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- Role of Cu in different layers on CdTe/CdS Solar cell Performance
- Measurement Automation

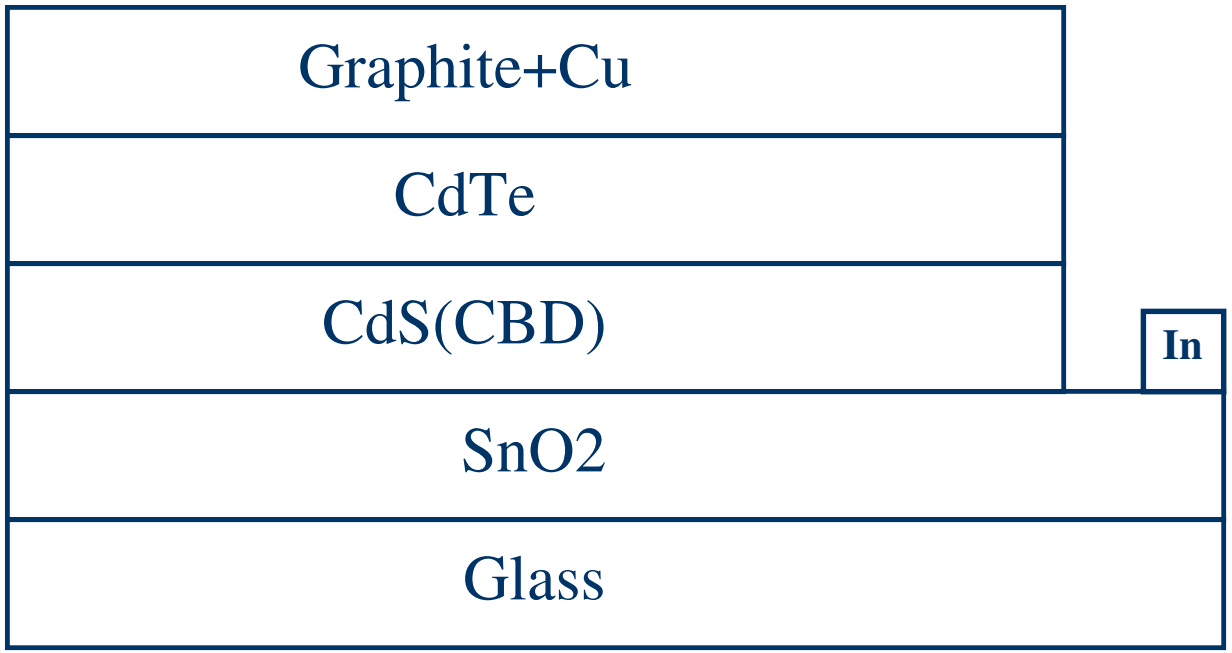
Acknowledgement

Senthil,Zhao,Vishwanath,Varuna,Murshadha,Mathesh

And Swetha

Role of Cu in different layers on CdTe/CdS Solar Cell Performance

I.Cu in Back Contact



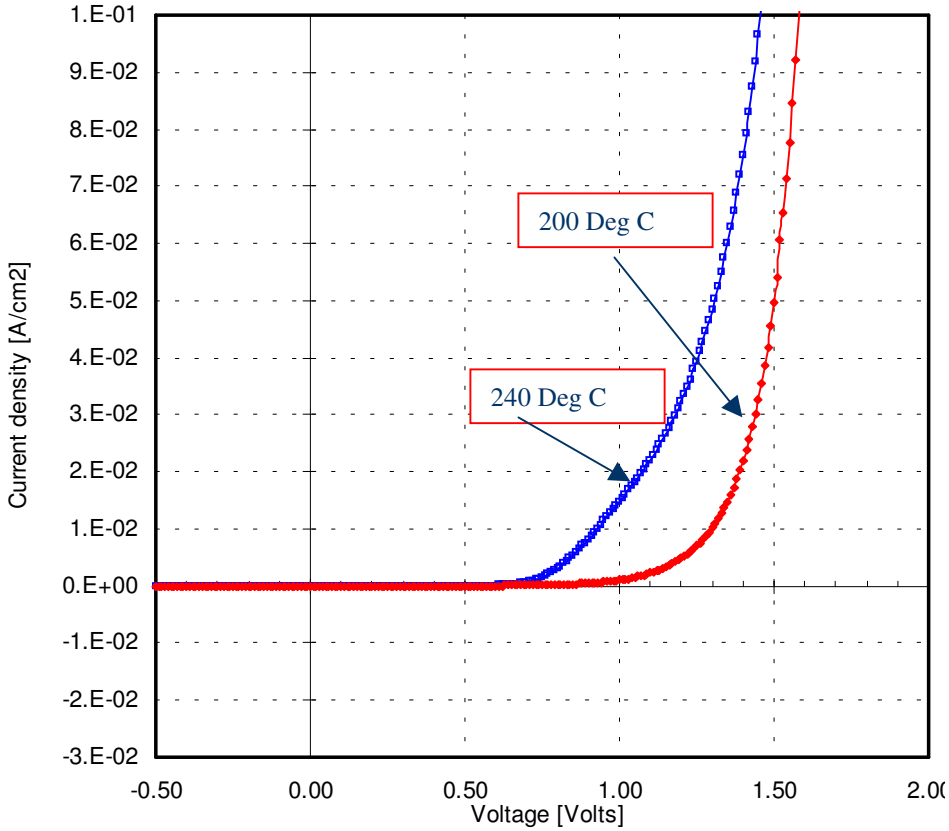
Note:CdCl2 treatment is done after CdTe deposition

Process Condition

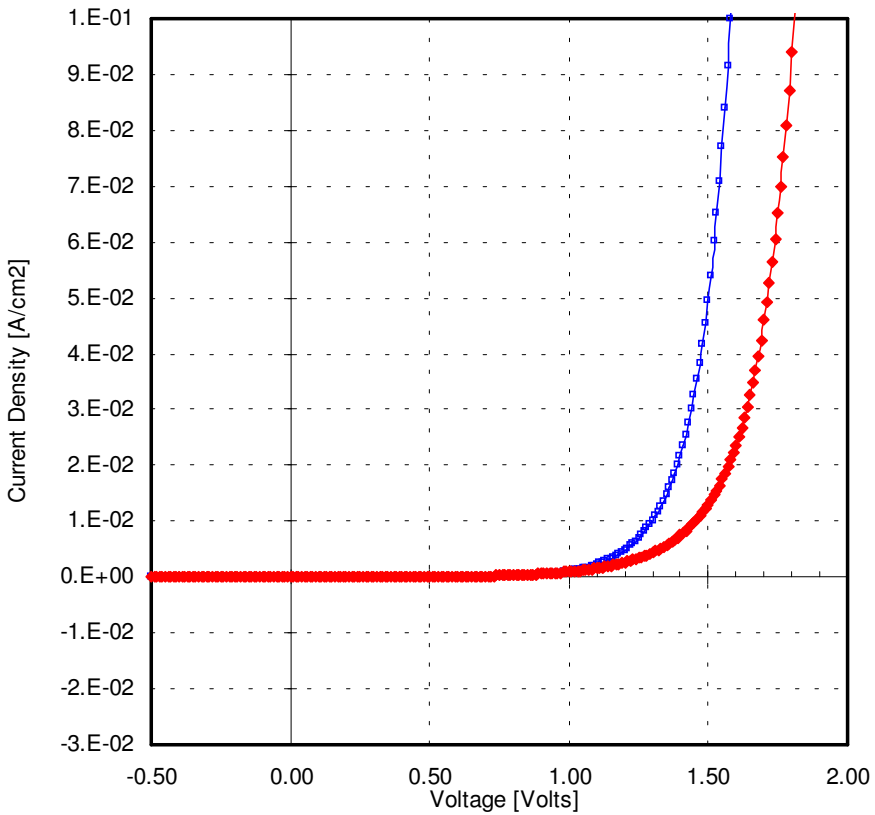
- SnO_2 is Bi Layer(Low and High conductivity)
- CdS is done by CBD technique for 100 min.
- CdTe is done by CSS
- For all samples CdTe thickness is about 5 micro m
- Annealing after $CdCl_2$ treatment is done at 390 deg C for 25 min
- Contact Annealing is done for 25 min
- Contact Annealing Temperature is varied as 175,200,225,235,240,245,250,255,275,300
- Cu concentration in Graphite back contact is varied as 0.05,0.1,0.2 gms of Cu in 10 gms of graphite and without Cu on the same substrate.

