On the dynamics of phase separation under laser irradiation of Si/Ge rich oxides

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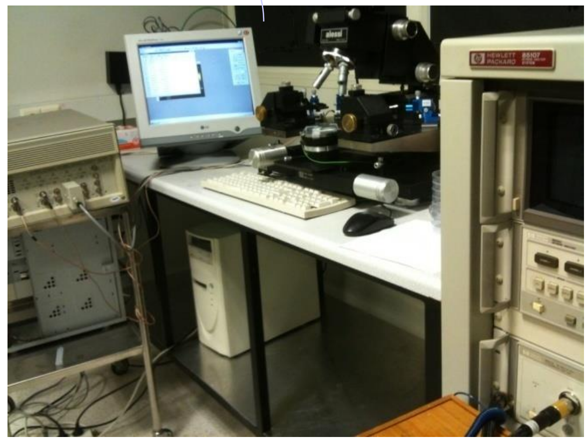
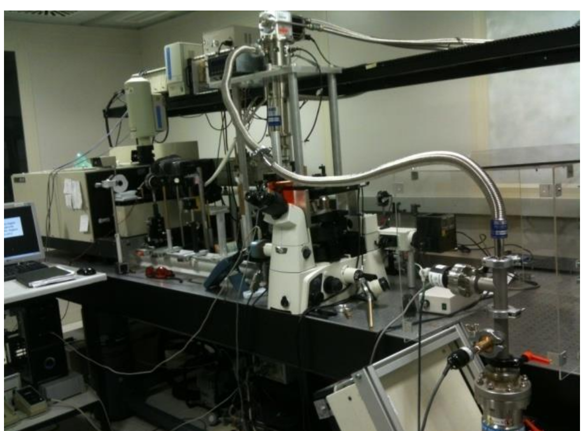
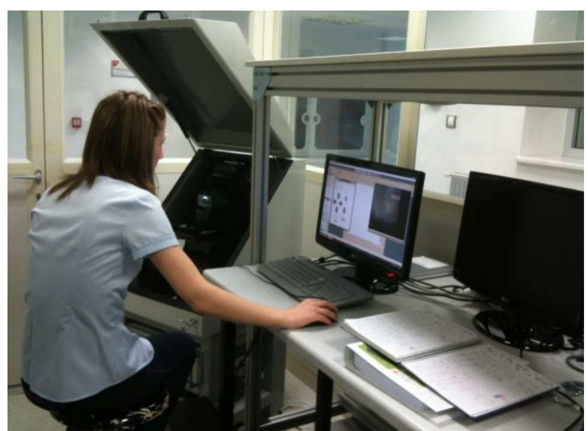
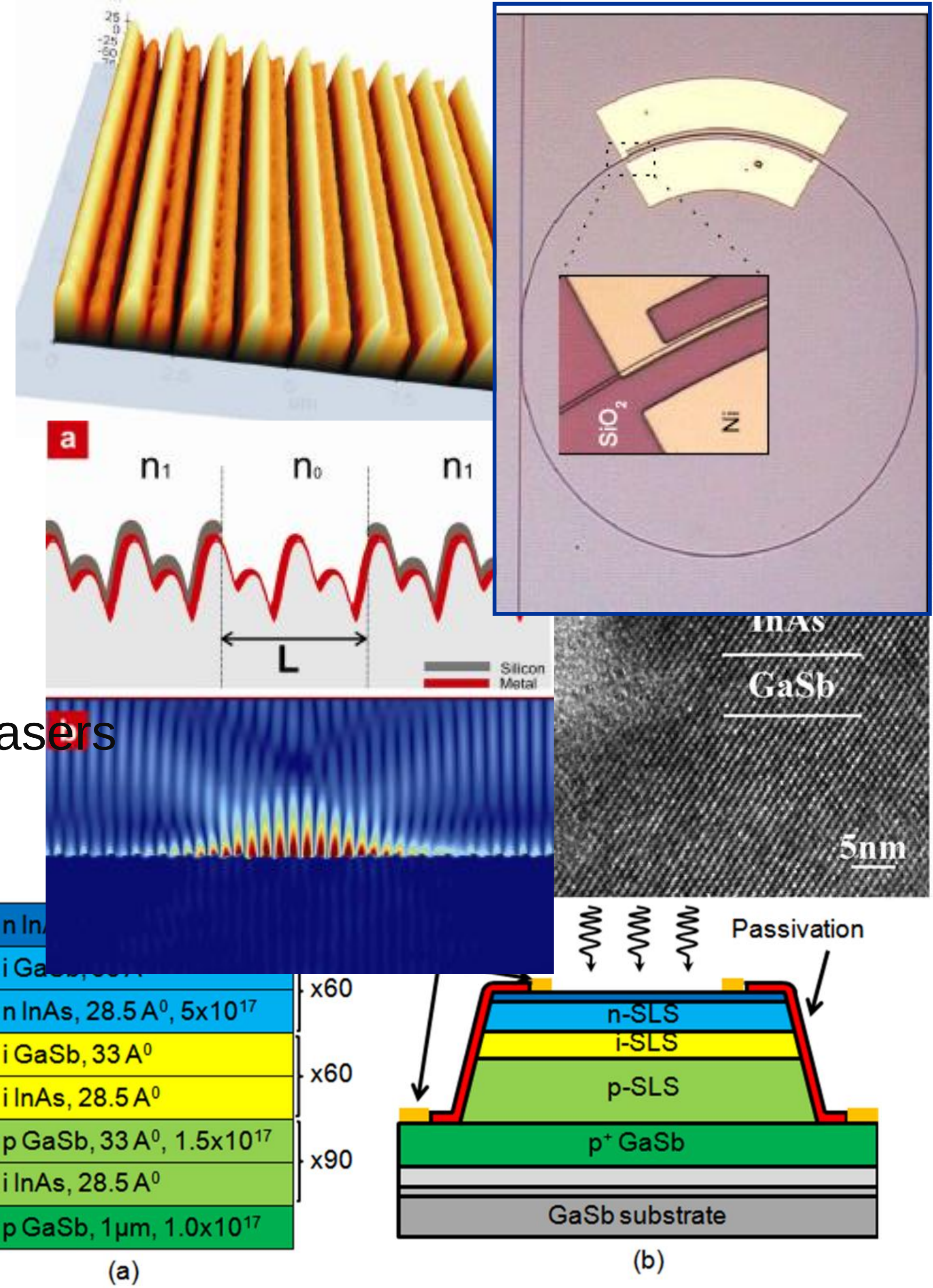



Research Portfolio

- InGaN/GaN Blue LEDs
- Type II SL IR photodetectors
- Quantum cascade lasers
- Si/Ge nanocrystals for solar cells
- Plasmonic cavities
- Plasmon-exciton interactions
- InGaAs/AlGaAs High power diode lasers
- Laser-matter interactions



