Optical Spectroscopy Study of Material Modification Induced by Ion Irradiation

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Optical spectroscopic probe of materials

Raman spectroscopy

Photoluminescence spectroscopy

Spectroscopic Ellipsometry

UV-VIS optical absorption

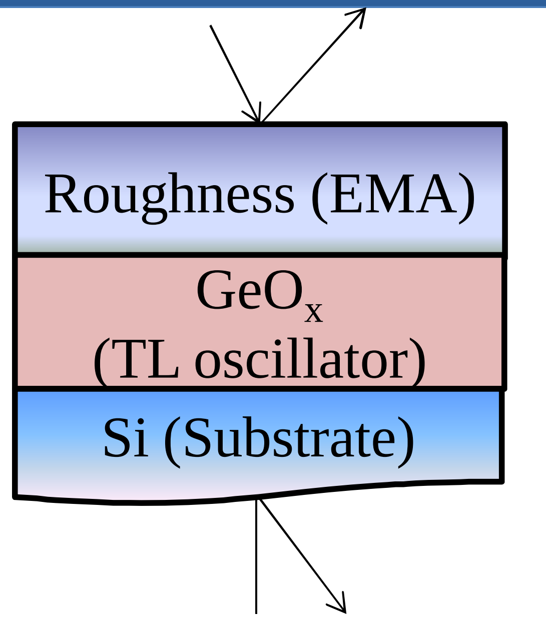
❖ Advantages:

- ❖ Contactless technique
- ❖ High spatial resolution
- ❖ Minimal sample preparation
- ❖ Compositional inhomogenities
- ❖ Rapid measurement
- ❖ Microscopic sample dimensions can be measured

lattice		*Microstructure*		*Impurity and defect*		*Free carrier*		*Wafer quality*	
alloy composition	•	layer thickness	**?**	Presence and type		**concentration**	•	Homogenity mapping	•
orientation	• •	Surface behaviour		**concentration**	•	mobility	•	Optical bandgap refractiveindex	
crystallinity	• •	interface	•			scattering time	•		
stress	•	Layer-by-layer anlaysis	•			resistivity			

Spectroscopic Ellipsometric study of GeO_2 Thin Films

- Ellipsometry is non-destructive and very fast
- Well applied for real time analysis of growing films.
- Ellipsometry is a model-based technique
- Best fit model must be evaluated to fit error and be physical meaningful.