Effect of Cu Concentration and Contact Annealing

0.05 gms of Cu



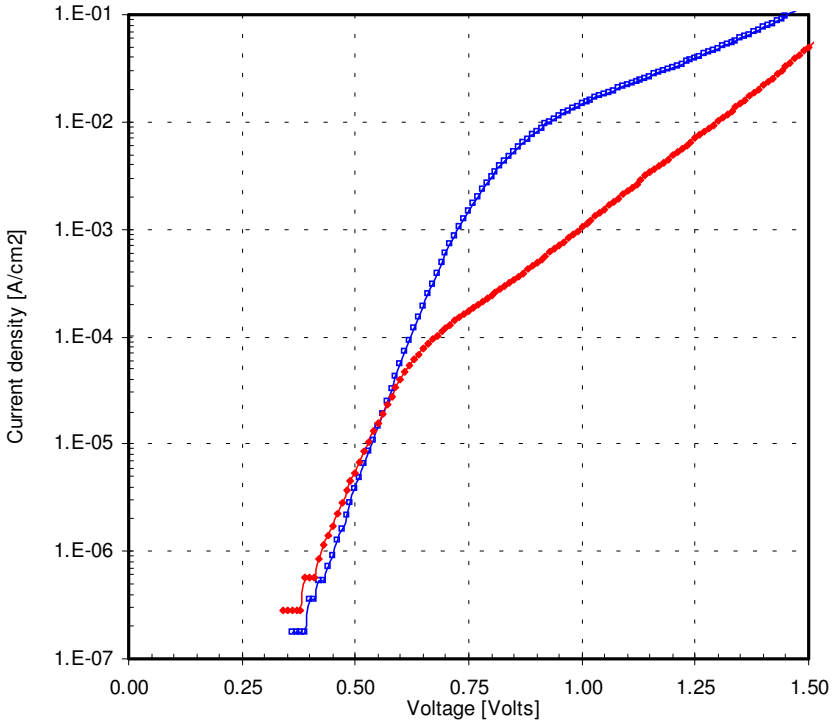
0.2 gms of Cu



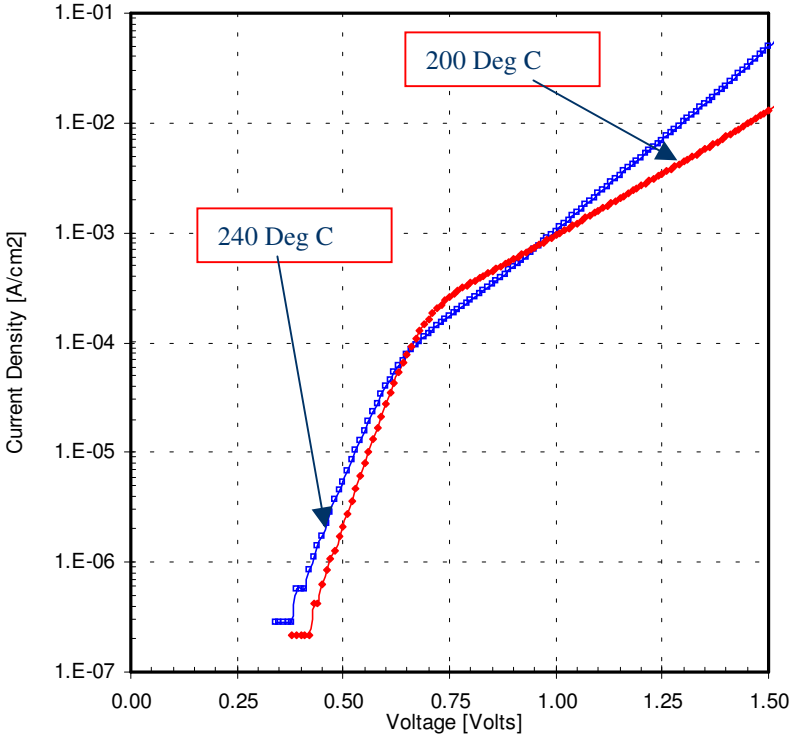
Note:Substrate has single concentration in this case