Si/Ge nanocrystals for solar cells

Solar Cells: First Generation

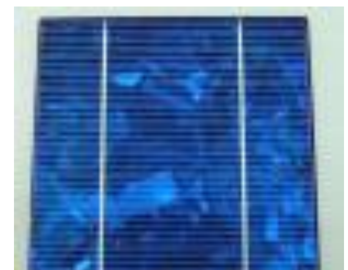
Single crystal Si

Multi crystal Si

Si single crystal based PV solar cells

Module efficiency: %15-20

Market share: % 35



Module efficiency: %13-16

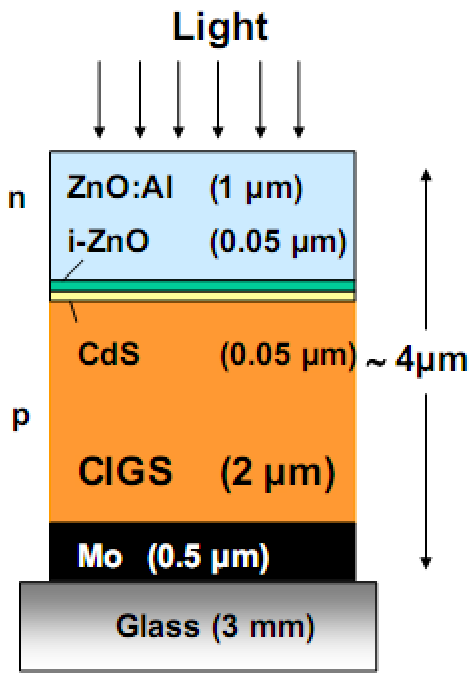
mc-Si PV Solar Module

Market share: % 49

Solar Cells: Second Generation

Module efficiency: %11-13

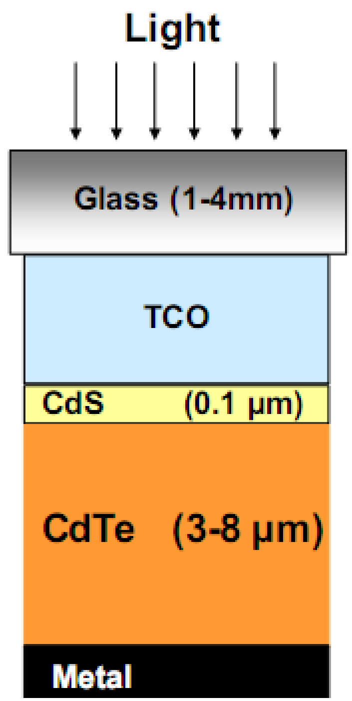
CIGS



Market share <%1

Module efficiency: %10-12

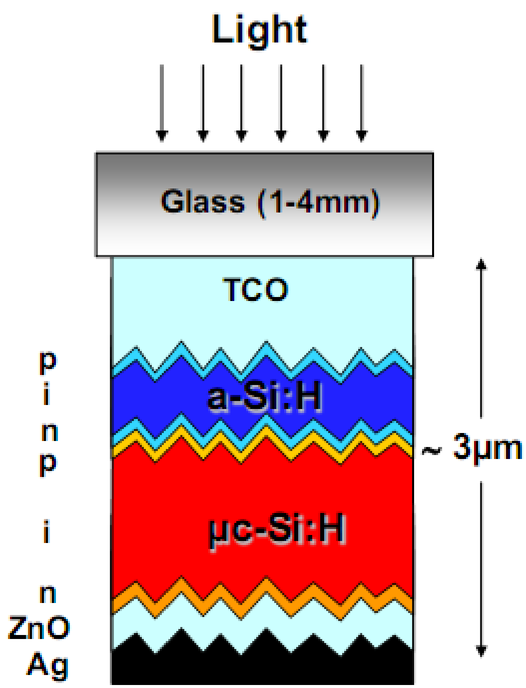
CdTe



Market share : % 8

Module efficiency: %8-10

a-Si/µc-Si



Market share : % 5

THIN FILM SOLAR CELLS

Third Generation Solar Cells

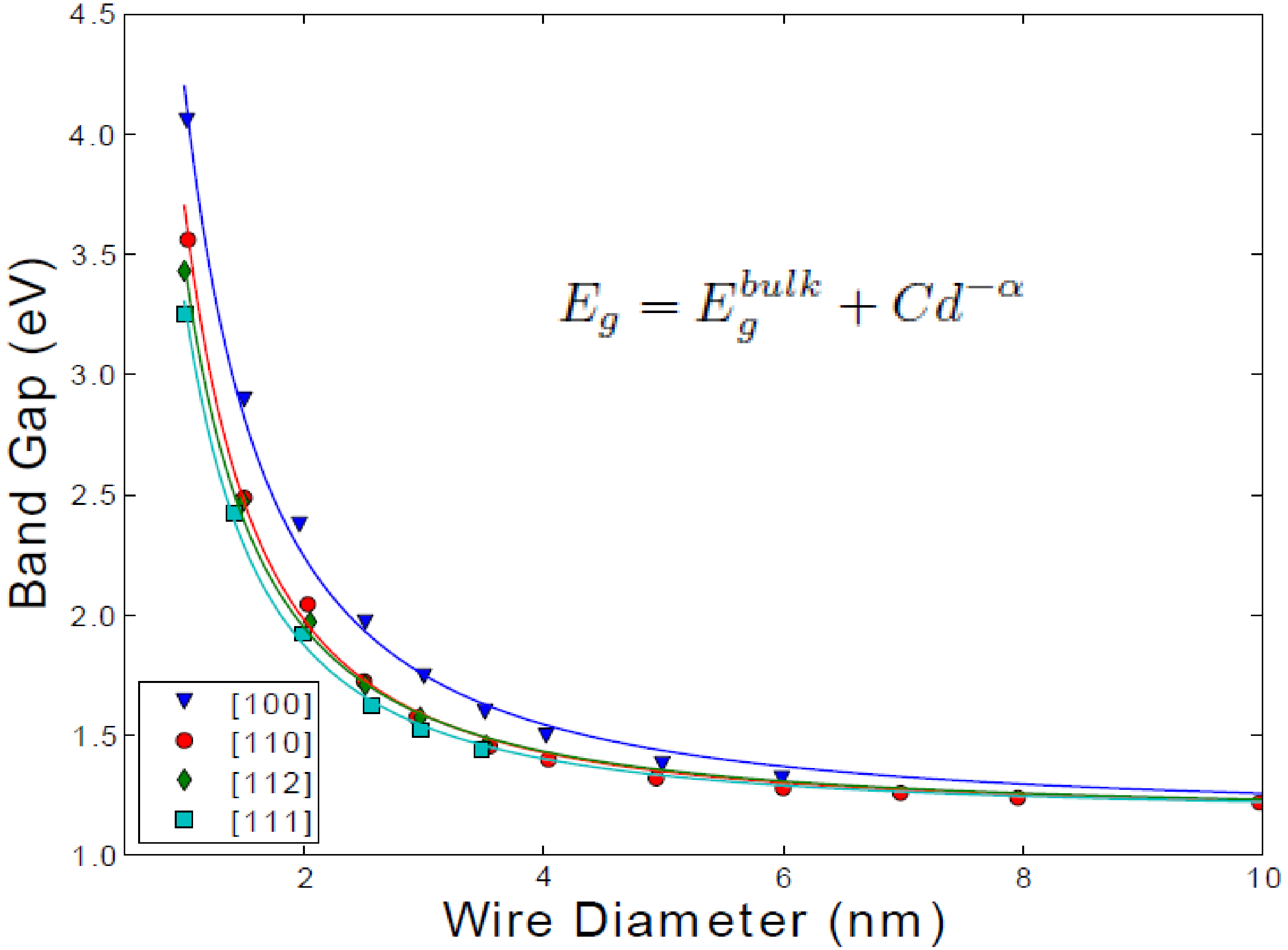
Any solar cell concept with limiting efficiency exceeding the single junction limit