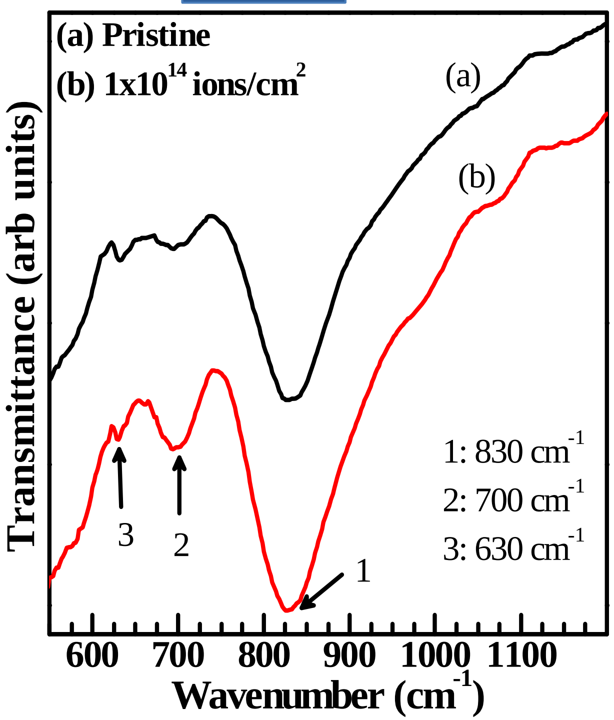
Pelletron facility at IUAC , New Delhi

Ion beam : Ag^{7+}

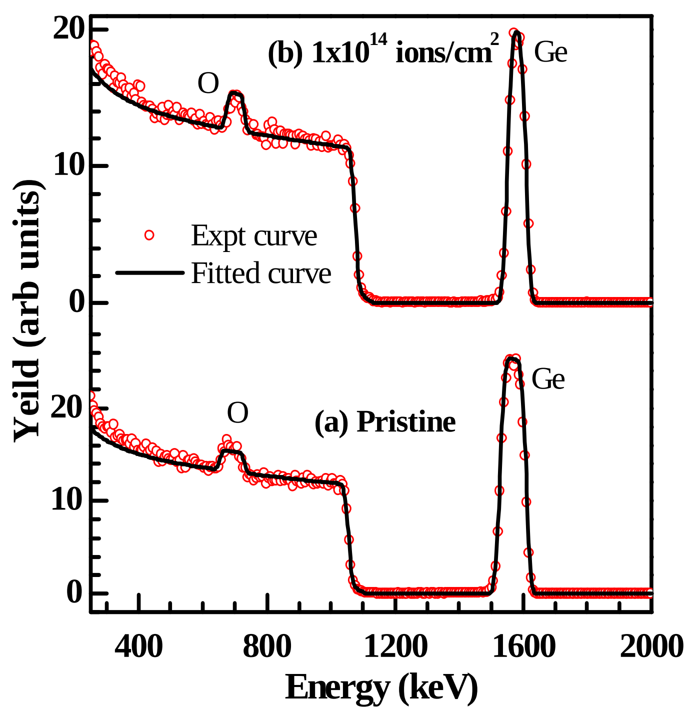
Energy : 120 MeV

Fluence : $3x10^{12}$ to $1x10^{14}$ ions/cm^2

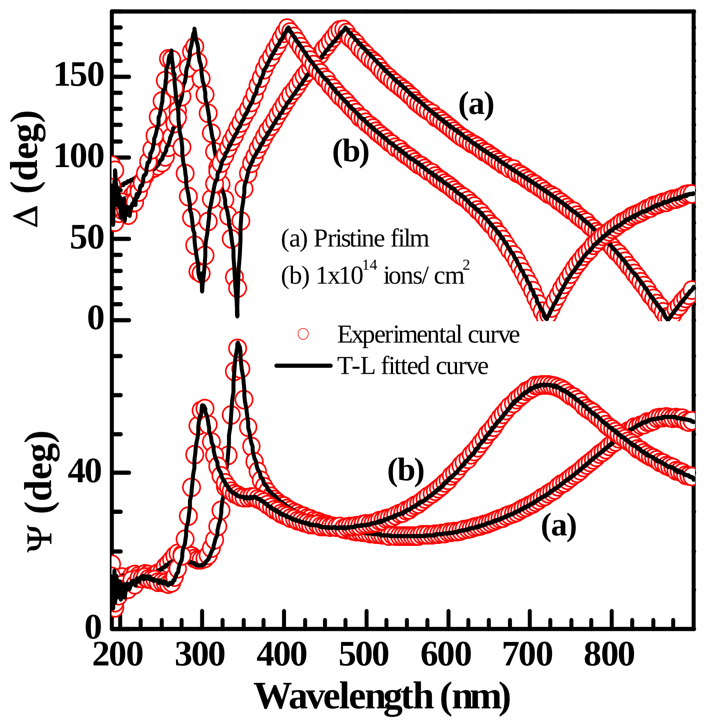
FT-IR



RBS

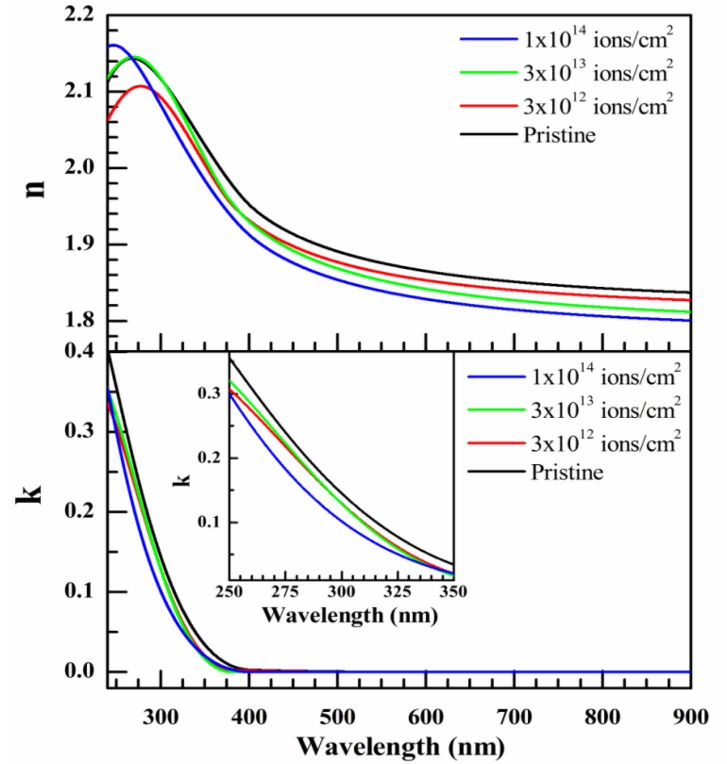


Fitted Psi and Delta spectra

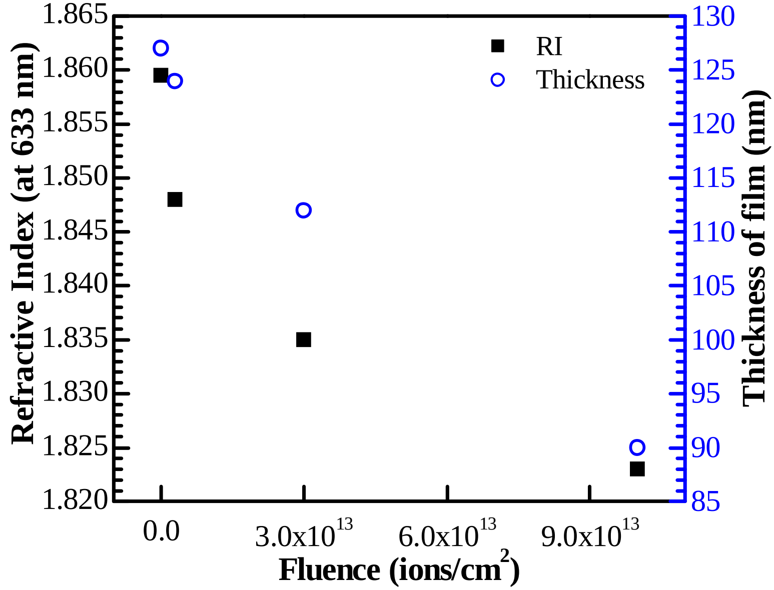


- FTIR spectra confirm the presence of Ge-O-Ge and calculated stoichiometry was 1.2 for pristine.
- RBS also shows the presence of Ge and O and irradiation leads to the more stoichiometry (x=1.2 for pristine and 2 for $1x10^{14}$ ions-cm^{-2} irradiated sample).
- In spectroscopic ellipsometry measurement double Tauc Lorentz oscillator model is used to fit the experimental psi and delta curve.
- Refractive Index is decreasing from 1.860 to 1.823 at 633 nm with increasing fluence because oxygen content is increasing as confirmed by FTIR and RBS measurement.
- Thickness also decreasing from 126 nm to 90 nm in higher fluence due to sputtering effect while ion beam irradiation.