Effect of Cu Concentration and Contact Annealing

0.05 gms of Cu in 10 gms of graphite

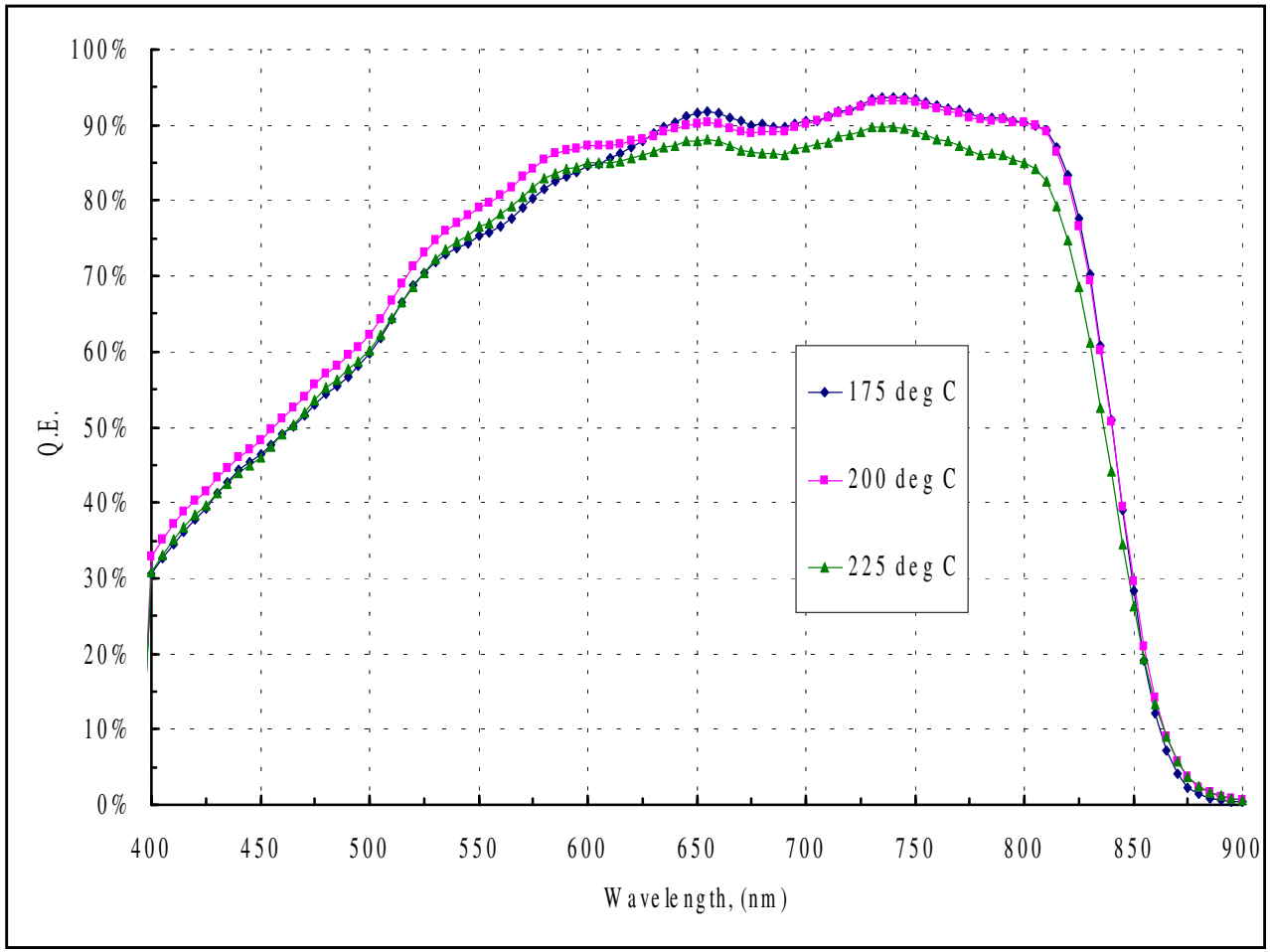


0.2 gms of Cu in 10 gms of graphite



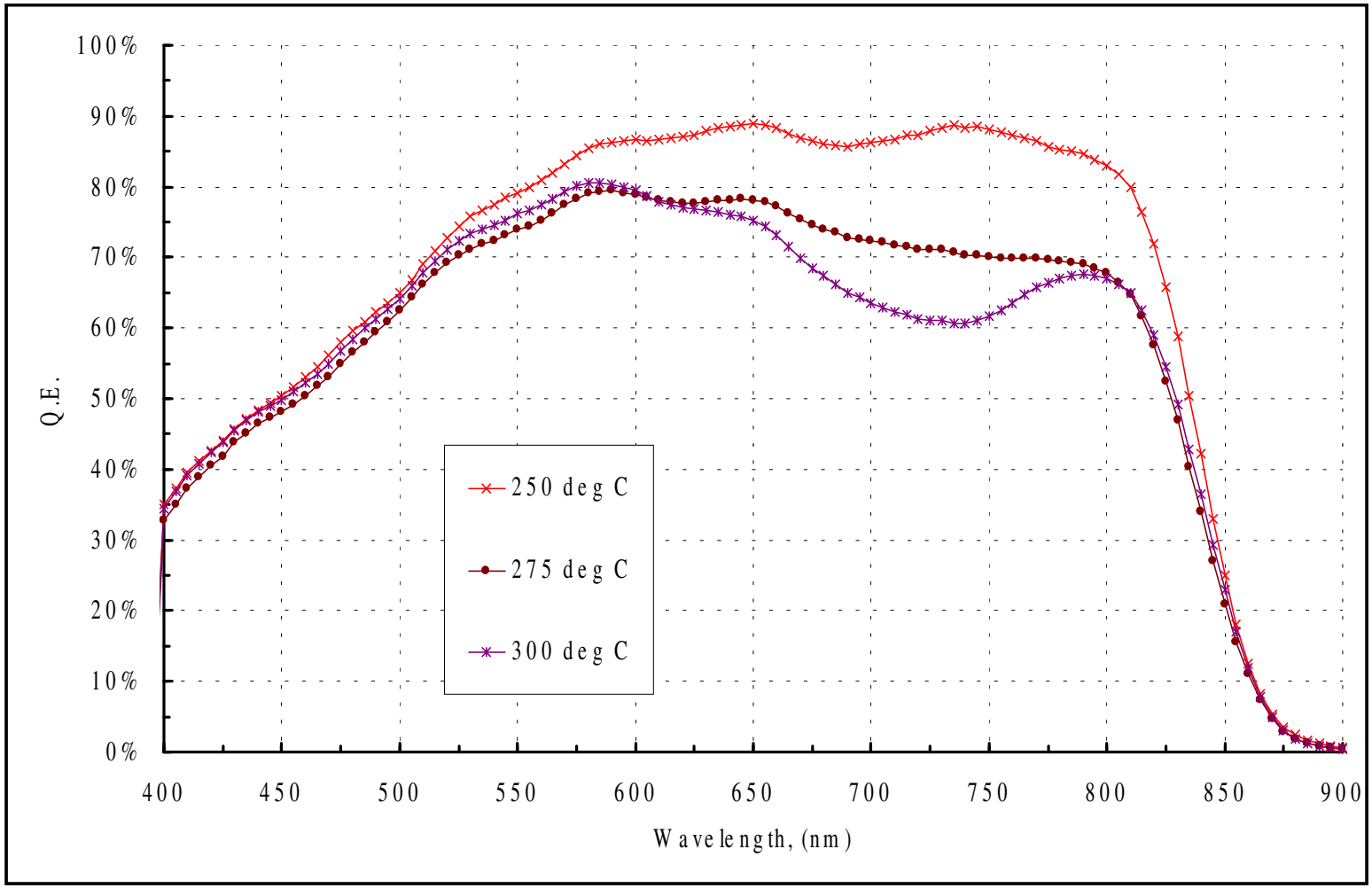
Note:Substrate has single concentration in this case

Effect of Contact Annealing on Spectral Response



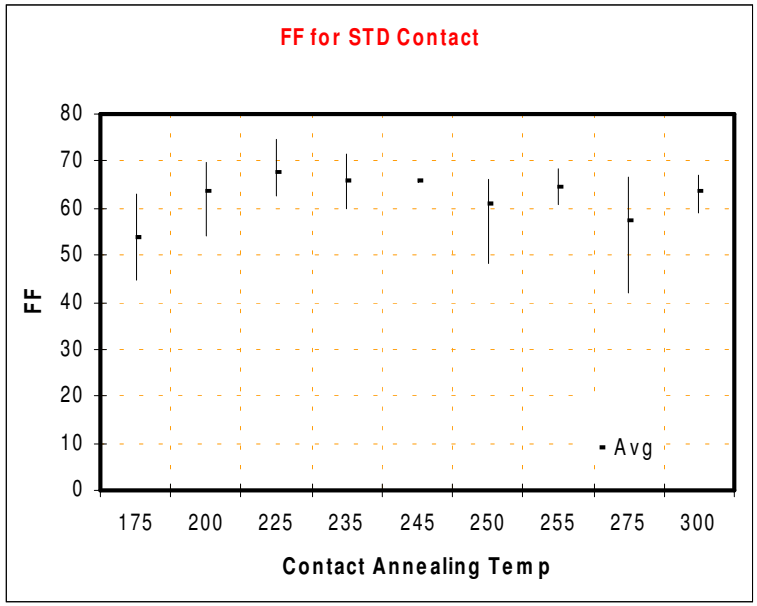
Note: 0.2 gms of Cu in 10 gms of Graphite

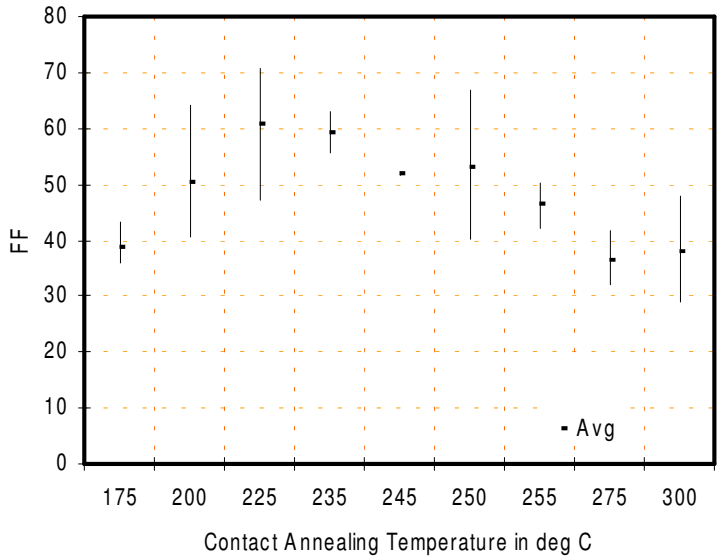
Effect of Contact Annealing on Spectral Response