3rd generation solutions

Nanosponge, Si/Ge Nanocrystal Networks

Main Motivation : lower cost, higher efficiency and/or lower production cost

Motivation: bandgap variation with the size
Si Nanowires in SiO_2



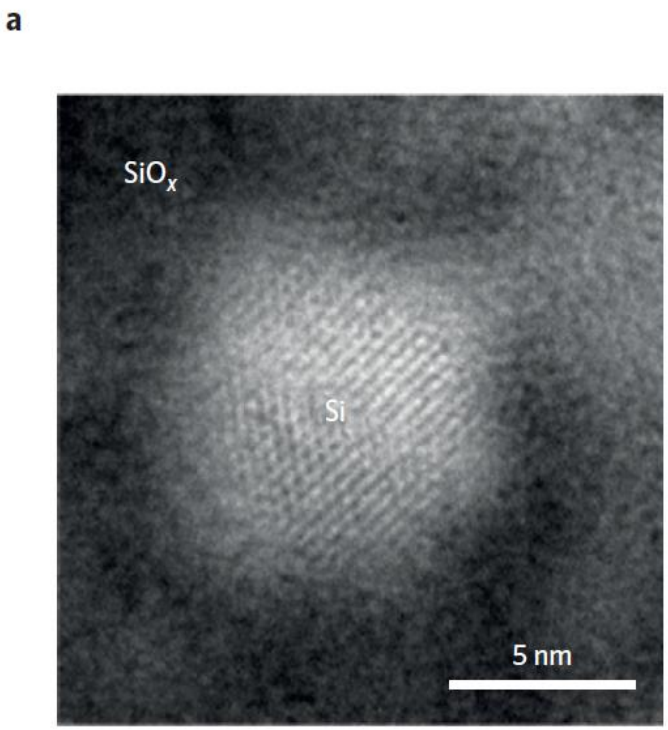
Courtesy:
C. Bulutay

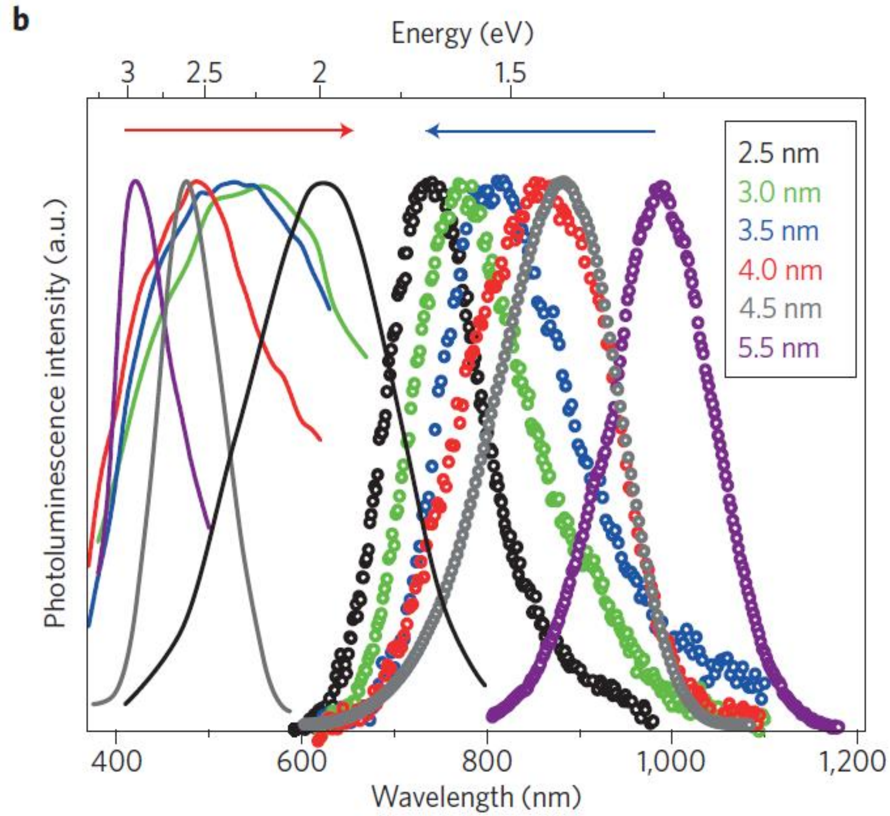
[1] Ma, D. D. D., C. S. Lee, F. C. K. Au, S. Y. Tong, and S. T. Lee, 2003, Science 299, 1874.

[2] Yan, J.-A., L. Yang, and M. Y. Chou, 2007, Phys. Rev. B 76, 115319.

[3] Delerue, G. Allan, and M. Lannoo, 1993, Phys. Rev. B 48, 11024.

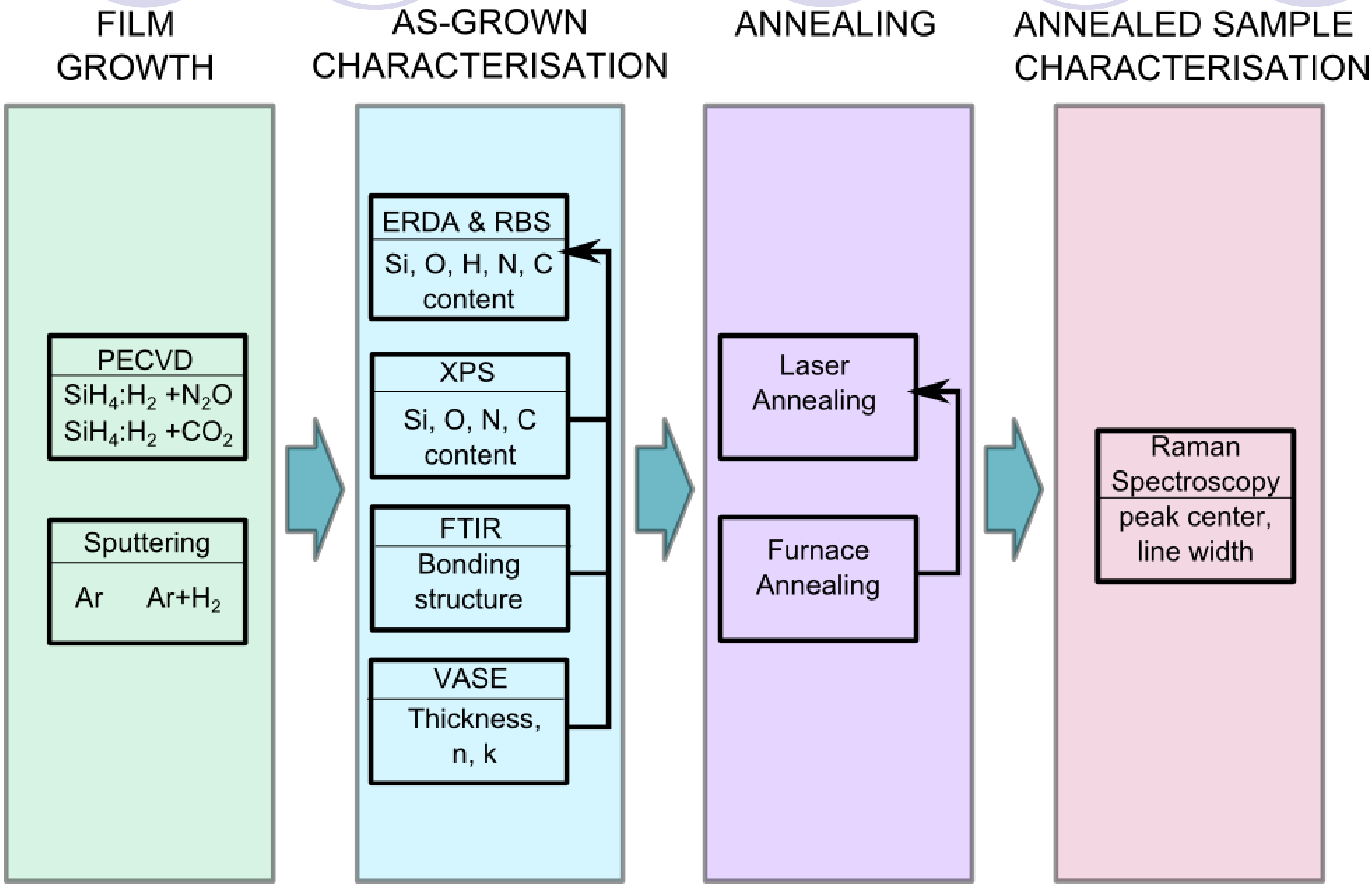
Bandgap variation with the size





Priolo et al., Nature Nanotechnology, 2004

Experiment

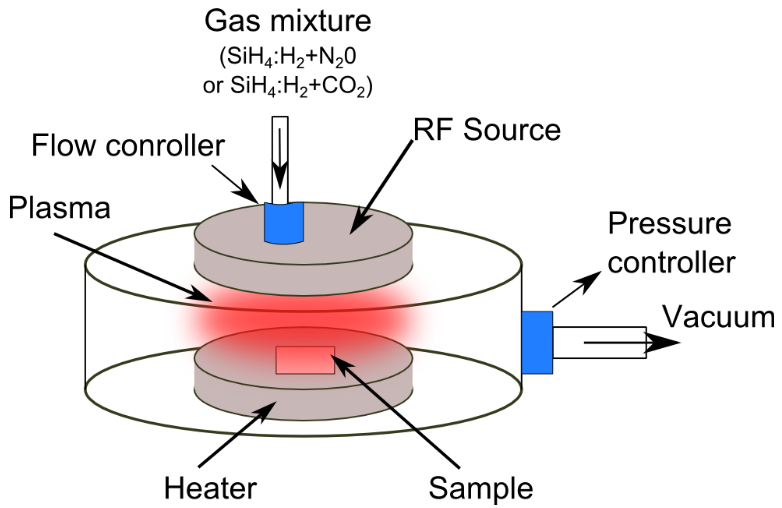


FILM GROWTH
AS-GROWN CHARACTERISATION
ANNEALING
ANNEALED SAMPLE CHARACTERISATION
PECVD
SiH_4:H_2 +N_2O
SiH_4:H_2 +CO_2
Sputtering
Ar
Ar+H_2
ERDA & RBS
Si, O, H, N, C content
XPS
Si, O, N, C content
FTIR
Bonding structure
VASE
Thickness, n, k
Laser Annealing
Furnace Annealing
Raman Spectroscopy
peak center, line width

Experiment

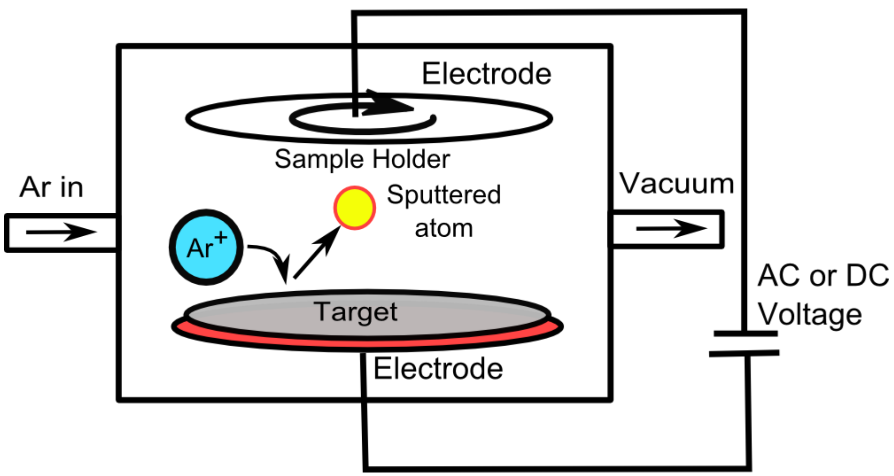
PECVD

H series : SiH_4:H_2 + N_2O
N series : SiH_4:N_2 + N_2O
C series : SiH_4:H_2 + CO_2



