Indian Nanoelectronics Users Program

Centre for Nano Science and Engineering (CeNSE), IISc. Bangalore

INDIAN SCHOOL OF MINES

उत्तिष्ठत जाग्रत प्राप्य वरान्निबोधत

Modeling, Design and Fabrication of Semiconductor Devices and Solar Cell

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Indian School of Mines Dhanbad, Jharkhand

Year of PhD Registration: 2014

Experience of Teaching & Research (**Supervisor**): More than 14 years

Research Group Details:

Heterostructured Device Group (HDG)

Reseacrh Scholars: Mrs. Bindu Priyadarshini, Mr. Prakash Pareek, Mr. Ravi Ranjan, Mr. Md. Aref Billaha, Mrs. Lipika Mondal, Syed Sadique Anwer Askari

Supervisor: Dr. Mukul K. Das, Assoc. Prof., Dept. of Electronics Engg. & Head, Centre of Excellence in Renewable Energy At ISM Under FAST, MHRD

Research Facility at ISM Dhanbad

X-RAY DIFFRACTOMETER (XRD)
Used for structural determination and phase identification of the materials.

FTIR SPECTROMETER
Used for determination of functional groups of the materials in bulk or thin film form.

FE-SEM SUPRA 55 WITH AIR LOCK, EDS, EBSD
Attachments available with the FE-SEM are Energy Dispersive Microanalysis (Oxford **Liquid Nitrogen free SDD X MAX 50 EDS**), Electron Backscatter Diffraction

THERMOLUMINESCENCE ANALYZER
Used to study the thermoluminescence phenomena, to characterize different defects and to identify different trap levels produced after energetic particle radiation/ionizing radiation.

FLUORESCENCE SPECTROPHOTOMETER
Used to study the photoluminescence phenomenon and to get the idea about the radiative/nonradiative transitions of dopant / host matrix.

SCANNING ELECTRON MICROSCOPE (SEM)
Used to find out Surface morphology and chemical characterization.

Proposed Facilities:

RF/DC sputtering, Thermal and E-beam Evaporation system for thin film deposition under the Project: Centre of Excellence in Renewable Energy, FAST, MHRD.

Simulation Software: CROSSLIGHT APSYS & SILVACO TCAD

HDG is working on:

- **Group-IV Alloy based Solar Cell,**
- **Tin incorporated Group-IV Alloy based Transistor-LASER & Photodetector,**
- **Group III-V compound based Photodetector & High Electron Mobility Transistor (HEMT).**

Si/SiGe Heterojunction Solar Cell

Model

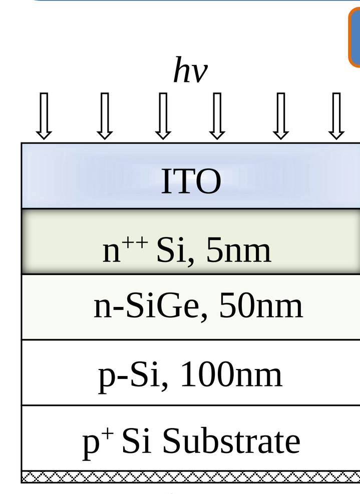
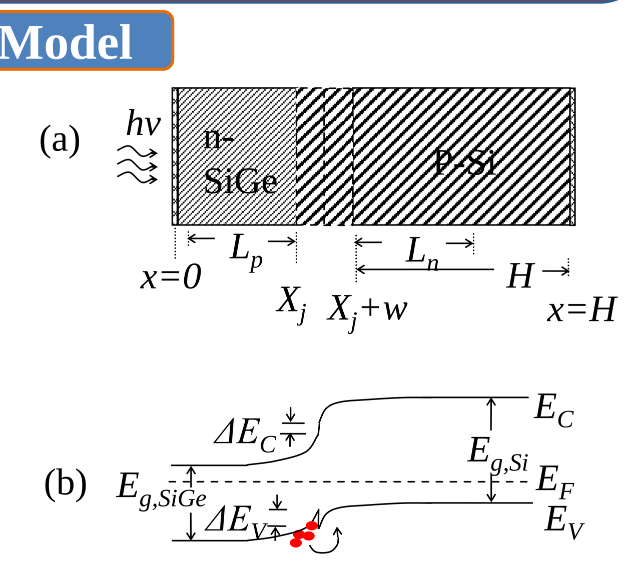