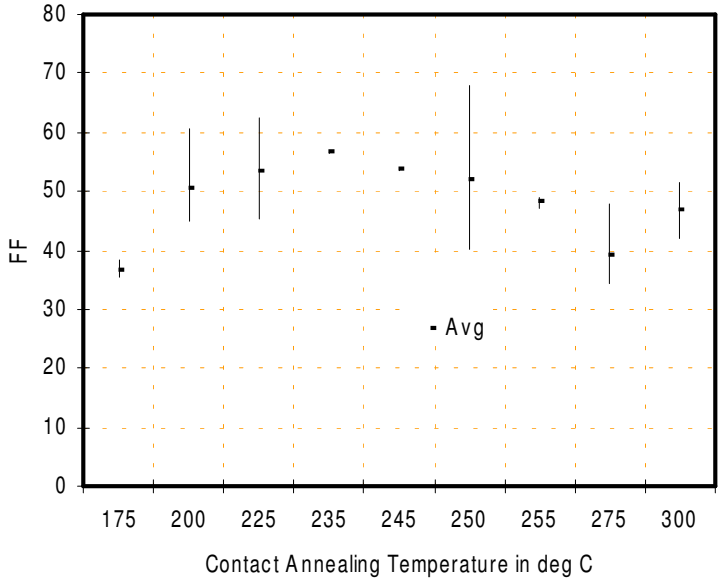


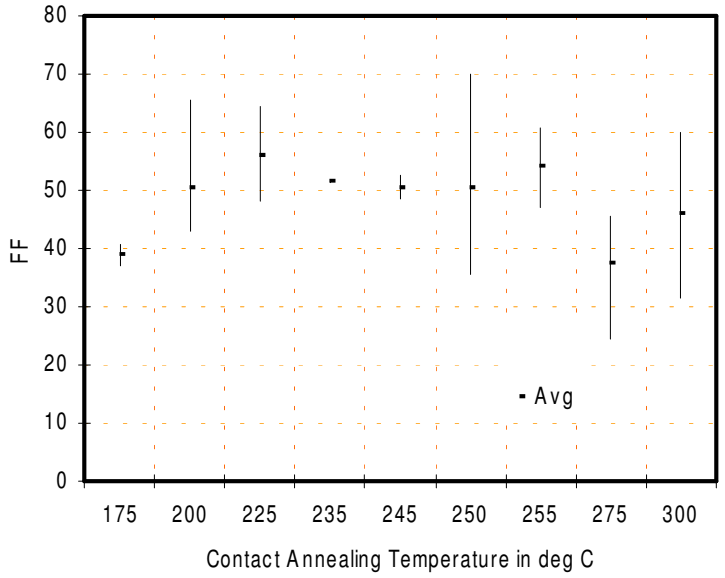
Note: 0.2 gms of Cu in 10 gms of Graphite