Sputtering

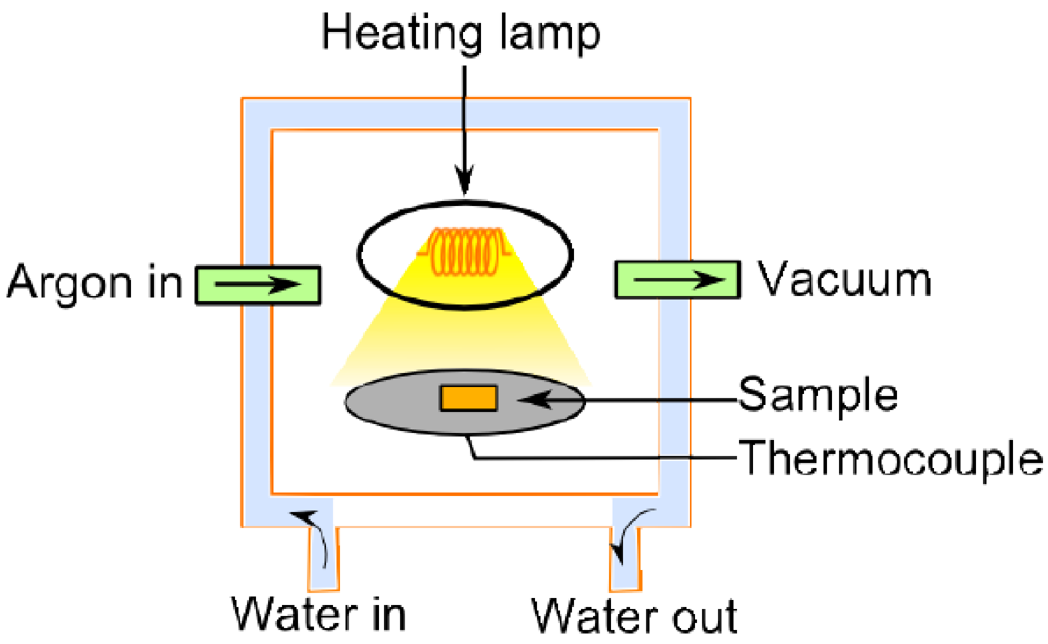
Base pressure	4.5x10−6 Torr
Working pressure	4 mBar
Process gases	Ar 20 sccm H_2 4 sccm
Process temperature	Room temperature
Time	1 hour
Power (Si)	54 W DC
Power (SiO_2)	180 W RF
Film thickness	250 nm



