of piecewise-constant alloy composition.

Films were grown using silane or dichlorosilane as a silicon source and germane (either 10% in hydrogen or undiluted) as a germanium source in an ASM Epsilon-2 chemical vapor deposition epitaxial reactor. Films were deposited either as a box profile or as a cap on a graded alloy buffer layer on either blank silicon wafers or silicon wafers with windows etched in a surface oxide layer. Measurements were performed on the optical and ultraviolet portions of the spectrum separately, each preceded by a reference scan of a freshly-cleaned Si wafer.

A comparison of the surface-film *t* and *x* values found to optimize the fit of the optical reflectance spectrum and those found to optimize the fit to the Rutherford backscattering spectrum for each shows excellent agreement in x with a slightly larger t extracted for the reflectance method than those determined to optimize the fit to the RBS data. The correlation between the measurements was excellent, however.

Thus, it is shown that the modeling technique is useful at measuring Ge contents of thick $Ge_x Si_{1-x}$ structures of depth-dependent *x*. Similarly, the effect of surface layers on such structures can also be modeled. Agreement between this method and the more expensive and destructive method of Rutherford Backscattering Spectroscopy is also demonstrated.