- The hump around 290 nm in refractive index spectra is getting shifted to higher energy side for film after irradiated at a fluence of $1x10^{14}$ ions-cm^{-2}. This is because after irradiation GeO_x (x=1.2) is changing to GeO_y (y=2) and GeO_2

Sample	Thickness Change from pristine (nm)		Sputtered thickness from TRIM (nm)
	Spectroscopic Ellipsometry	RBS	
$3x10^{12}$ ions/cm^2	3	10	2.2
$1x10^{13}$ ions/cm^2	7	6	7.5
$3x10^{13}$ ions/cm^2	15	26	22
$1x10^{14}$ ions/cm^2	37	34	75



Spectral dependence of refractive index and extinction coefficient



Variation of thickness and refractive index with fluence

Spectroscopic Ellipsometric study of SiC Thin Films

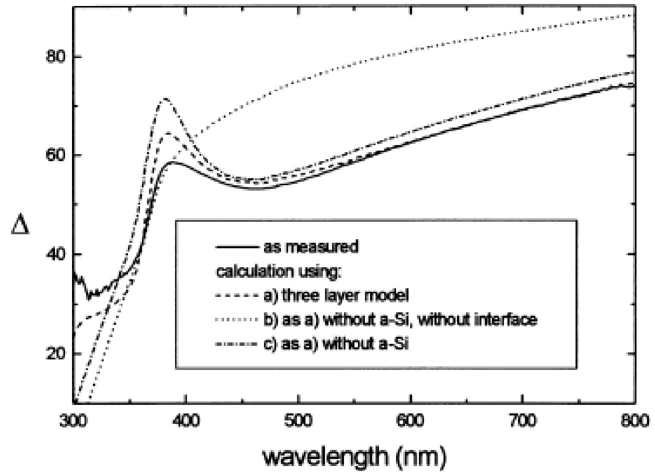
Wohner et al - Thin Solid Films 364 (2000) 28-32

- Film growth and morphological defects during carbonization can be monitored and controlled by in-situ SE study
- In-situ monitoring of SiC during ion irradiation or implantation can help as to understand defect formation due the process.

