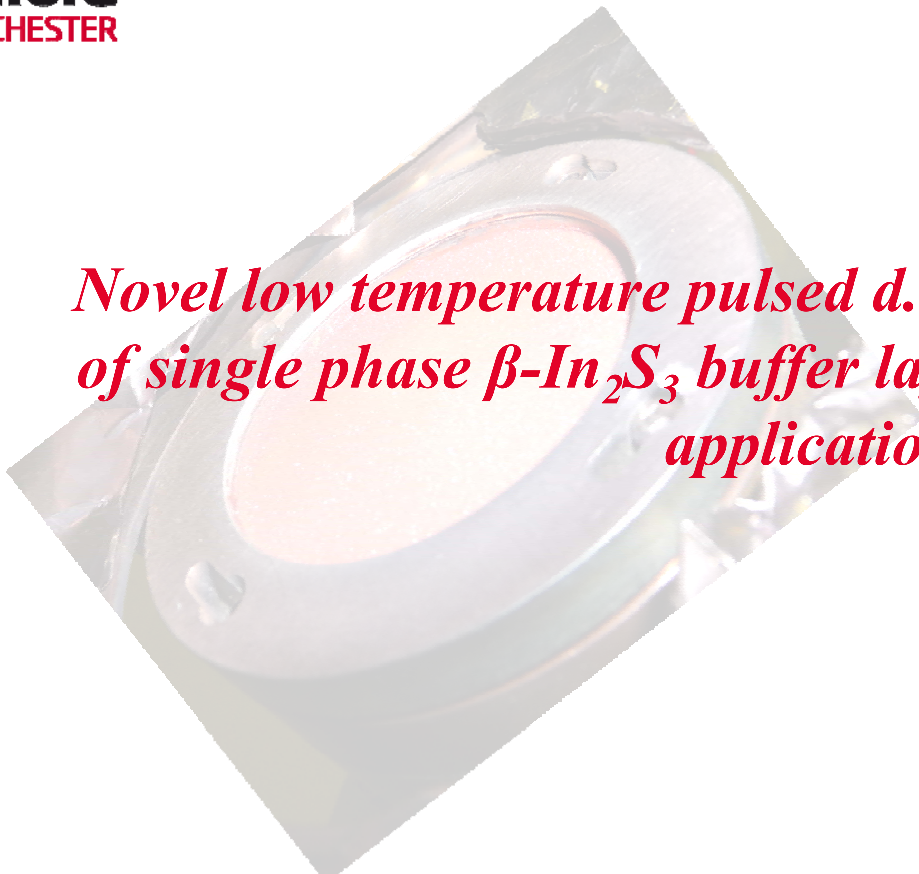

Novel low temperature pulsed d.c. magnetron sputtering of single phase β-In_2S_3 buffer layers for CIGS solar cell application

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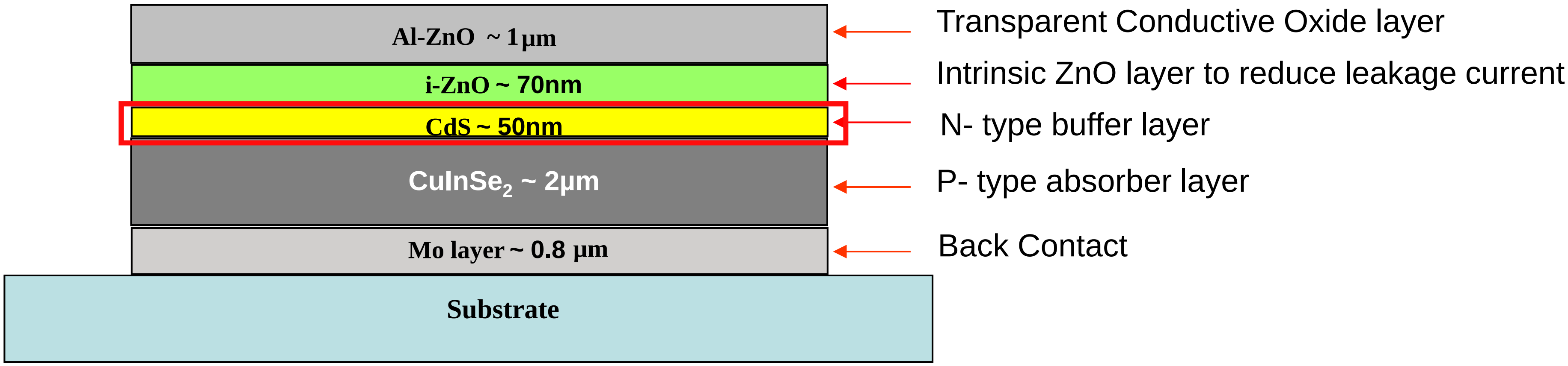
Introduction

CIS/CIGS thin film based solar cells are the most promising renewable energy source because of their relatively high solar efficiency and stability.