Effect of Cu Concentration and Contact Annealing on FF

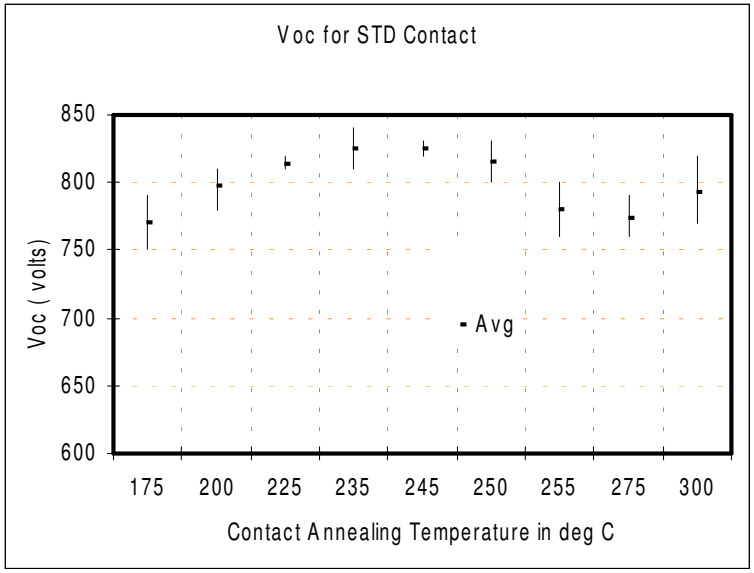


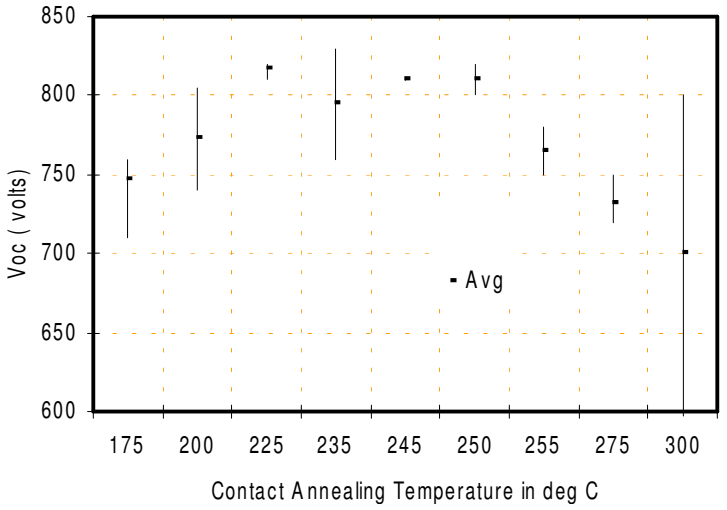


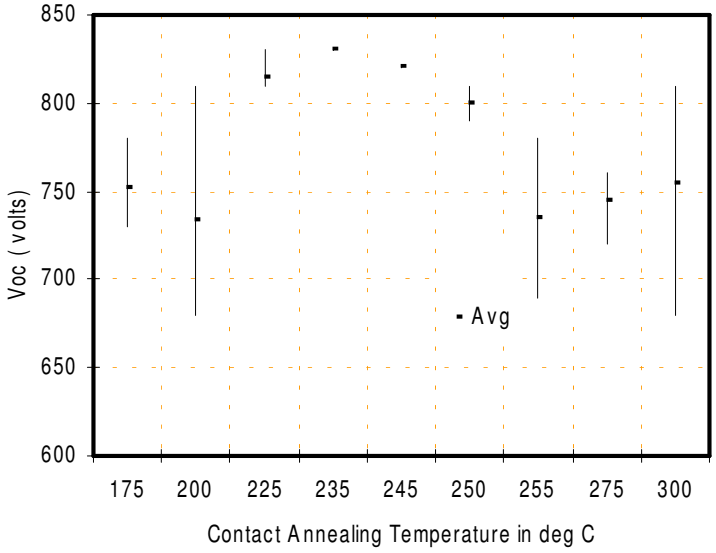


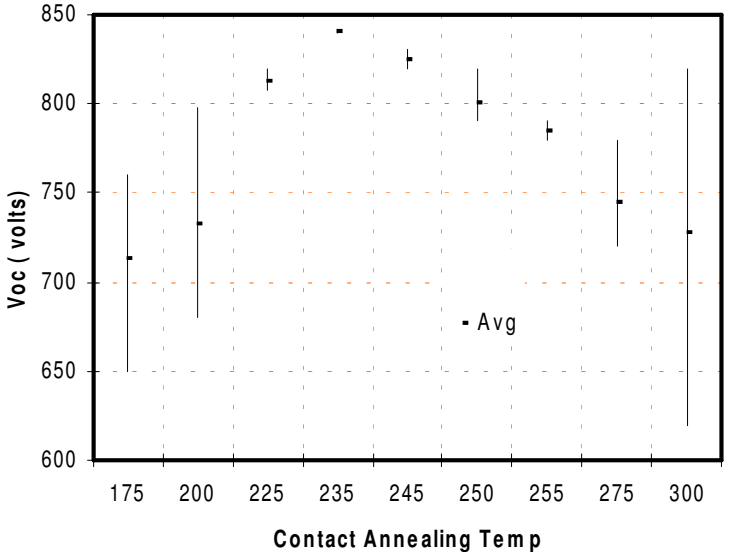


Effect of Cu Concentration and Contact Annealing on Voc

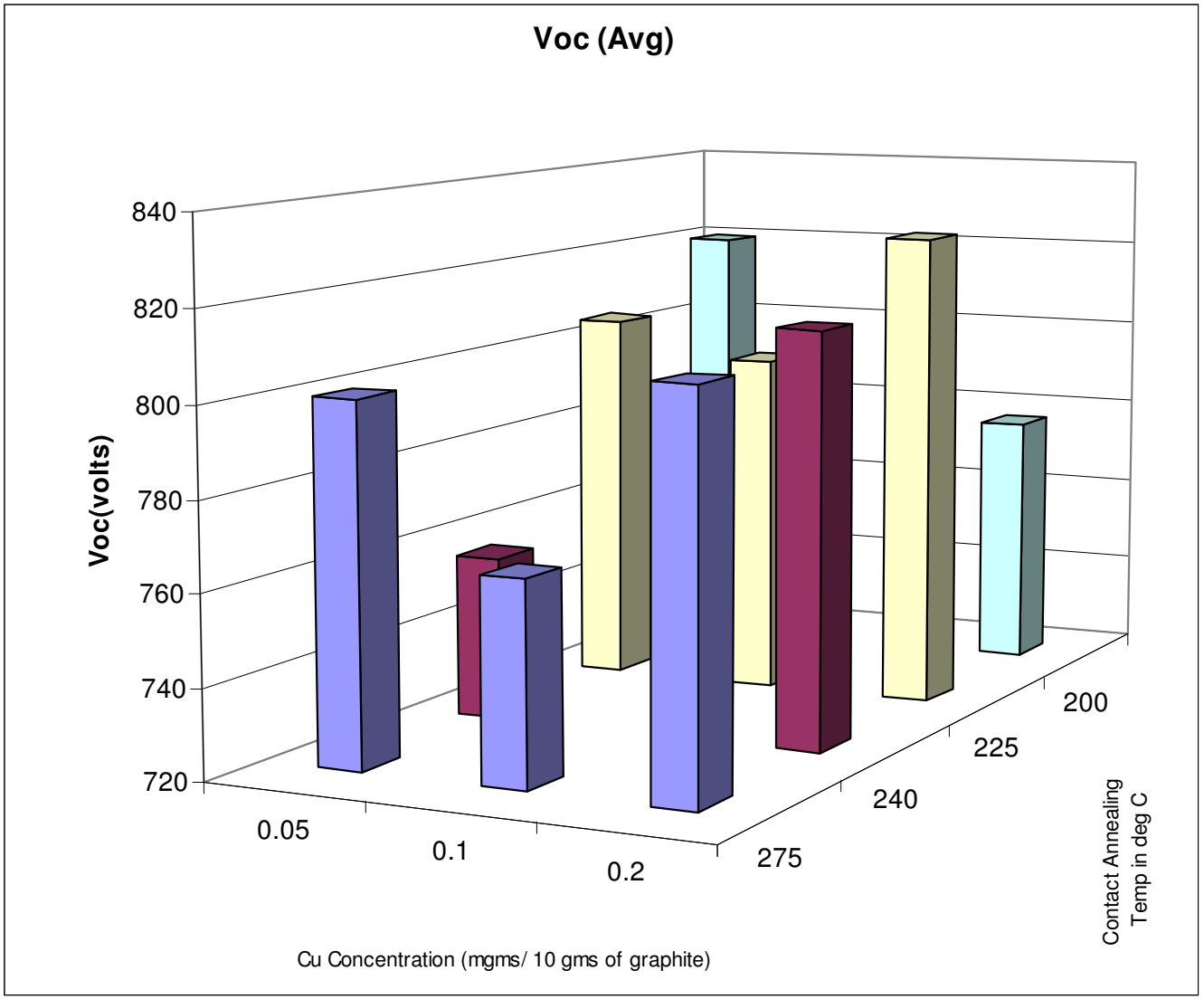






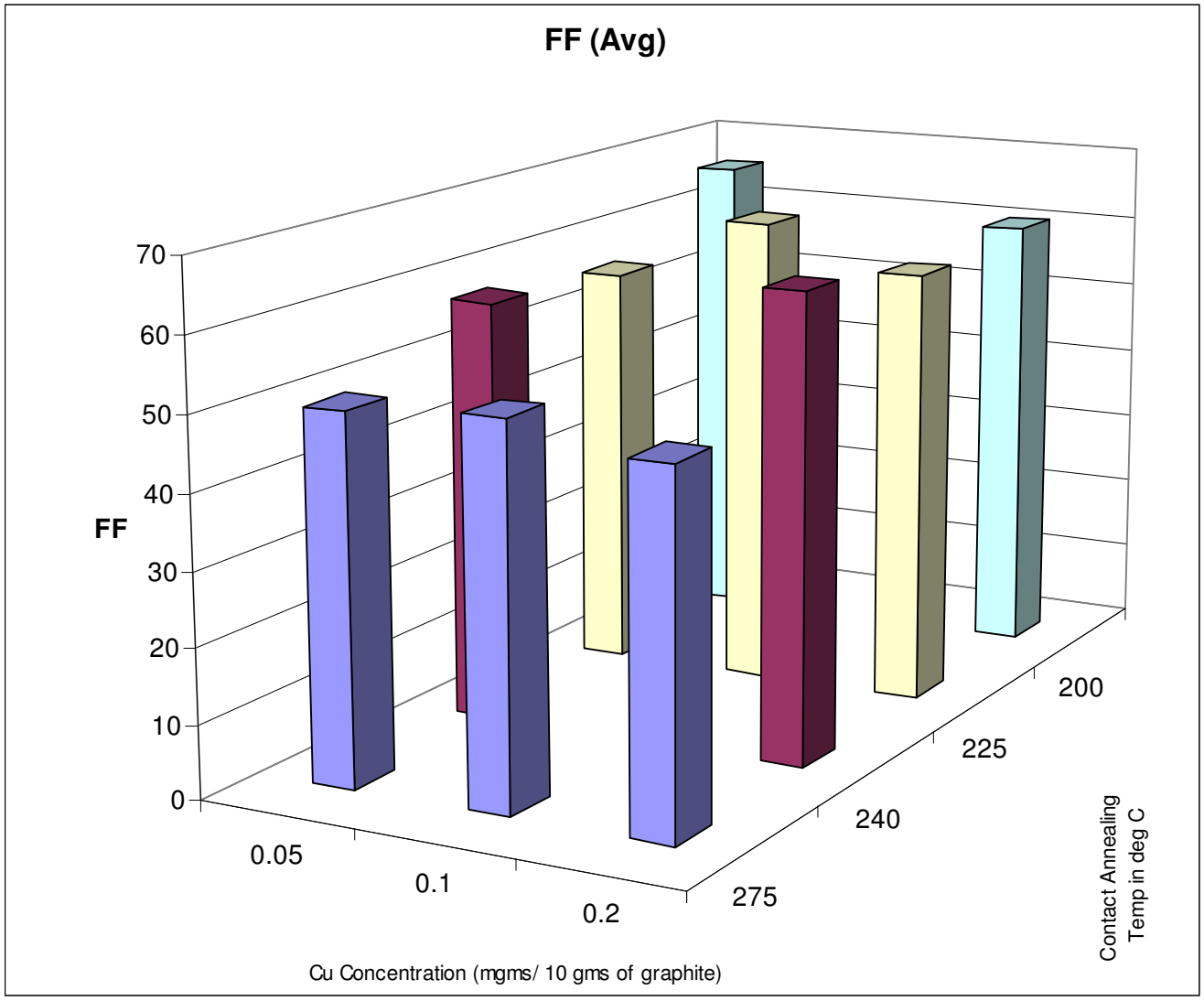


Effect of Cu Concentration and Contact Annealing on Voc



Note:Substrates are contacted at single Cu concentration

Effect of Cu Concentration and Contact Annealing on FF



Note:Substrates are contacted at single Cu concentration

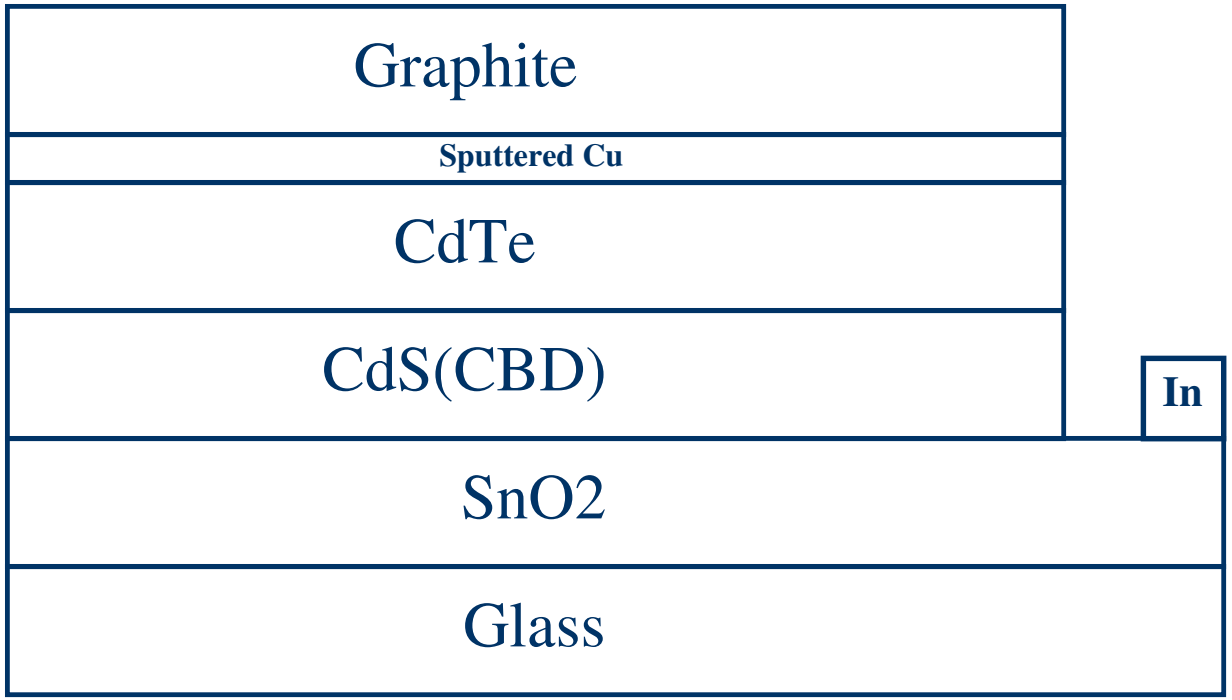
Summary-I

- Photocurrent response is reduced as contact annealing temperatures increase over 250 deg C for 600-800 nm wavelength range
  - •May be due to increased recombination centers in CdTe bulk and interface because of Cu diffusion through CdTe region
  - •Change in diode factor and Series resistance as the contact Annealing temperature increases
  - •Dark JV reveals that main junction is nearly unafffected initially, though Cu is considered to be fast diffuser in CdTe.
  - •Increase in Contact Annealing improves contact rectification for small amount of Cu in back contact.
  - •Increase in Cu content in back contact levels off contact Annealing effect possibly by readily diffusing in CdTe and forming recombination centers in bulk.

Summary-I…..Contd

•The optimum contact temperature range 225-250 deg C gives better performance for all Cu concentration levels