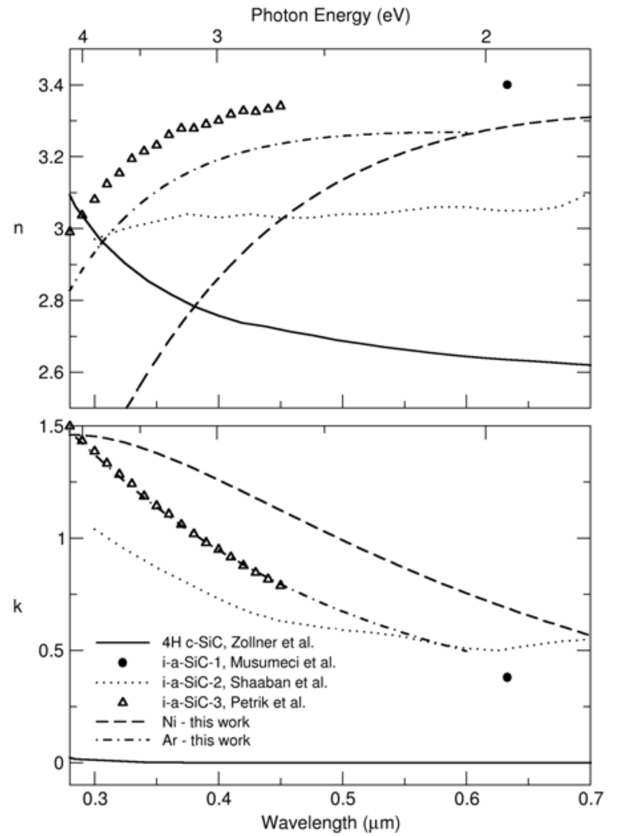
Lohner et al., Phys. stat. sol. (c) 5, No. 5, 1374–1377 (2008)

Ion beam : Ni and Ar
Energy : 860 keV and 40 keV
Fluence : $1x10^{16}$ and $3x10^{15}$ ions/cm^2

The change in the refractive index and absorption co-efficeint with ion and fluence is attributed to a stoichiometric change and structural transformation.



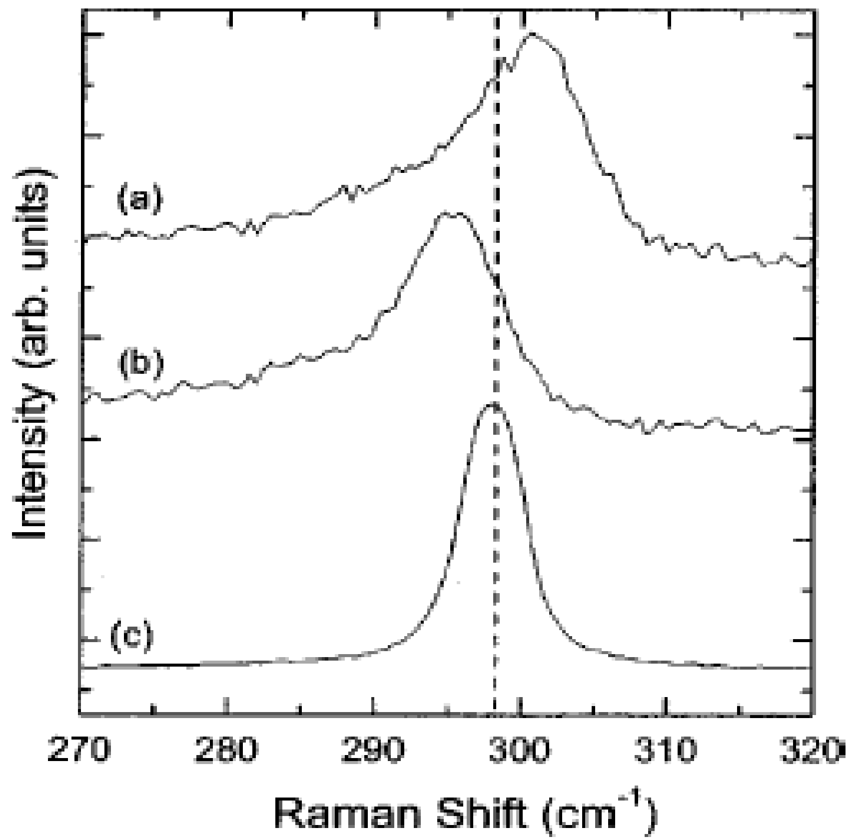
Ellipsometric Δ spectrum after SiC growth on Si(111)



