SISC 94

25th IEEE SISC 94

ELECTRON DEVICES SOCIETY

IEEE

San Diego, California **Dec 8-10, 1994**

ABSTRACTS

General Chair: **H. Z. Massoud**

Technical Chair: **W. L. Warren**

Arrangements Chair: **R. E. Stahlbush**

Executive Committee:

Hisham Z. Massoud
General Chair
Department of Electrical Engineering
Duke University
Durham, NC 27708-0291

William L. Warren
Technical Chair
Sandia National Laboratories
Advanced Materials Laboratory
Albuquerque, NM 87185-1349

Robert E. Stahlbush
Arrangements Chair
Naval Research Laboratory
Code 6816
Washington, D.C. 20375

Lalita Manchanda
Ex-Officio
AT&T Bell Laboratories
101 Crawfords Corner Rd., Rm. 4C-406
Holmdel, NJ 07733

Program Committee:

M. O. Andersson	Chalmers University of Technology, Sweden
H. E. Boesch, Jr.	Army Research Laboratory, USA
Doug A. Buchanan	IBM Watson Research Center, USA
D. M. Fleetwood	Sandia National Laboratories, USA
W. B. Fowler	Lehigh University, USA
Guido Groeseneken	IMEC, Belgium
Gregg Higashi	AT&T Bell Laboratories, USA
Akihiko Ishitani	NEC Corp., Japan
W. T. Lynch	Semiconductor Research Corp., USA
T.-P. Ma	Yale University, USA
Mizuho Morita	Tohoku University, Japan
E. H. Nicollian	Univ. North Carolina-Charlotte, USA
N. S. Saks	Naval Research Laboratory, USA
M. J. Schulz	Erlangen University, Germany
J. H. Stathis	IBM Watson Research Center, USA
A. M. Stoneham	AEA, United Kingdom
H.-H Tseng	Motorola Inc., USA

Paper P6.4

Silicon Surface Passivation Control of High Temperature Photoluminescence in $Si/Si_{1-x}Ge_x/Si$ Quantum Wells

A. St. Amour and J.C. Sturm, Dept. of Electrical Engineering, Photonic and Opto-Electronic Materials Center (POEM), Princeton University, Princeton, NJ 08544 USA

Y. Lacroix and M.L.W. Thewalt, Dept. of Physics, Simon Fraser University, Burnaby, BC V5A 1S6 Canada

The high temperature (T >> 77K) band-edge photoluminescence of $Si/Si_{1-x}Ge_x$ structures is of great interest for future Si-based light emitters. For the first time, it is definitively shown through experiment and a model that the intensity of the luminescence of Si/strained $Si_{1-x}Ge_x/Si$ quantum wells at high temperature is controlled, not by the carrier lifetime in $Si_{1-x}Ge_x$, but by recombination at the top Si surface. By passivating the top Si surface with oxide, the intensity of the high temperature luminescence from the $Si_{1-x}Ge_x$ was increased by nearly an order of magnitude. By employing a high pump power density and an oxide passivated sample, essentially constant $Si_{1-x}Ge_x$ plotoluminescence was achieved from 77 to 250K, leading to the most efficient room temperature $Si_{1-x}Ge_x$ plotoluminescence yet reported. Furthermore, these results indicate that the temperature dependence of integrated photoluminescence intensity can be used to examine the quality of Si/SiO_2 interfaces.

The samples for this work were grown by Rapid Thermal Chemical Vapor Deposition (RTCVD) using dichlorosilane (DCS) and germane as precursors and at a growth temperature of 625°C. The samples initially consisted of nominally undoped strained single $Si_{1-x}Ge_x$ quantum wells on an undoped Si buffer and capped by 25nm of Si. The surfaces of a piece of each sample were passivated by wet oxidation at 800°C for 10 minutes resulting in about 10nm SiO_2. Si and $Si_{1-x}Ge_x$ plotoluminescence from these samples was measured from 6 to 300K.

A model for the temperature dependence of the integrated intensity of the Si and $Si_{1-x}Ge_x$ plotoluminescence was developed. The model assumes that the quasi-fermi levels are flat and that all carrier lifetimes are independent of temperature. At low temperature, nearly all carriers generated by the pump are confined to the $Si_{1-x}Ge_x$ quantum well and therefore the luminescence intensity depends on properties of the $Si_{1-x}Ge_x$ and is constant with temperature. At higher temperatures, as carriers are thermally excited from the quantum well into the Si cladding they are exposed to the top Si surface. If the Si has a low effective carrier lifetime (τ_{Si}) due to surface recombination, the $Si_{1-x}Ge_x$ luminescence will decay sharply, not because the fraction of carriers in the well decreased but because the total number of carriers in the system decreased. The position of the "knee" in an Arrhenius plot of integrated intensity is determined by τ_{Si}. That τ_{Si} appears to increase by more than an order of magnitude at high pump power density is not well understood.

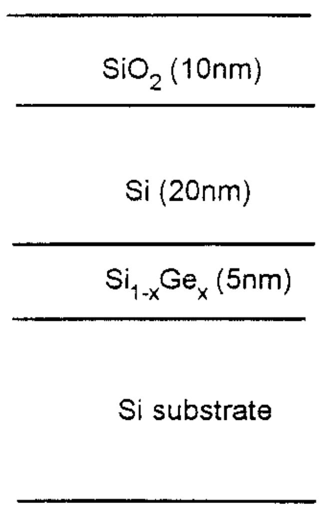

Figure 1. Structure of passivated sample.