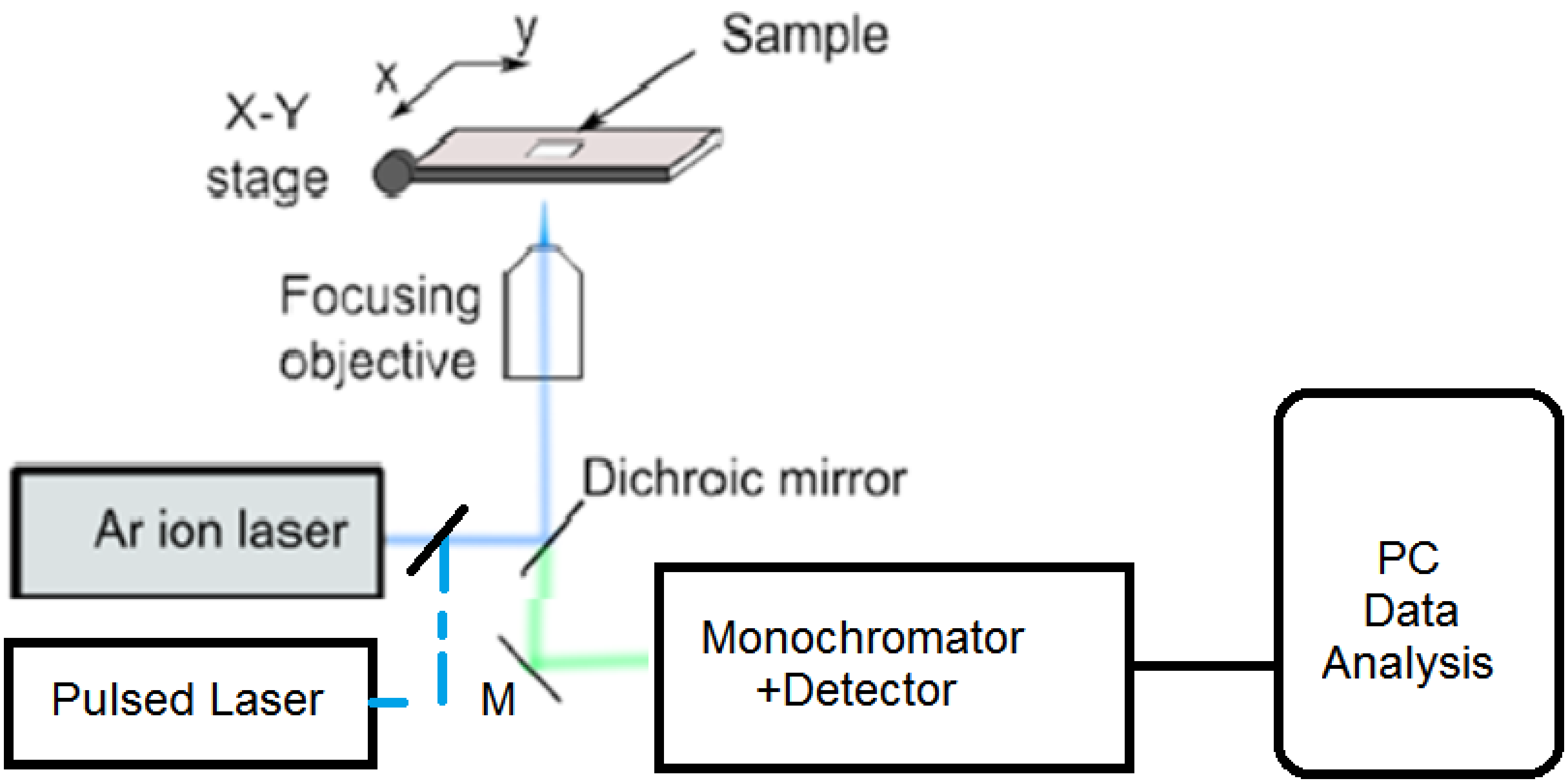
O/Si ≈1

Experiment: Furnace Annealing

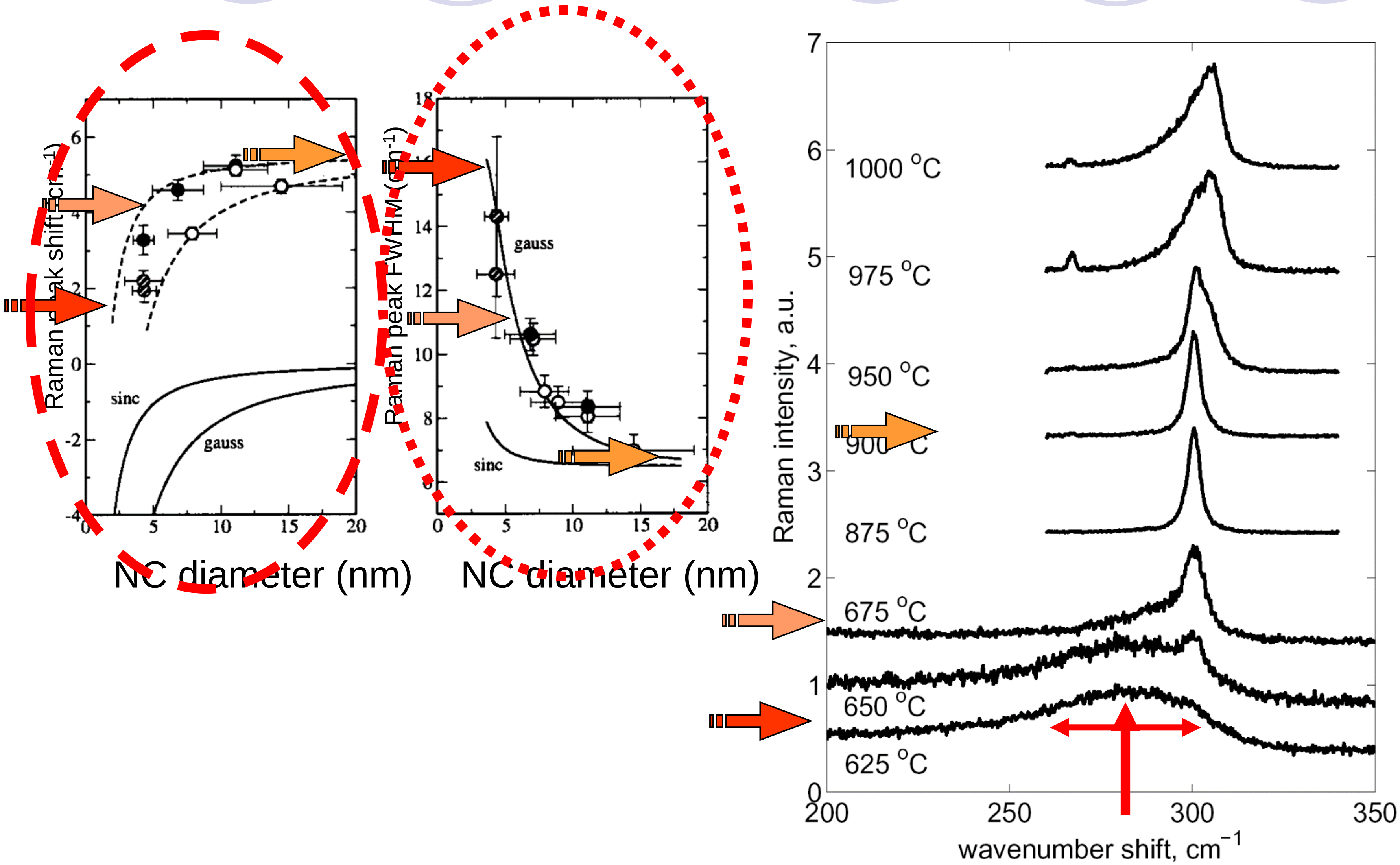
- (Rapid Thermal Procesing)