Raman study of Ge nanocrystals embedded in silica

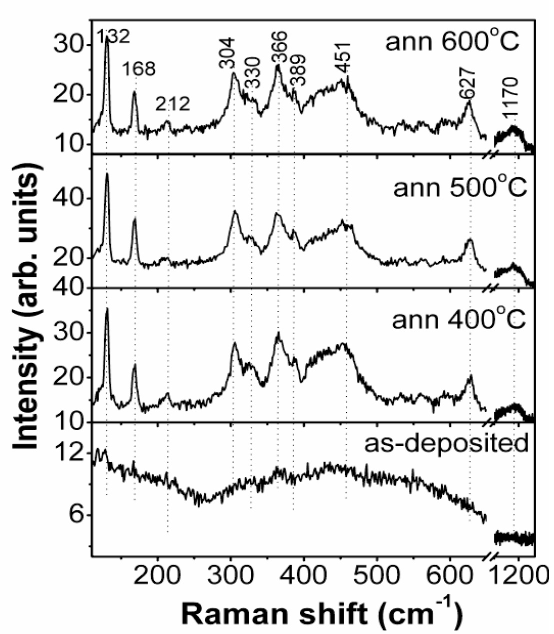
I.D. Sharp et al Appl.Phys. Lett. ***86*** *063107 (2005)*

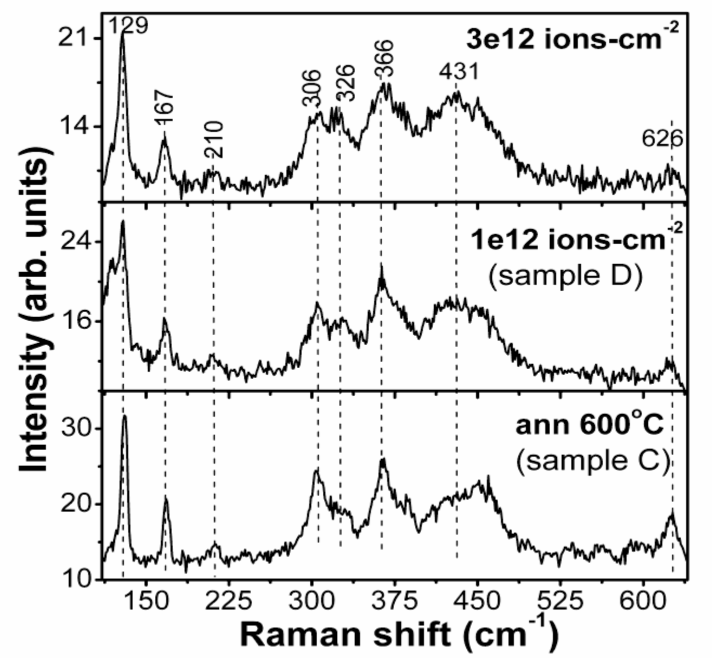
- 500 nm thermally grown SiO^2 on Si substrate
- Multi-energy implantation
- 50 keV 1.1016 cm^{-2}
- 80 keV $1.2x10^{16}$
- 120 Kev 2.10^{16}
- Thermal annealing in Ar atmosphere at 900 ^{o}C followed by quenching
- Raman spectra recorded with 488 nm line of Ar laser using 150 mW power.
- Post-growth annealing smaller Raman shifts reduces compressive stress
- Stress generated during growth of Ge nanocrystals in a silica matrix can be controlled by post-growth thermal annealing
- The stress can be estimated by RS.
- Compressive stress :achieve self-organisation and control over size distribution