Single crystal Si cells need more material to absorb light due to its indirect band gap.

Presently CIGS cells have achieved a maximum efficiency of 20.3% [1].

A typical cell CIS/CIGS structure is in the form of a heterojunction.



A typical CIGS solar cell

References

[1] P. Jackson et. al Progress in Photovoltaics: Research and Applications, (2011) EU PVSEC WCPEC-5, Valencia, Spain, 2010.

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Introduction

CdS layers are deposited using a chemical bath deposition process

CdS buffer layer - main functions

- The optimum thickness (60 nm to 80 nm) CdS layer builds a sufficiently wide depletion layer that minimises tunnelling and reduces recombination, which in turn increases the efficiency of the solar cell.
- The chemical bath deposited CdS layer coats the absorber CIGS surface, minimising voids at the metallurgical interface.
- The CdS layer provides electronic and metallurgical junction protection against subsequent sputter damage from the TCO layer deposition and acts as a mechanical protective layer.

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Why Do We Need An Alternative Buffer Layer ?

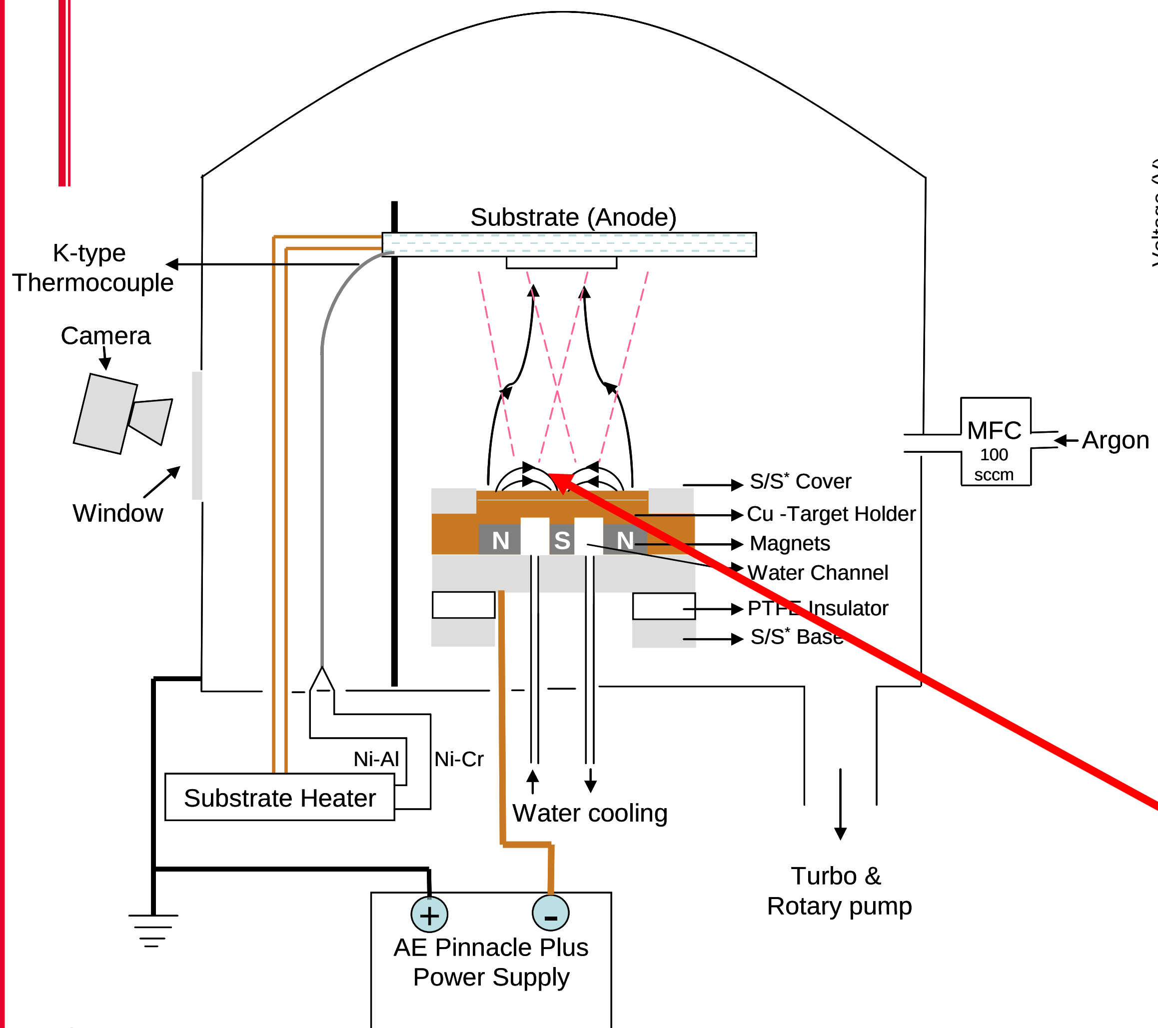
- Toxicity of Cd
- The light absorption in the buffer layer reduces the spectral response of the solar cell in the blue region of the solar spectrum (band gap is 2.4 eV)
- Integrating the CBD technique with other vacuum processes in the production line when it comes to the in-line production of CIGS solar cells is difficult.