II.Sputtered Cu over CdTe

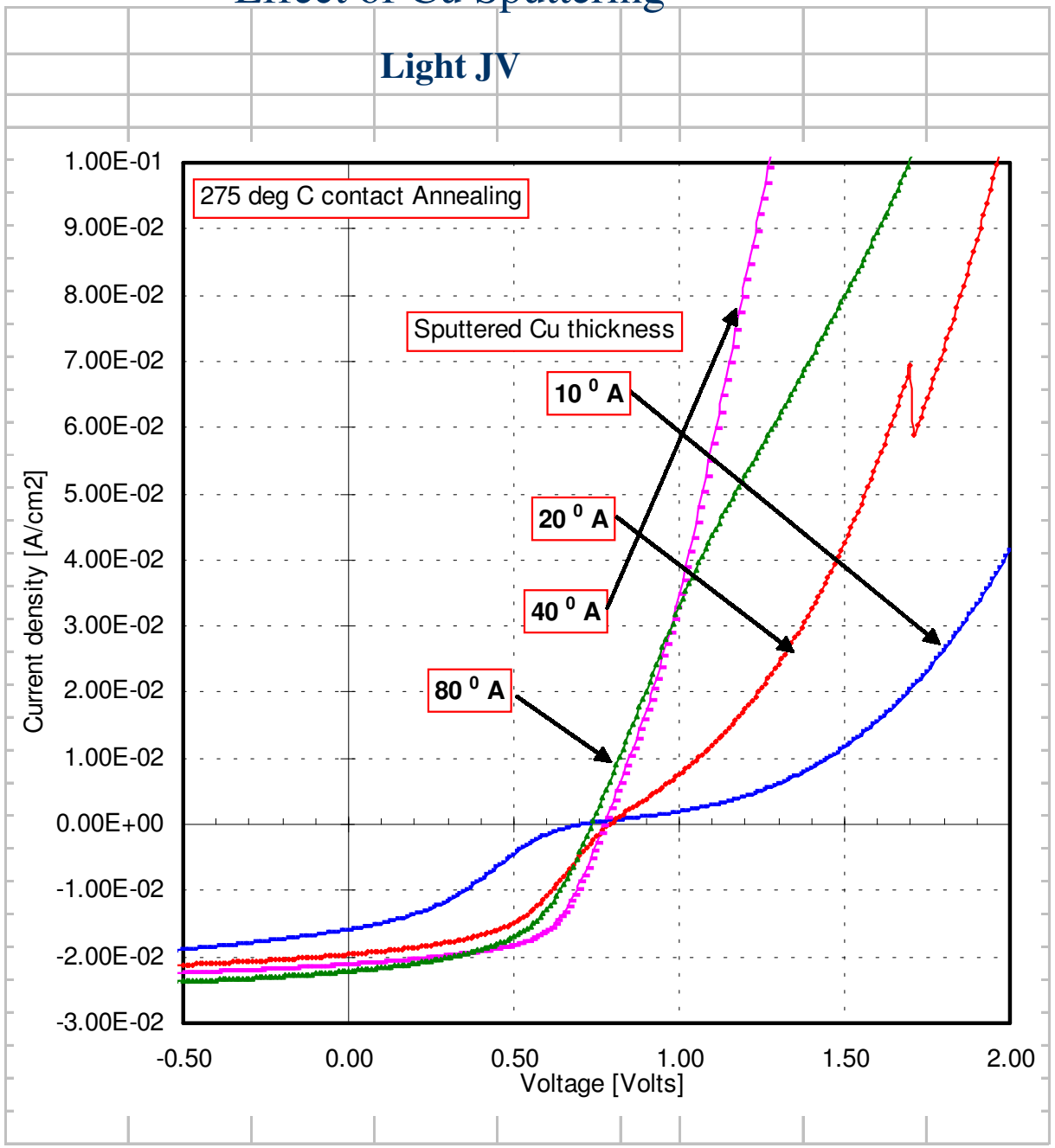


Note:CdCl2 treatment is done after CdTe deposition

Process Condition

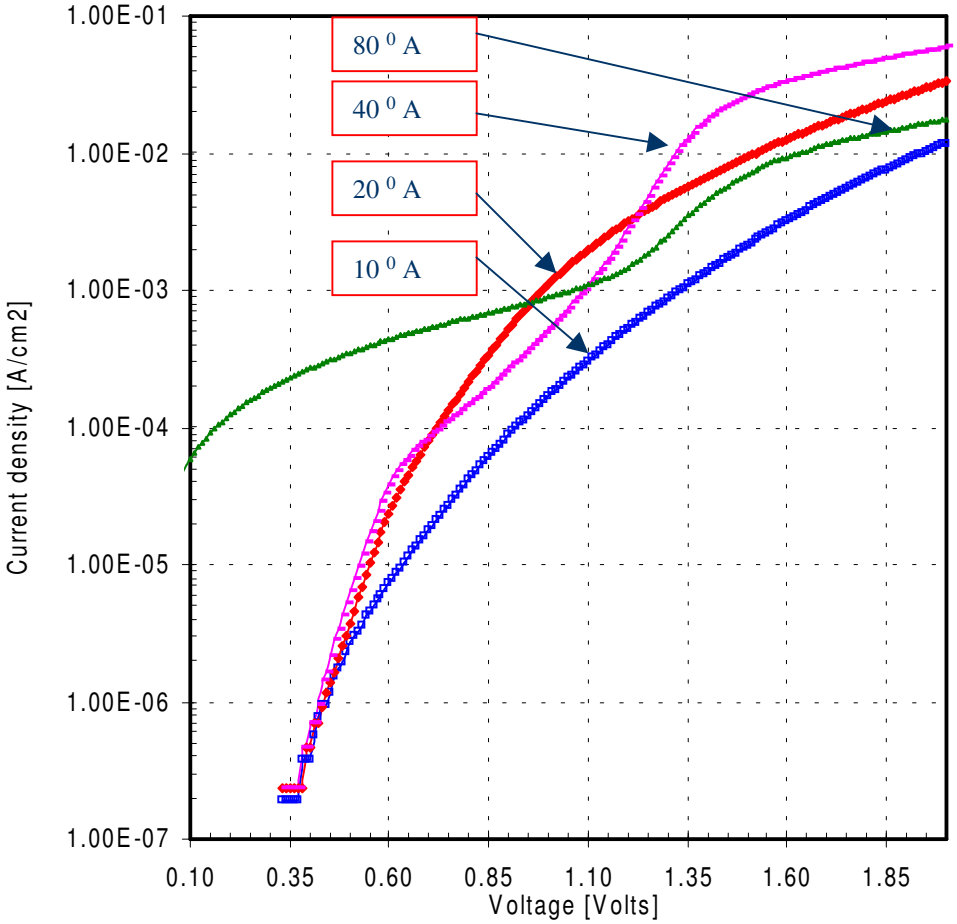
- SnO2 is Bi Layer(Low and High conductivity)
- CdS is done by CBD technique for 100 min.
- CdTe is done by CSS
- For all samples CdTe thickness is about 5 micro m
- Annealing after CdCl2 treatment is done at 390 deg C for 25 min
- Contact Annealing is done for 25 min
- Contact Annealing Temperature is varied as 200,225,240,275 deg C
- Sputtered Cu thickness over CdTe is varied as 10,20,40,80 A.