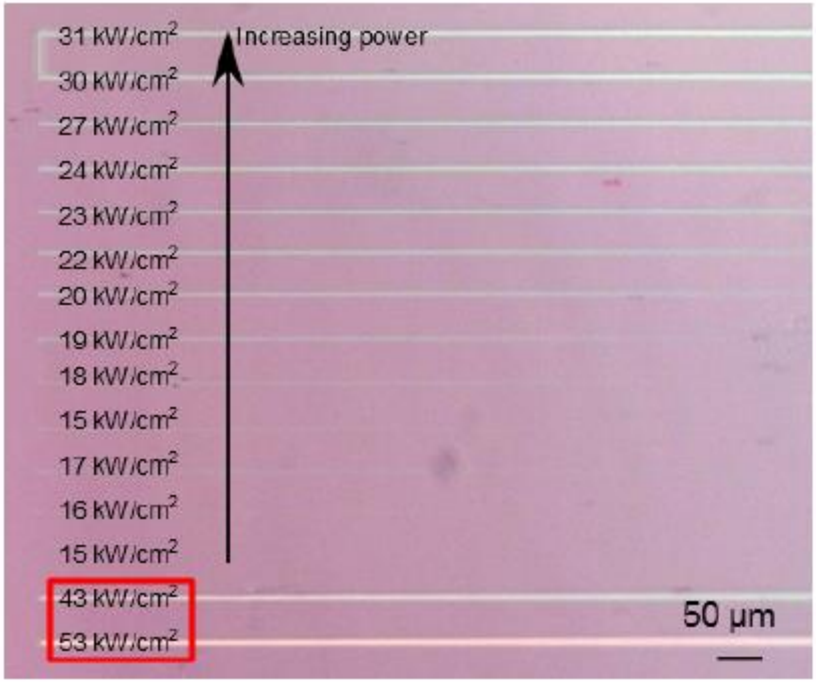
Experiment:Laser processing

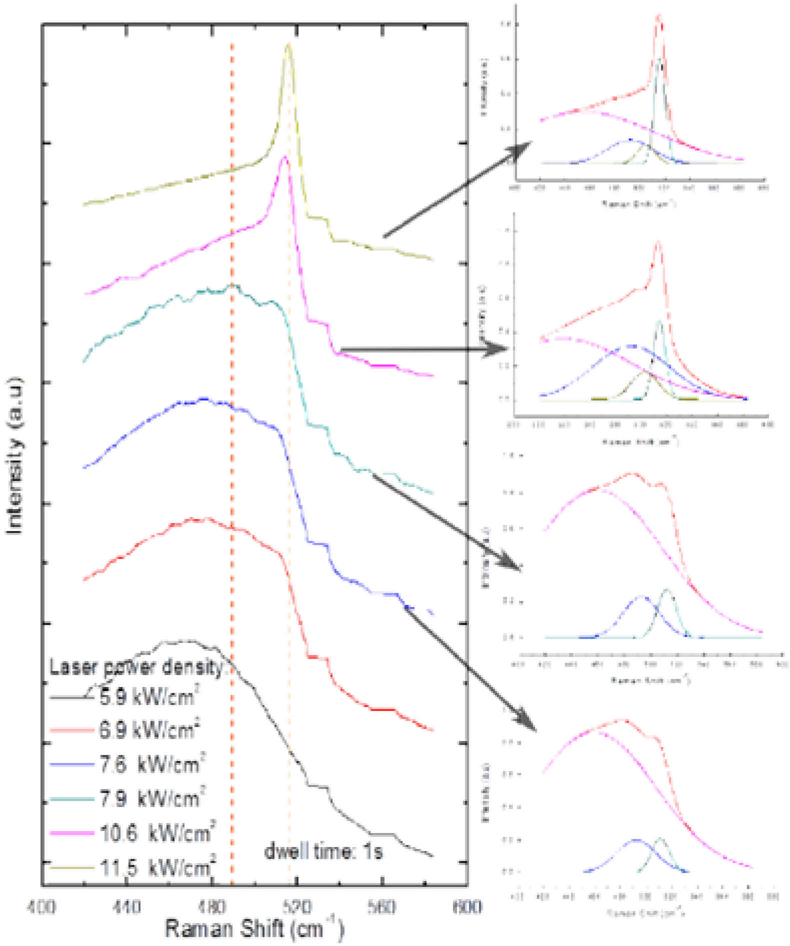


Raman characterization



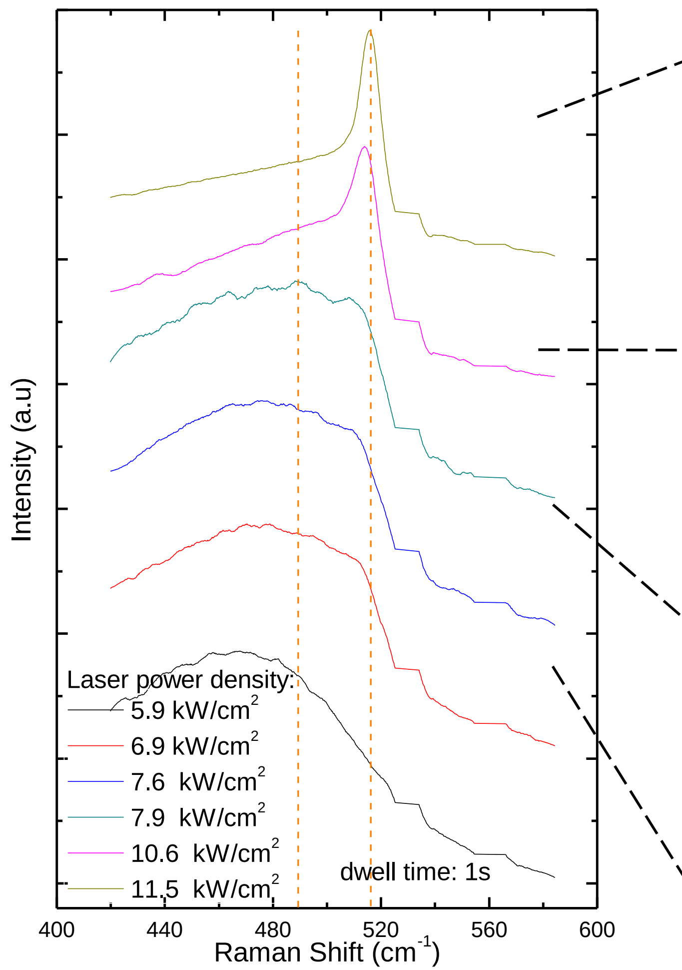
Laser Processing

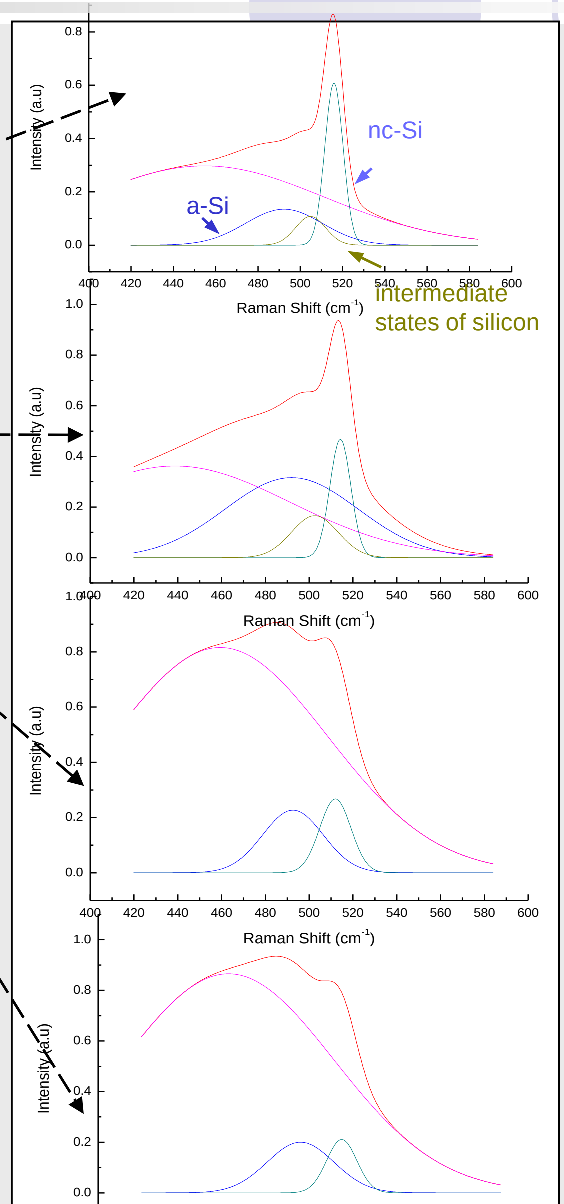




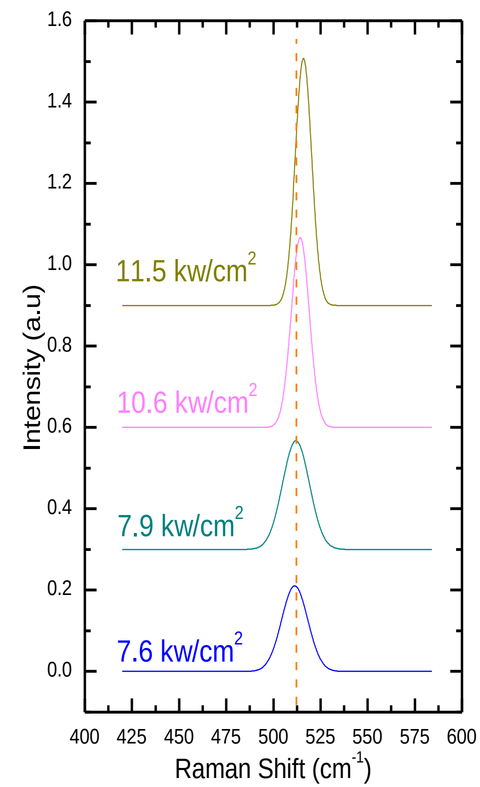
Sample H3

Raman spectroscopy analysis of laser annealed SiO_x films: effect of irradiation laser power density.





Si_{nc} peak after deconvolution



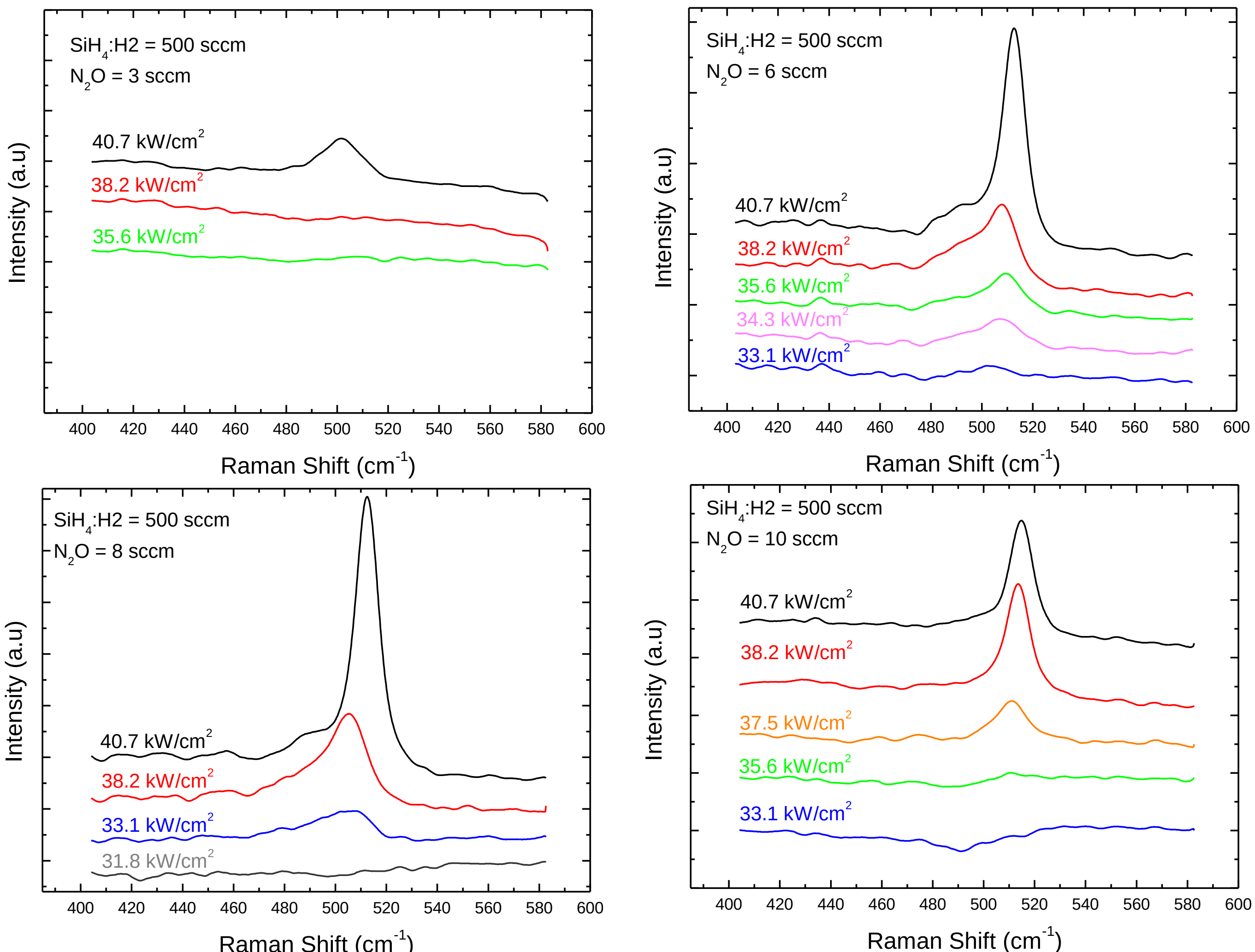
PECVD grown sample, precursor gasses: *SiH_4:H_2 500sccm / N_2O 6sccm*