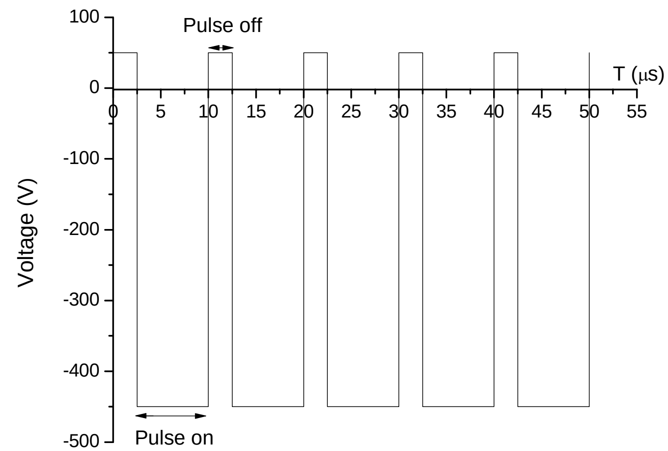
Solution

Replace the CdS buffer with an alternative buffer material with higher band gap energy and optical constants similar to those of CdS

ZnS	In(OH)3	In_2S_3 ←
ZnSe	ZnMgO	ZnO

Pulsed D.C. Magnetron Sputtering System





Ideal pulsed d.c signal for 100kHz

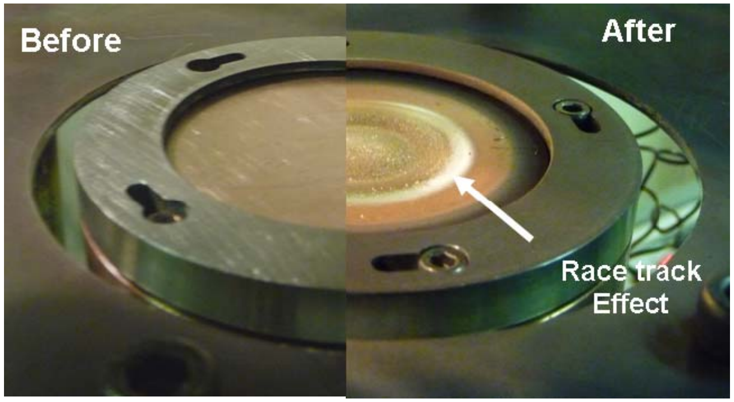
In_2S_3 powder target

Reference

S. Karthikeyan *et al*, Vacuum, 2010, 85; pp.634-638.

Why Pulsed D.C Sputtering From Powder Targets

- Long term arc free sputtering.
- Insulators and semiconductors can be sputtered.
- The enhanced ion flux near the substrate can help to crystallise the compound at low substrate temperatures.
- No material wastage associated with the Race Track effect.



Reference

Bradley JW et al, Plasma Sources Science and Technology, 11, 2002, 165p

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Materials Deposited

1. Molybdenum (back contact) [1]
2. Copper indium diselenide (absorber layer)[2]
3. Indium sulphide (buffer layer)
4. Indium oxide (Transparent Conductive Oxide layer)[3]

[1] S. Karthikeyan *et al*, Thin Solid Films, 2011, 250, pp.266-271.