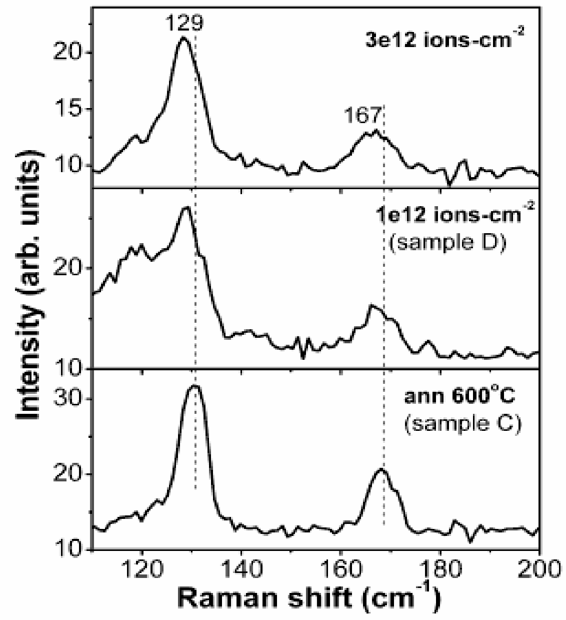


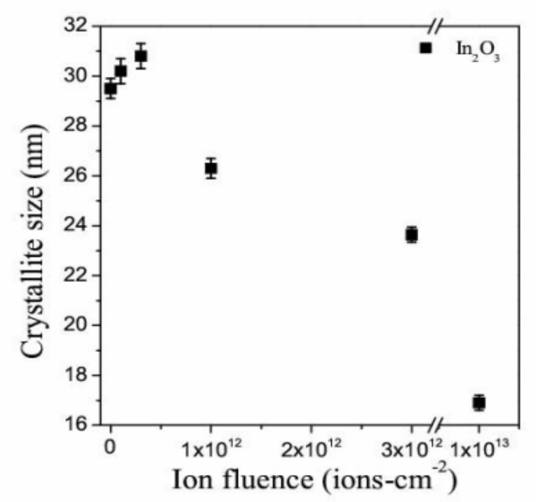
Bulk Ge
As grown Ge NC embedded in SiO2
After post-growth thermal annealing

Raman spectra of indium oxide: disorder induced by SHI









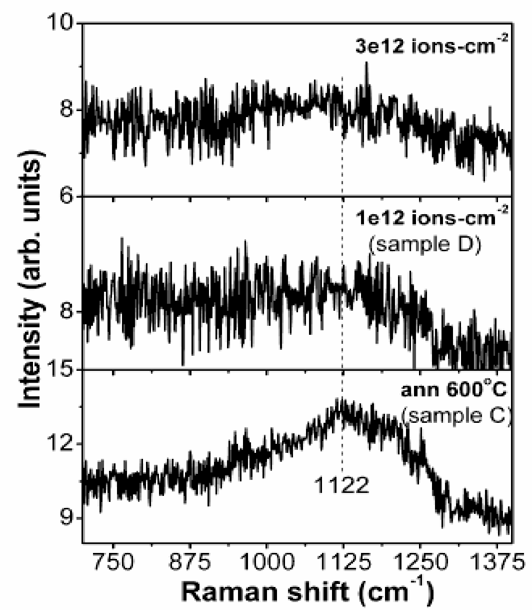
Pelletron facility at IUAC , New Delhi

Ion beam : Ag^{7+}

Energy : 100 MeV

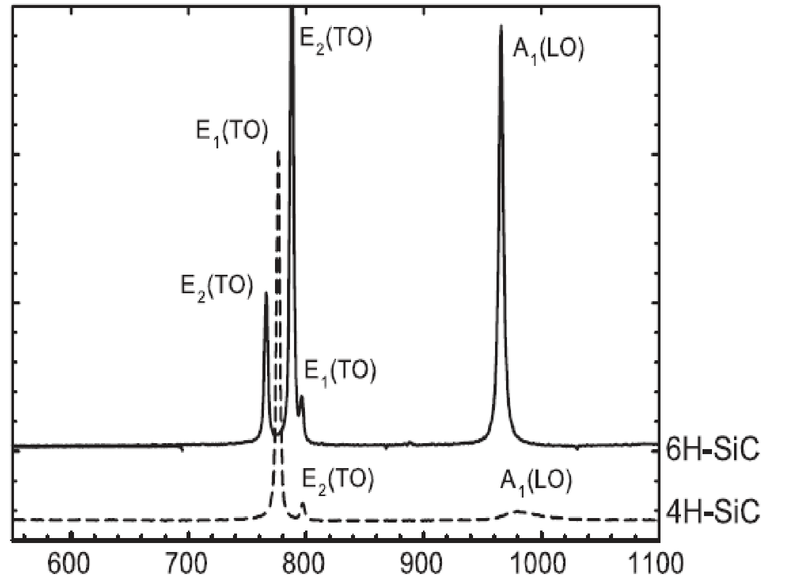
Fluence : $1x10^{12}$ and $3x10^{13}$ ions/cm^2

- Reduction in crystallite size
- Broadening & asymmetry of Raman modes
- Analysis of stress and strain by fitting