-peak shift from 512 to 516 cm^{-1}

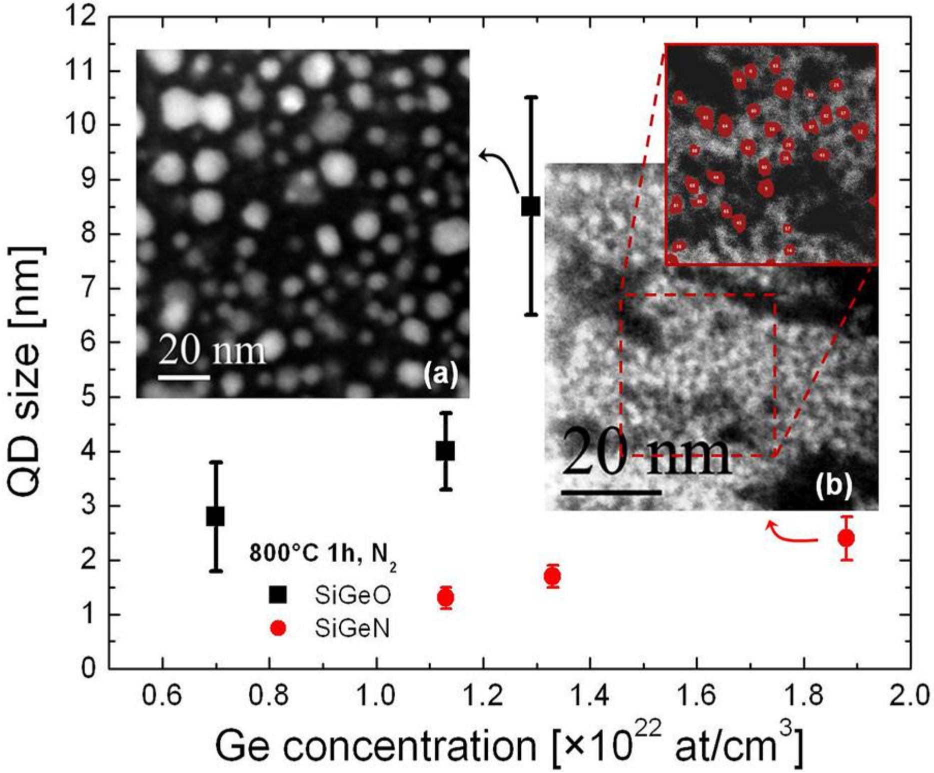
-decrease of FWHM

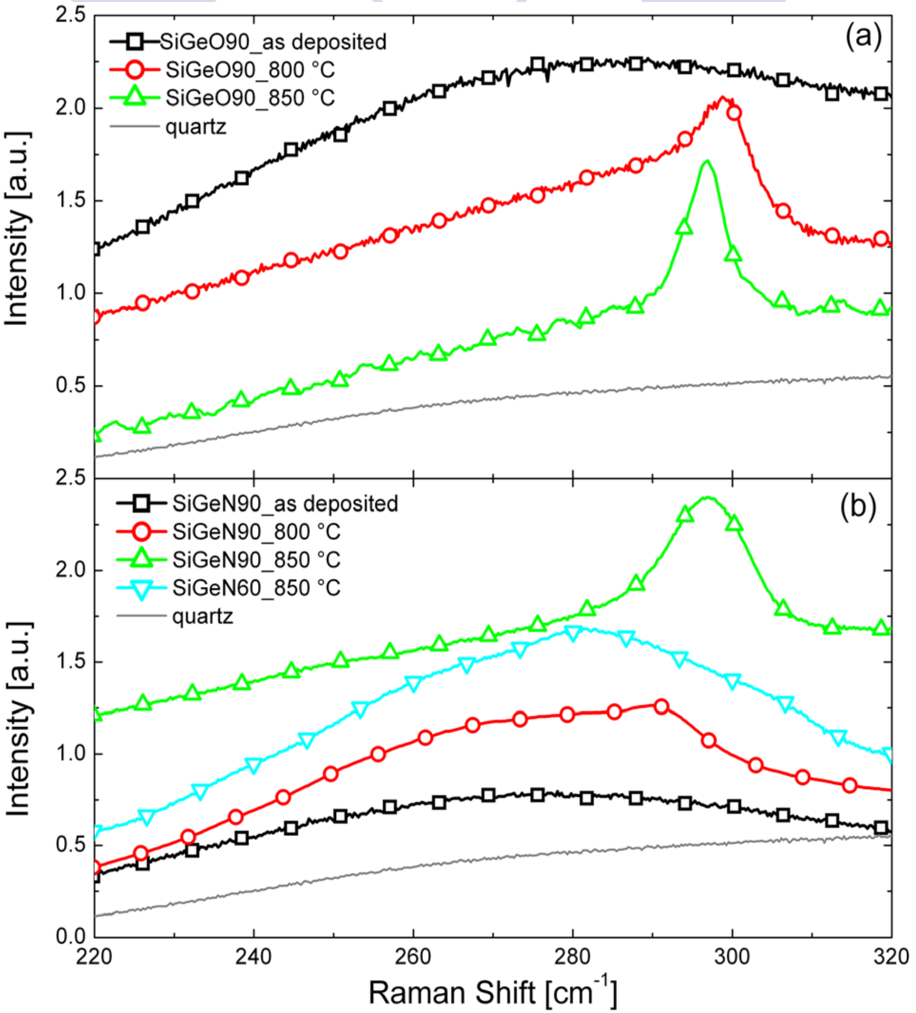
Raman spectroscopy analysis of laser annealed SiO_x films: effect of composition.

Raman spectra of PECVD grown hydrogenated SiO_xN_y films with different precursor gas flow ratios, after irradiation with Ar+ laser beam up to 40.7 mW/cm² power density.



Ge Nanocrystals embedded in SiO_2 and Si_3N_4





Light harvesting with Ge quantum dots embedded in SiO_2 or Si_3N_4

Cosente et al., J.Appl. Phys., 115 043113, 2014

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The role of the interface in germanium quantum dots: when not only size matters for quantum confinement effects†‡

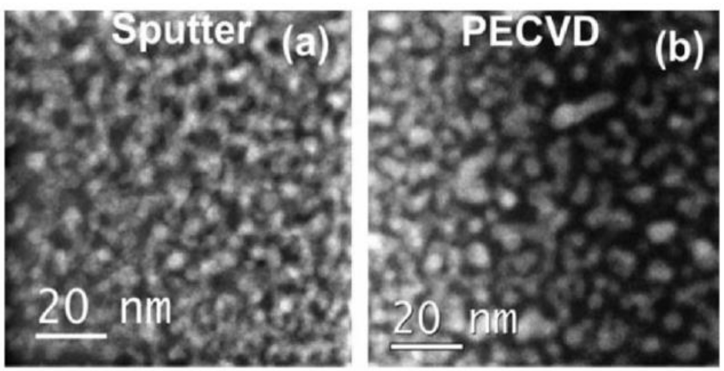
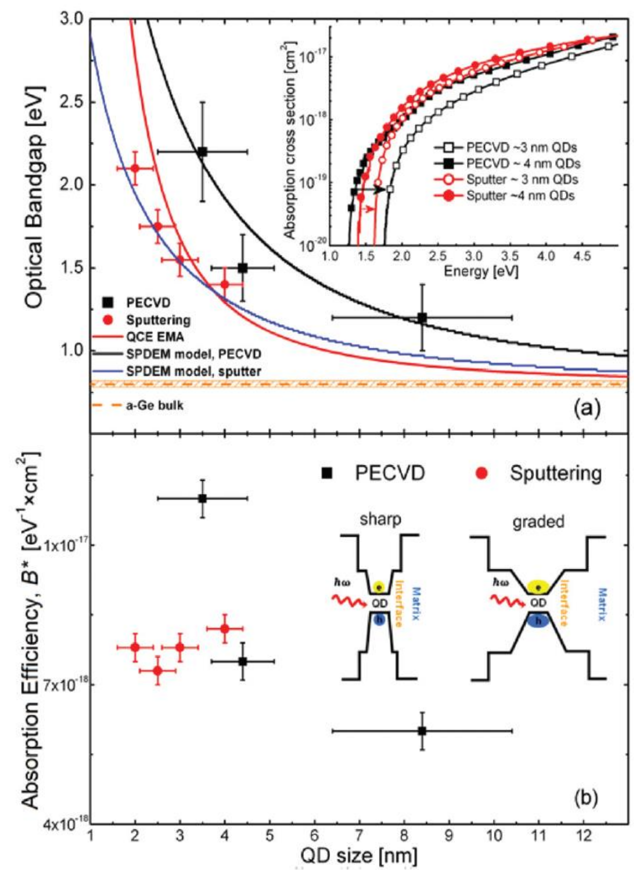


Fig. 1 Typical cross sectional HAADF STEM images of Ge QDs in SiO_2. Bright spots correspond to Ge QDs obtained by sputter (a) or PECVD techniques (b) from SiGeO films having ~1.3×10^{22} at cm^{-3} of Ge.