[2] S.Karthikeyan *et al*, Thin Solid Films, 2011, 519; pp.3107 -3112

[3] S.Karthikeyan et al,*The effect of oxygen on the properties of pulsed d.c magnetron sputtered In2O3 films.* in: **1st CSE Postgraduate Conference 2010**, University of Salford, United Kingdom.

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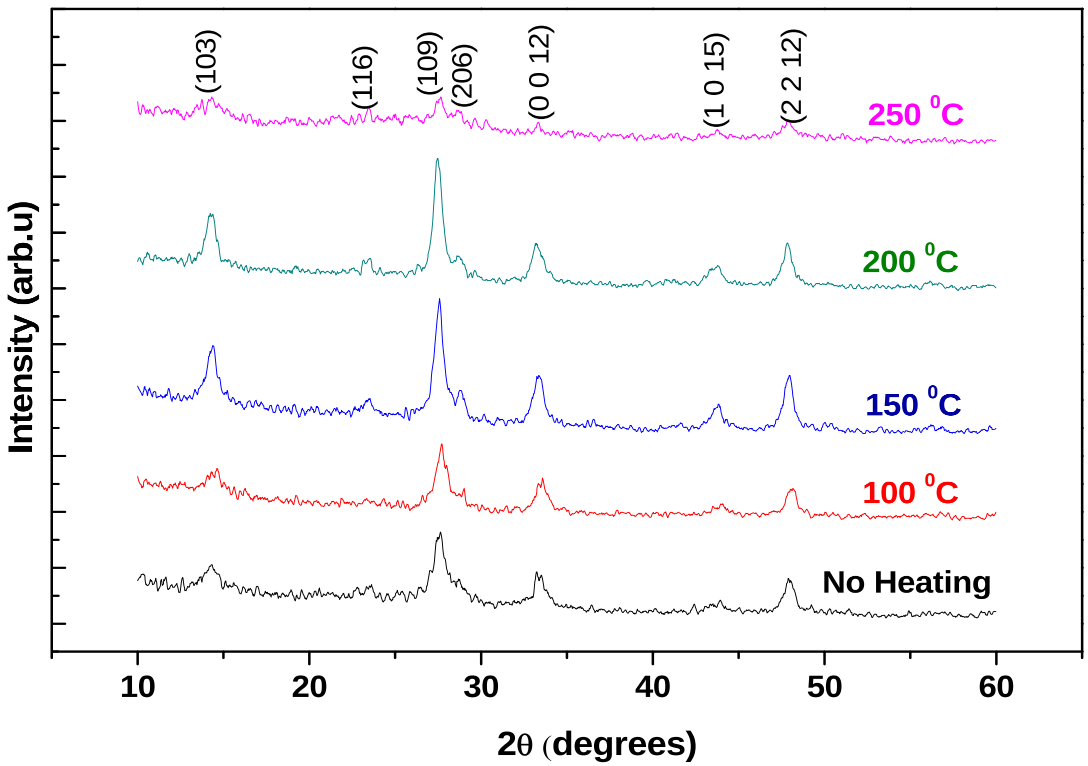
Sputtering in argon atmosphere from commercial In_2S_3 powder.

Films sputtered at different substrate temperatures

Indium Sulphide Films

XRD of In_2S_3 Films



Deposition Parameters

Pressure : 7.3×10^{-3} mbar
Mode : Constant Power (25 W)
Frequency : 100 kHz
Pulse off Time : 0.5 µs
Distance : 8 cm