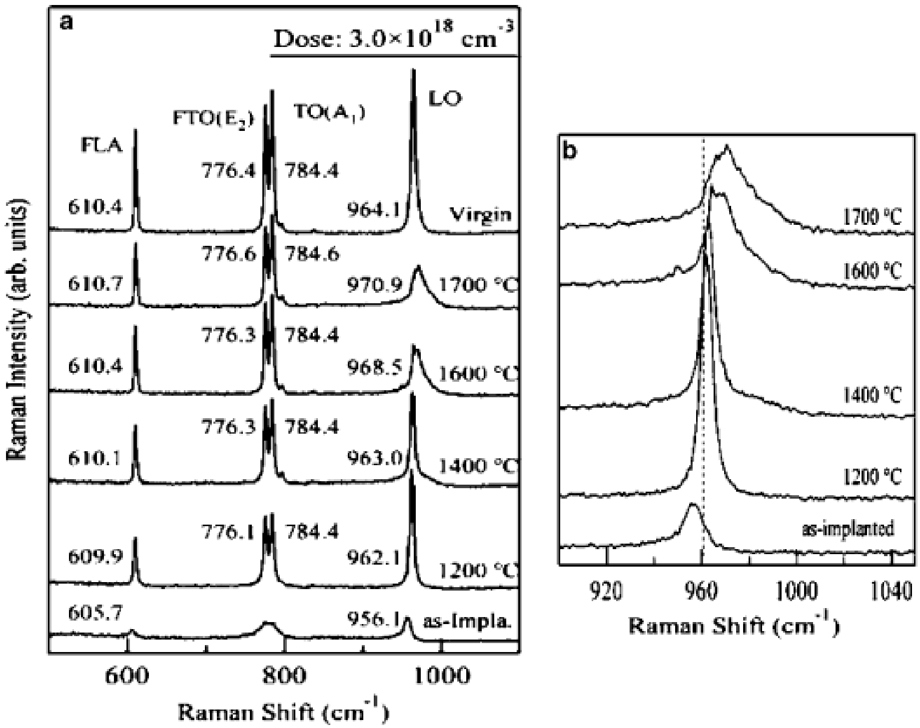


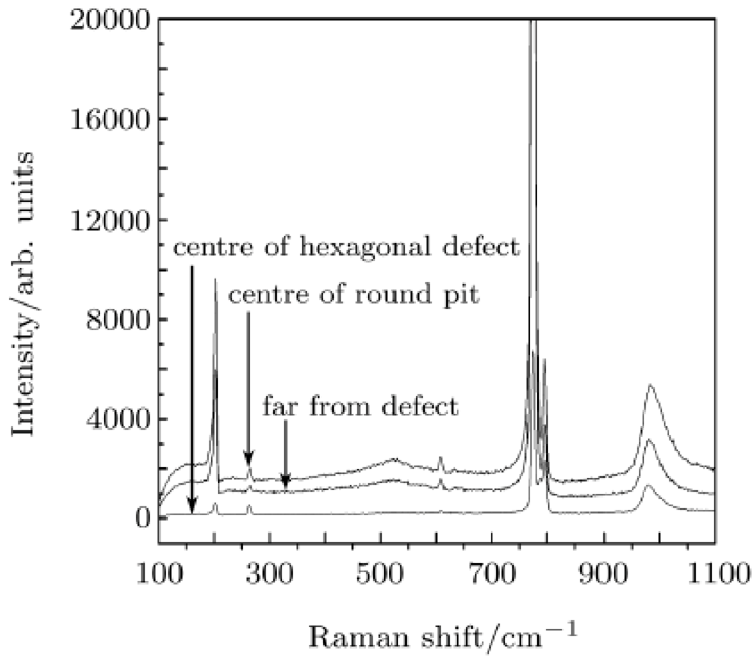
Defects study in SiC by Raman

- SiC wafers contain dislocations, planar defects (triangular or polygonal), round pits, micropipes and so on.
- The first-order Raman spectrum of SiC is sensitive to defects, so it is very reliable to use Raman to study defect
- The intensity of the first-order Raman peaks is comparable between the defects