Ge nanocrystals in SiNy

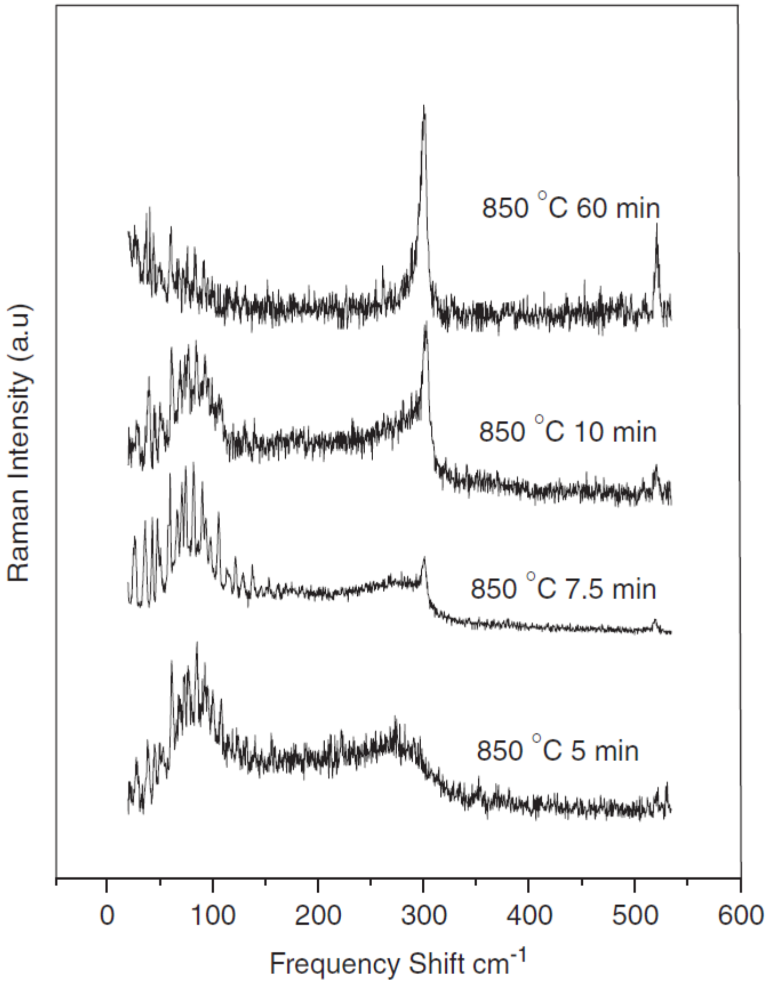


Fig. 2. Raman spectra of SiN_x:Ge films annealed in vacuum at 850 °C for various durations. Growth of Ge phonon mode at 300 cm^{-1} as a function of annealing time observed, without any quenching.

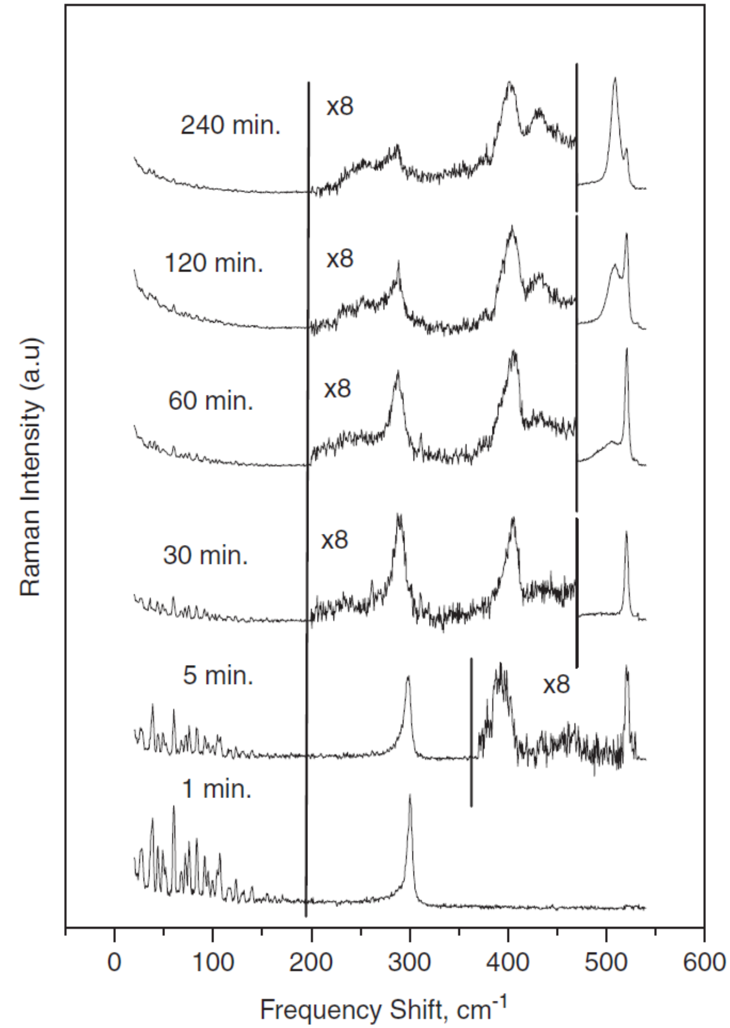
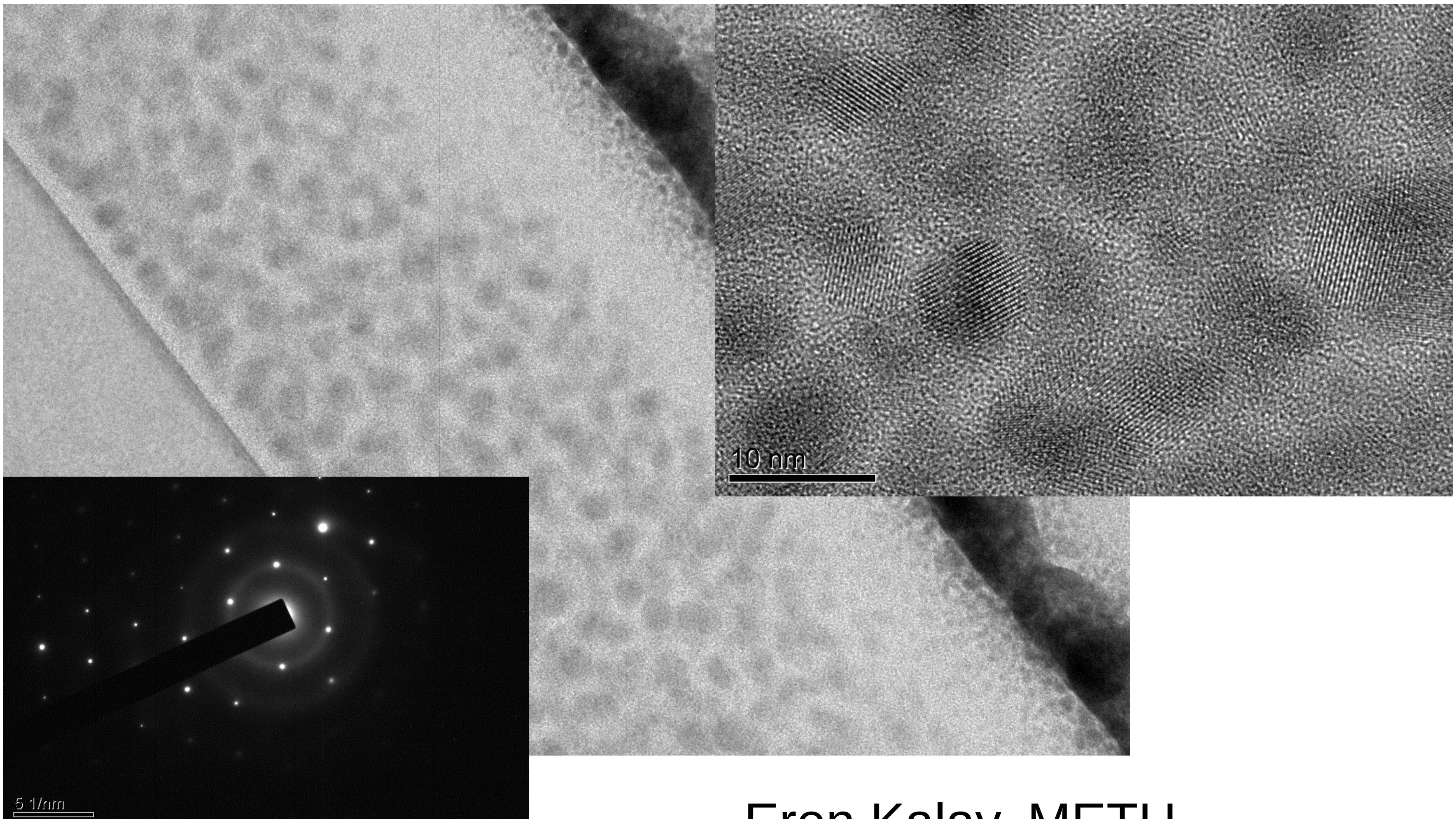


Fig. 3. Raman spectra of samples with prolonged vacuum anneal of SiN_x:Ge films at 1050 °C.

Structural Analysis: TEM



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Proposal

- Study in-situ dynamics of phase separation during cw/pulsed laser irradiation of Si/Ge rich oxides.
- Study in-situ crystallisation dynamics,using short pulse X-rays produced in PETRA III. Very fine collimated beams may make it possible to study extremely small nanocrystals of <10 nm.
- Grazing Incidence Nuclear Resonant Scattering for morphological and structural changes along with mapping of the strain on the nanocrystals, effecting their optical and electronic properties.

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