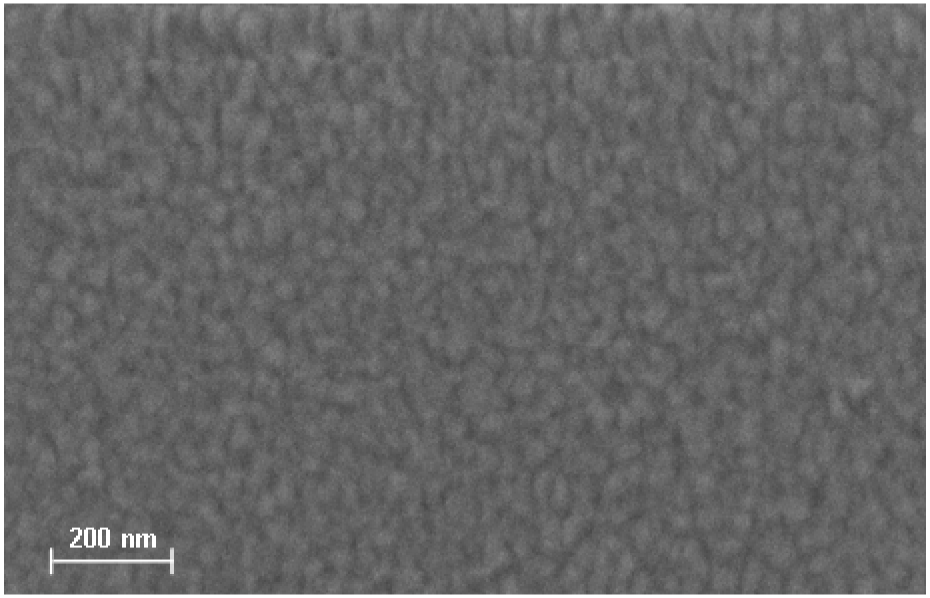
Preferred (109) orientation

Tetragonal – β In_2S_3 formed with

No heating !!