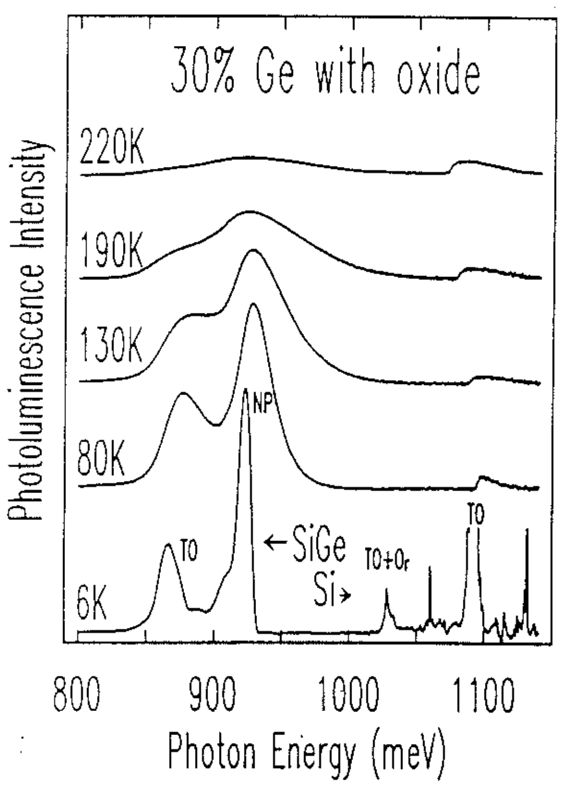

Figure 2. Photoluminescence spectra of the sample with 30% Ge and oxide passivation. The pump power density was $0.1 W/cm^2$. Note that in the 6K spectrum the Si peak is cut off so as not to obscure other spectra.

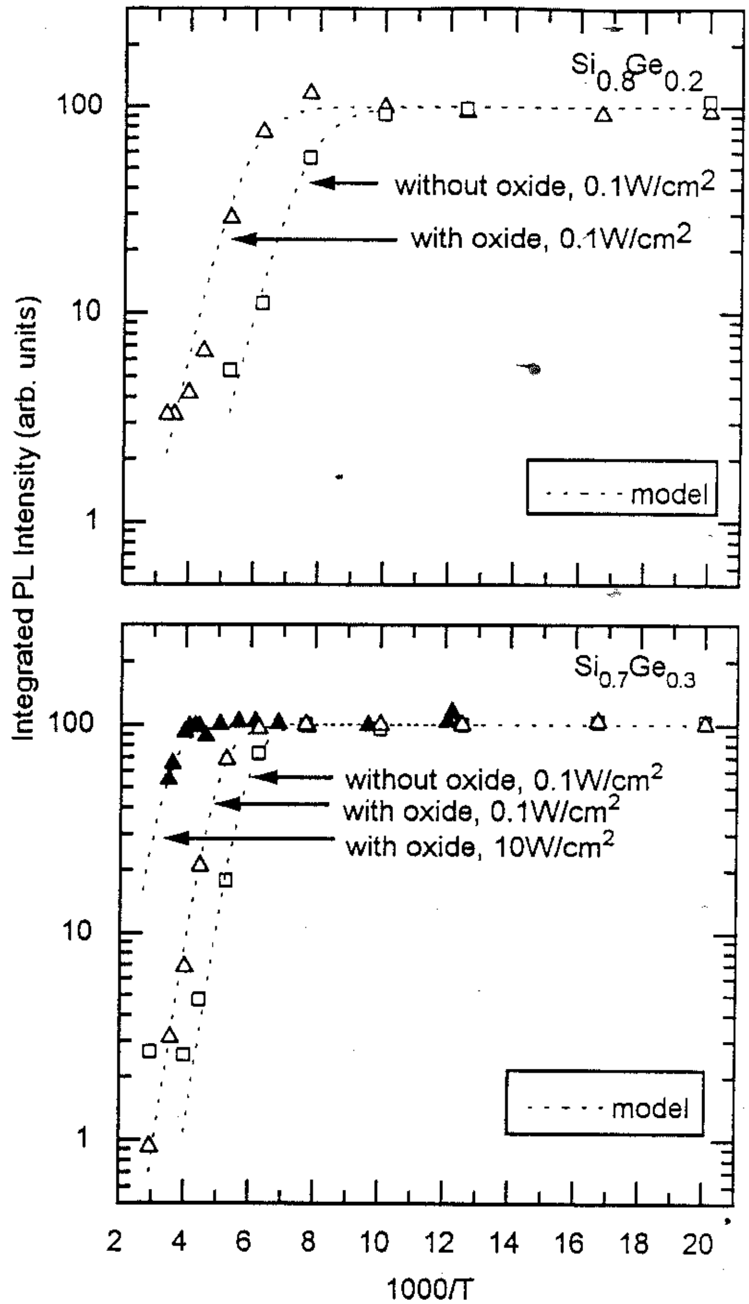

Figure 3. Integrated photoluminescence intensity from $Si_{1-x}Ge_x$ alloy as a function of inverse temperature. The position of the "knee" is determined by the effective carrier lifetime in the Si cladding. Higher temperature of onset of roll-off means higher lifetime.