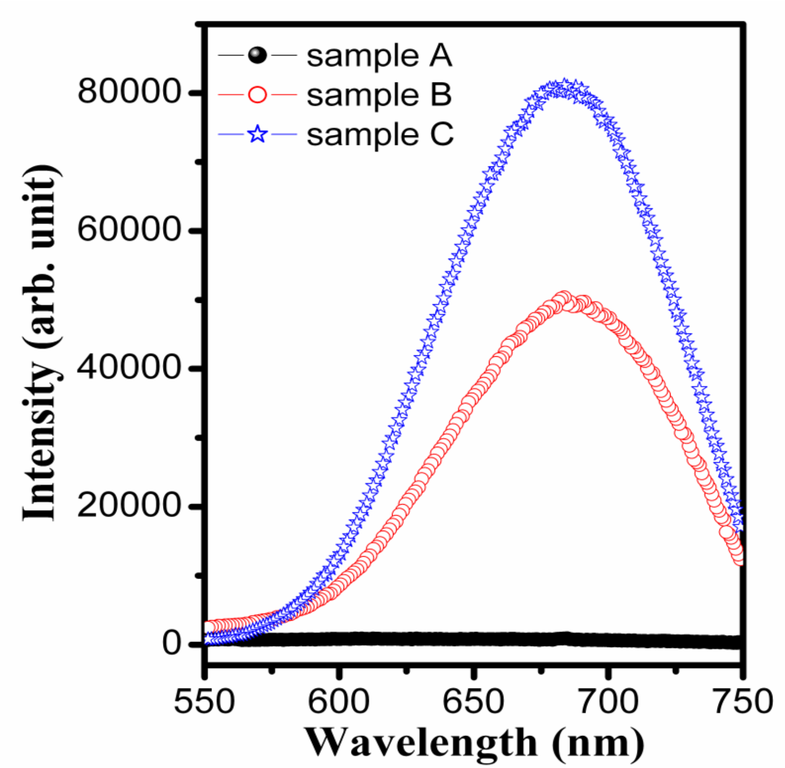
H. Harima / Microelectronic Engineering 83 (2006) 126–129



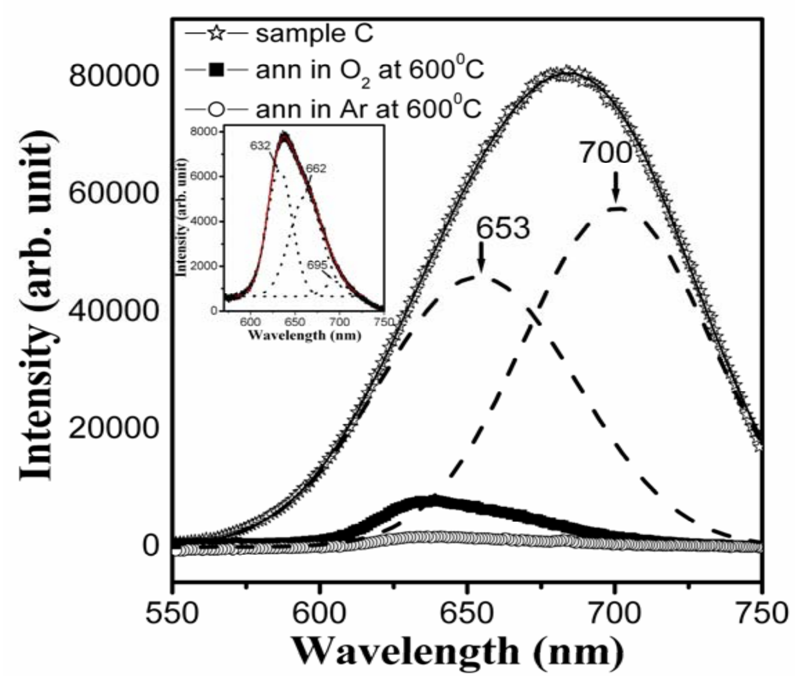


Raman spectra for n-type 4H-SiC taken at room temperature with excitation at 514.5 nm.

PL study of In_2O_3 Thin Films



A	Pristine
B	$1x10^{11}$ ions-cm^{-2}
C	$1x10^{12}$ions-cm^{-2}
D	$1x10^{13}$ ions-cm^{-2}



- A strong and broad PL peak centered at 680 nm is observed.
- Suggesting the incorporation of larger number of structural defects with the increasing ion fluence from 1×10^{11} to 1×10^{12} ions-cm^{-2}.
- Annealing in oxygen atmosphere results the suppression of both the PL band whereas, annealing in argon atmosphere shows the persistence of 653 nm PL band.
- SHI irradiation creates oxygen vacancies and other stable defects such as point defects, vacancies, interstitials, trapping centers etc., which can not be annealed out even after annealing at 600˚C.