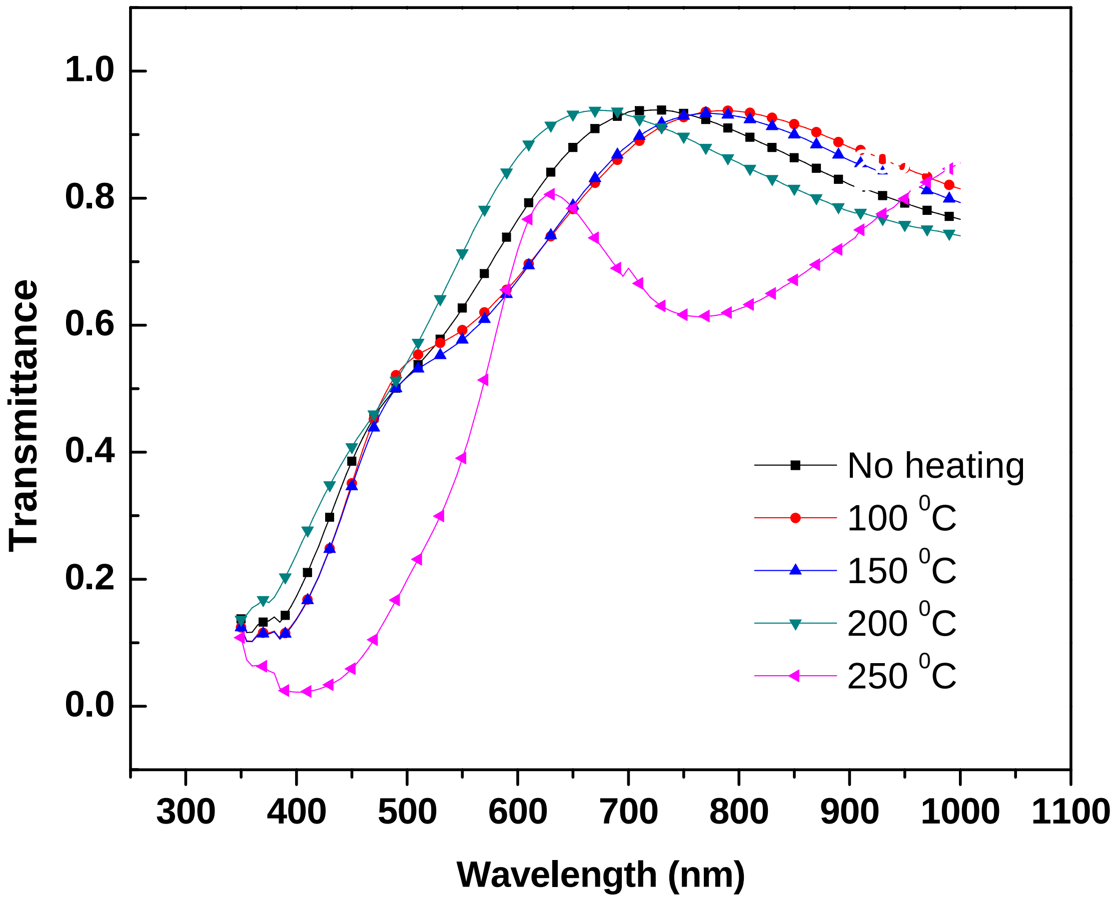
SEM of In_2S_3 Films

An SEM image of the sample deposited at 200 ^{0}C

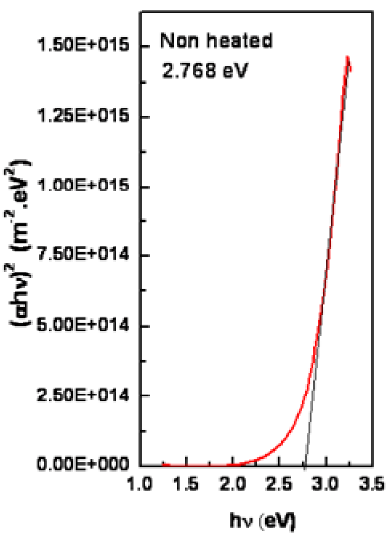


The very thin and smooth nature of the films was a barrier for high resolution SEM images. The films were analysed using AFM to obtain a clear picture.

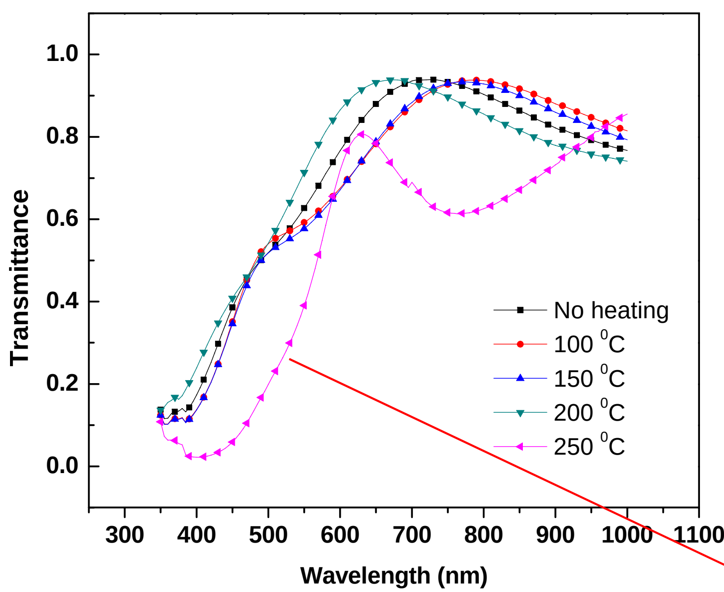
Optical studies of In_2S_3 Films

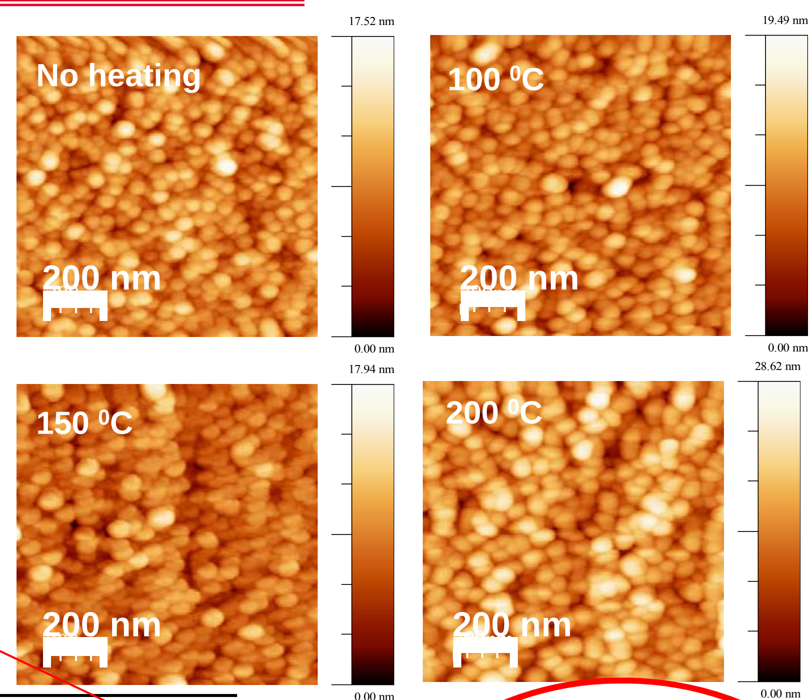


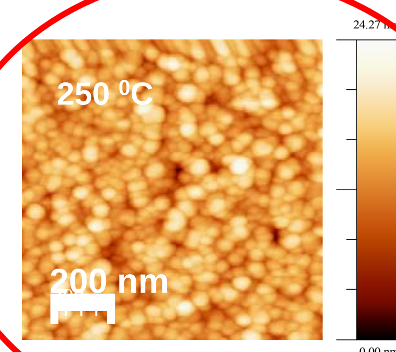
$$\alpha = -\frac{1}{d}.\ln\left(\frac{T}{(1-R)^2}\right)$$