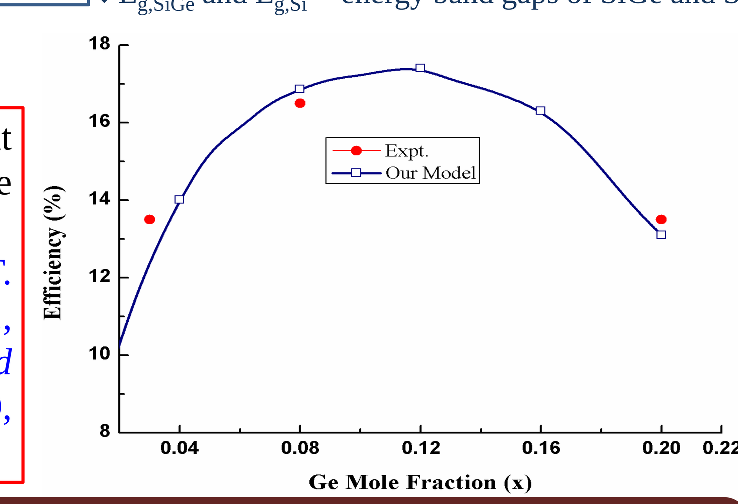
Fig. Device Structure of Si/SiGe Solar Cell



❖ L_n (L_p) are the Diffusion Length of p-type (n-type)
❖ $E_{g,SiGe}$ and $E_{g,Si}$ - energy band gaps of SiGe and Si

Results

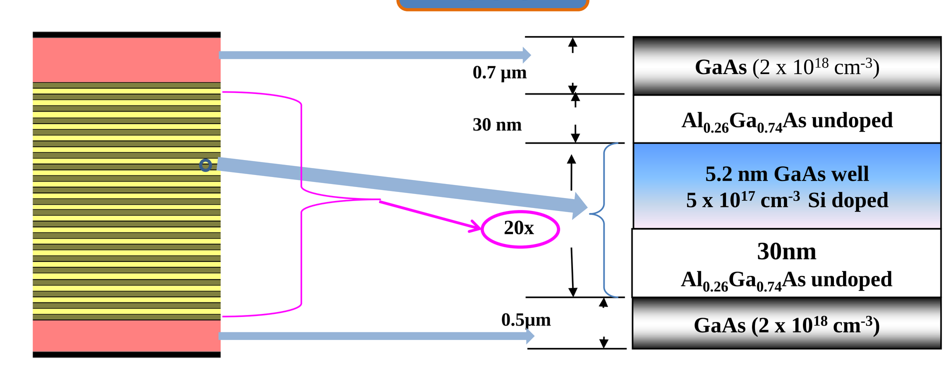
Good agreement with the experimental result [S. T. Chang, *et.al., Thin Solid Films*, Vol. 519, 2011]



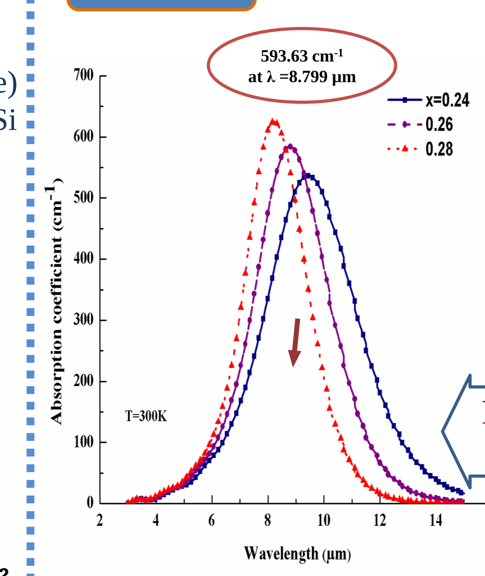
- ✓ **Capability of absorbing solar radiation and heterointerface carrier trapping have combined effect on the performance of the device.**
- ✓ **Variation of efficiency with Ge-content(x) is nonlinear, initially increases and after a particular x, it decreases, hence, choice of Ge-content is very important for the optimized design of solar cell.**
- ✓ **Choice of layer thicknesses in particular for SiGe layer is also important**