Optical and AFM studies of In_2S_3 Films







Deposition Temperature	% In	%S	$\frac{[\%S]}{[\%In]}$	Band Gap eV
Non heated	41.26	58.74	1.42	2.768
100 ^{0}C	41.84	58.16	1.39	2.735
150 ^{0}C	42.86	57.14	1.33	2.708
200 ^{0}C	43.5	56.5	1.29	2.667
250 ^{0}C	48.51	51.49	1.20	2.526

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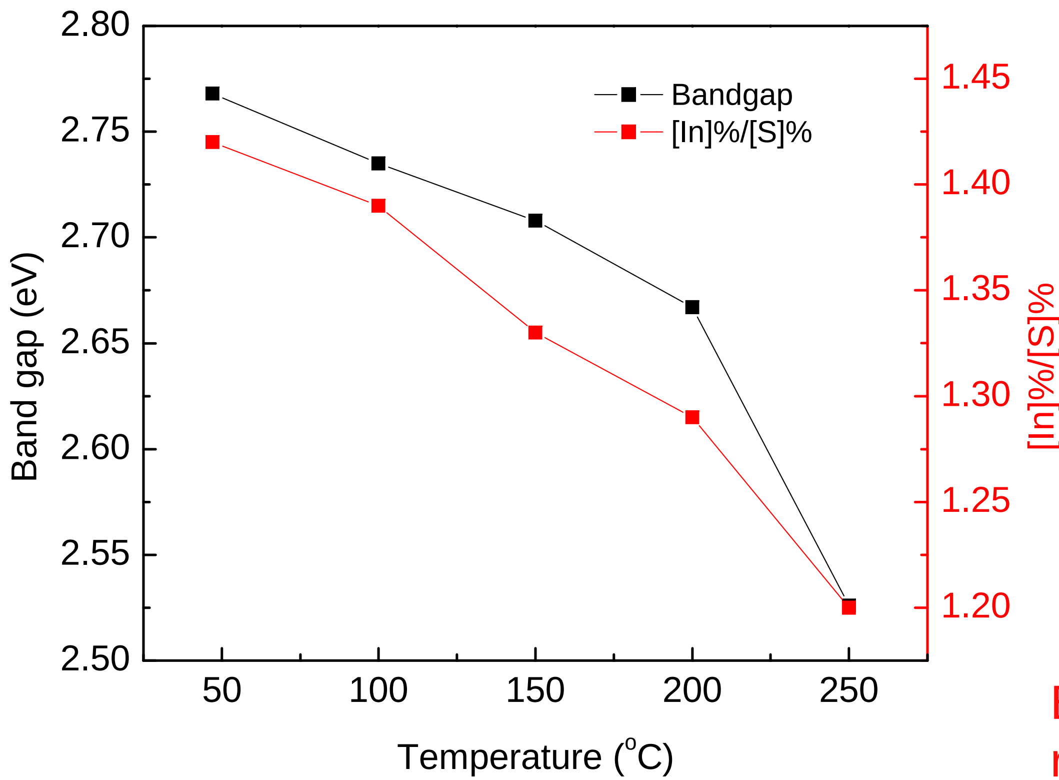
Band gap vs [In]/[S] ratio



Band gap reduced with reduction in sulphur content

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Conclusions

- The possibilities of pulsed d.c magnetron sputtering for the deposition of In_2S_3 and films from powdered targets were studied.
- The XRD analysis revealed that the films are in single phase.
- The room temperature sputtered In_2S_3 films showed a maximum band gap about 2.768 eV which is higher compared to reported single crystal value.
- The higher band gap reduces the absorption in the blue region of the solar spectrum and can increase the solar cell efficiency.
- The band gap of the In_2S_3 thin films reduced with sputtering temperature possibly due to the reduction in sulphur content.
- A single process for all the layer can cut down the overall cost of production of the solar cell and use of an In_2S_3 buffer layer can produce Cd free solar cells

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