Bound-to-Continuum Transition in GaAs/AlGaAs QWIP using APSYS

Model



Results



BAND GAP ESTIMATES AT 300 K

Mole fraction (x)	Band Gap Energy GaAs (eV)	Band Gap Energy $Al_xGa_{1-x}As$ (eV)	Conduction Band Offset (ΔEc) eV	Bound state (eV)
0.24	1.4225	1.7209	0.1850	0.0670
0.26	1.4225	1.7477	0.2016	0.0694
0.28	1.4225	1.7748	0.2134	0.0716

Fig.: Plot of absorption coefficient as a function of wavelength for different x

Good agreement with the experimental result [F. D. P. Alves, et.al., J. Appl. Phys., 103 , 114515, **2008**]

- **Peak absorption coefficient of 593.63 cm^{-1} at λ=8.799μm.**
- **With increase in Al(x) in $Al_xGa_{1-x}As$ alloy, peak absorption coefficient is enhanced.**
- **Detection window will be narrower.**
- **Shifting of detection window is due to the quantum confined stark effect.**

Theoretical Analysis of Direct Transition in Tin Incorporated Strained QW

Structure

$Si_{0.1}Ge_{0.9}$
$Ge_{1-x}Sn_x$
$Si_{0.1}Ge_{0.9}$

- **Potential of compressively strained Group IV QW structures in photonic applications is explored in this work.**
- **SiGe/GeSn QW structure is investigated for photo detection applications by examining its direct transition characteristics.**
- **The simulated results indicate that for x>0.15, GeSn well become direct band gap in nature.**
- **The peak absorption lies in short wave infrared range, so this QW structure can be used for SWIR photodetecion.**

Results

Good agreement with the theoretical result [N. Yahyaoui, et.al., "Band engineering and absorption spectra in compressively strained $Ge_{0.92}Sn_{0.08}$/Ge (001) double quantum well for infrared photodetection" Phys. Status Solidi C, pp.1–5 / DOI 10.1002/ pssc.201400054, **2014**]

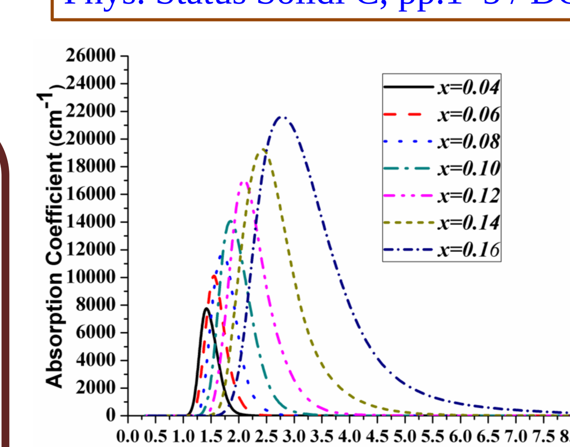


Fig: Plot of absorption coefficient for direct transition. versus wavelength for different values of x. HH- Γ, transition

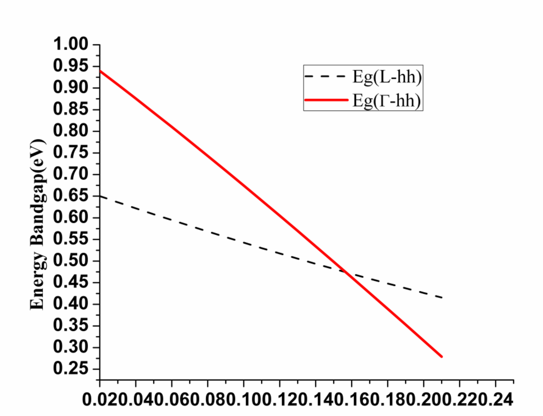


Fig: Plot of direct and indirect bandgap HH- Γ energies as a function of x

Facilities required from IISc, Bangalore

For enhancing our research following Facilities required from IISc, Bangalore :

- **Oxford Instruments Plasma Technology: PECVD for deposition of SiGe layer.**
- **Molecular Beam Epitaxy (MBE) for deposition of GR-IV & III-V compound based layers.**
- **Ellipsometer to determine film thickness and optical constants of deposited layer.**
- **Four Point Probe Mapping System.**
- **Mask Aligner, MICROTECH Laser Writer, Beam Lithography system.**
- **First Nano's EasyTube® 6000 Horizontal Furnace System for Oxidation, Annealing, Diffusion (n-doping and p-doping) and Low Pressure Chemical Vapor Deposition (LPCVD – Silicon nitride, Polysilicon (doped and undoped), SiGe and LTO).**
- **Film Thickness Probe for film thickness mesurement.**