Effect of Cu Sputtering

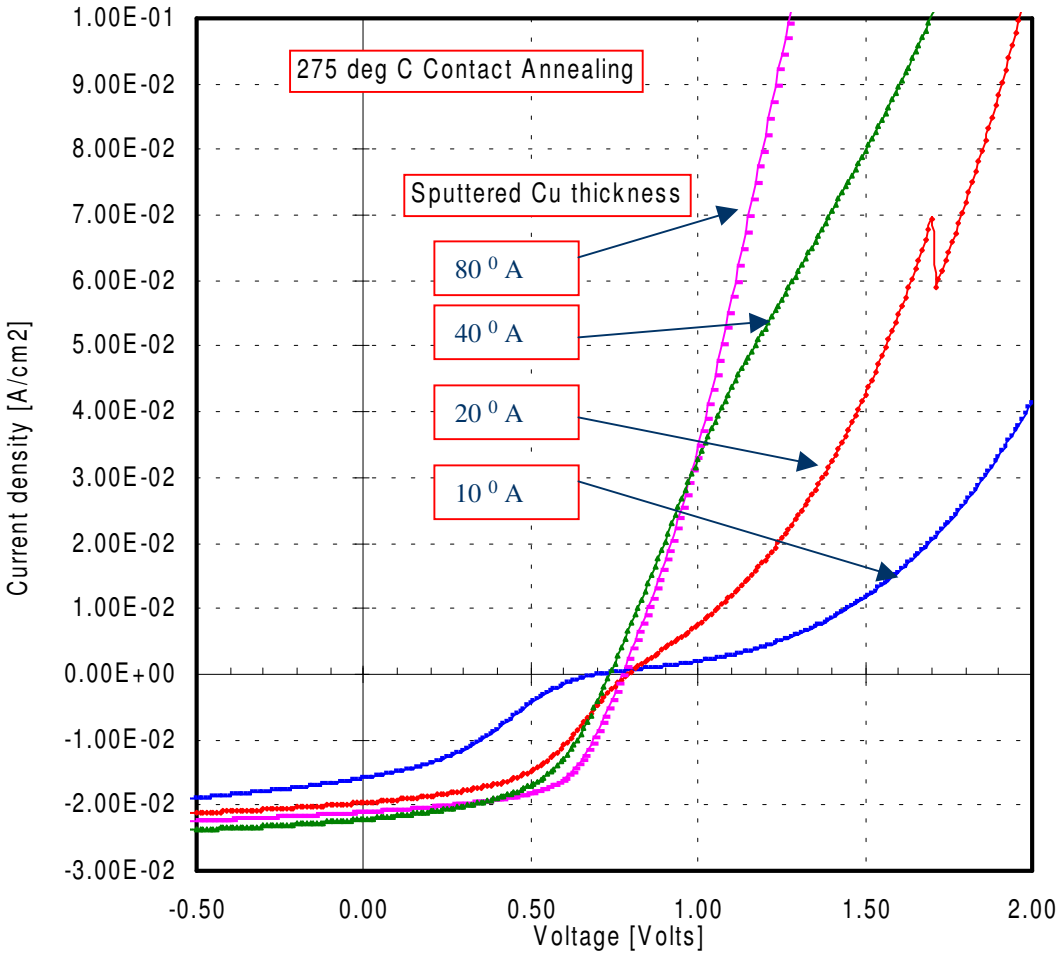


Effect of Cu Sputtering

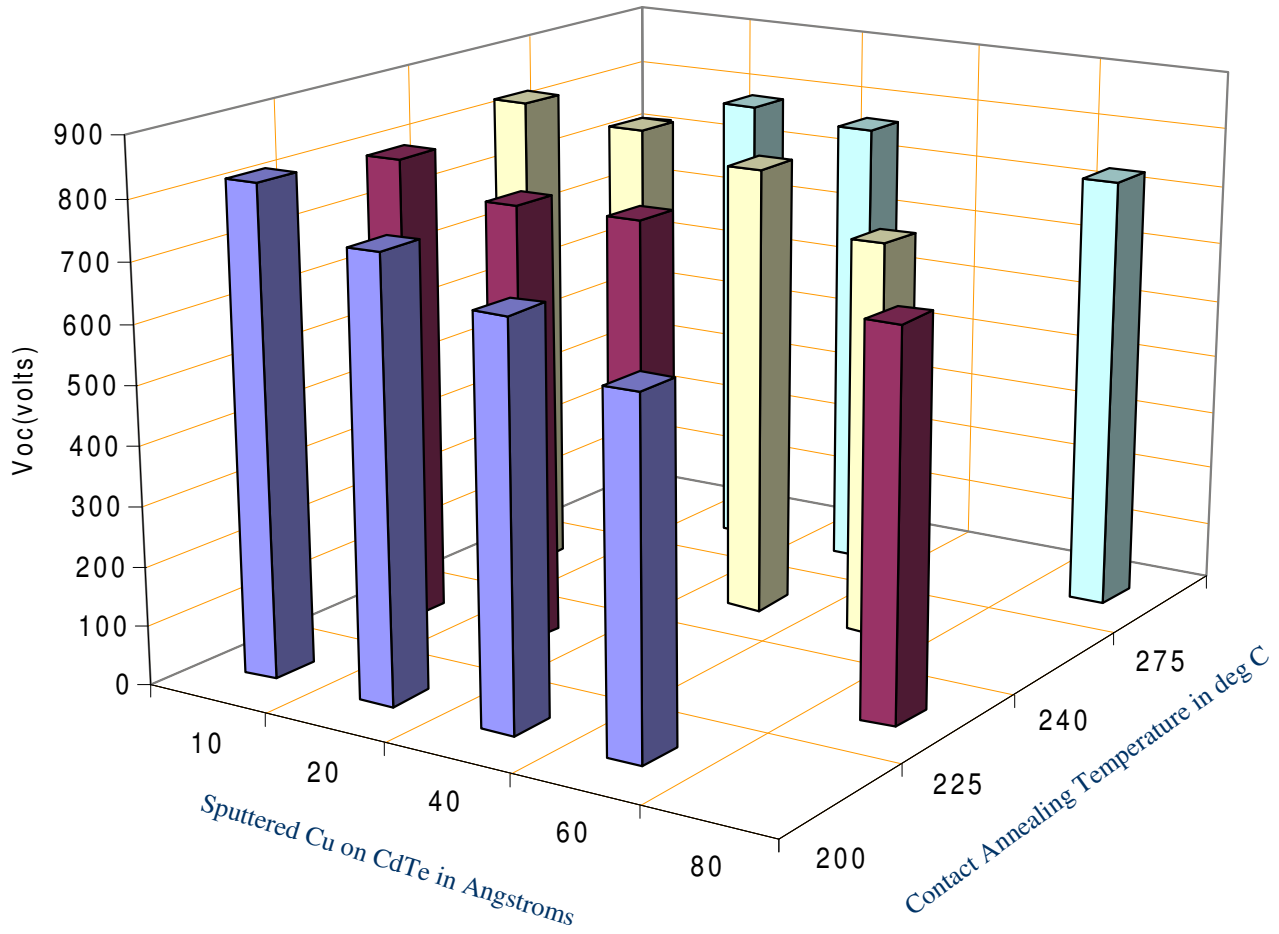
Dark JV



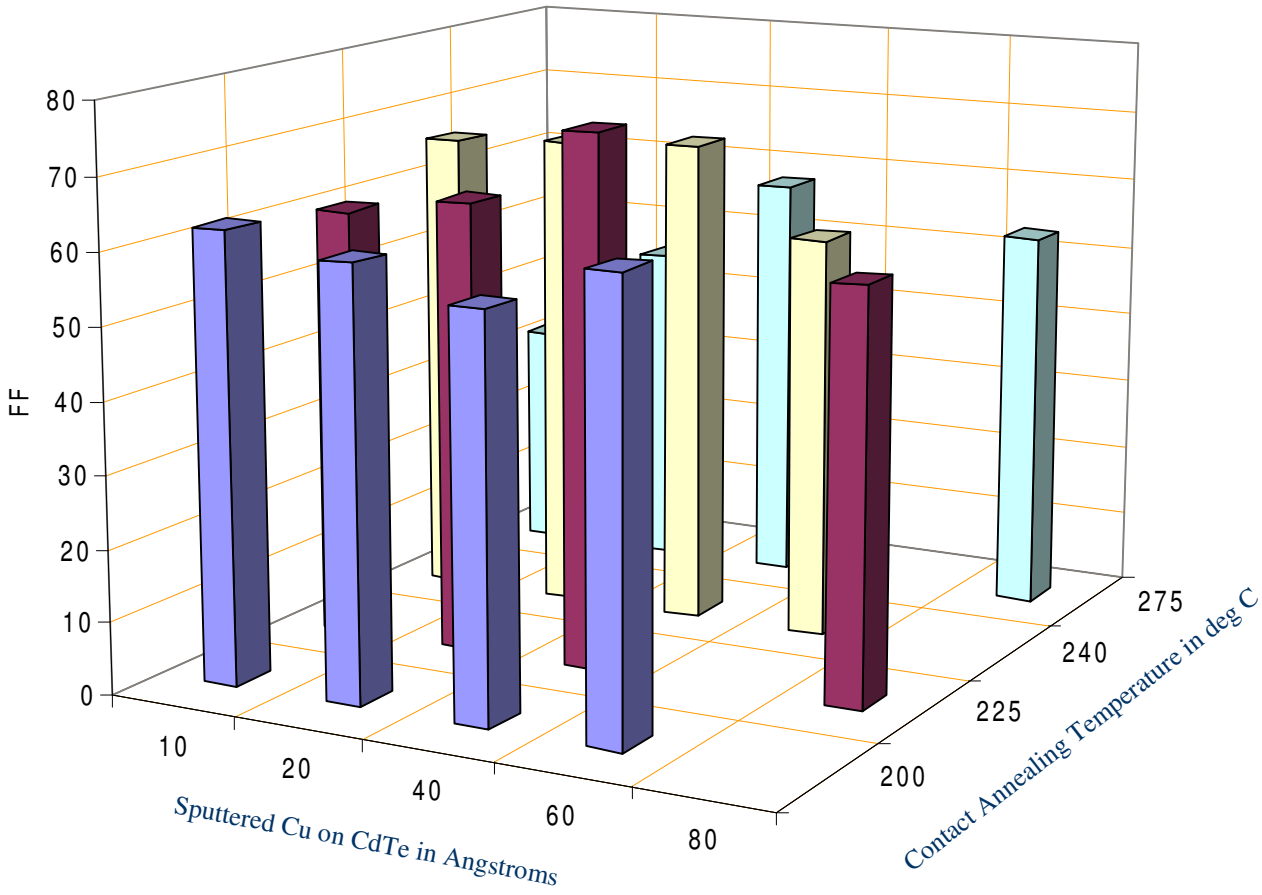
Note: Contact Annealed at 275 deg C


275 deg C Contact Annealing
Sputtered Cu thickness
80 0 A
40 0 A
20 0 A
10 0 A
Current density [A/cm2]
1.00E-01
9.00E-02
8.00E-02
7.00E-02
6.00E-02
5.00E-02
4.00E-02
3.00E-02
2.00E-02
1.00E-02
0.00E+00
-1.00E-02
-2.00E-02
-3.00E-02
-0.50
0.00
0.50
1.00
1.50
2.00
Voltage [Volts]

Effect of Cu sputtering on CdTe and Contact Annealing on Voc



Effect of Cu sputtering on CdTe and Contact Annealing on FF

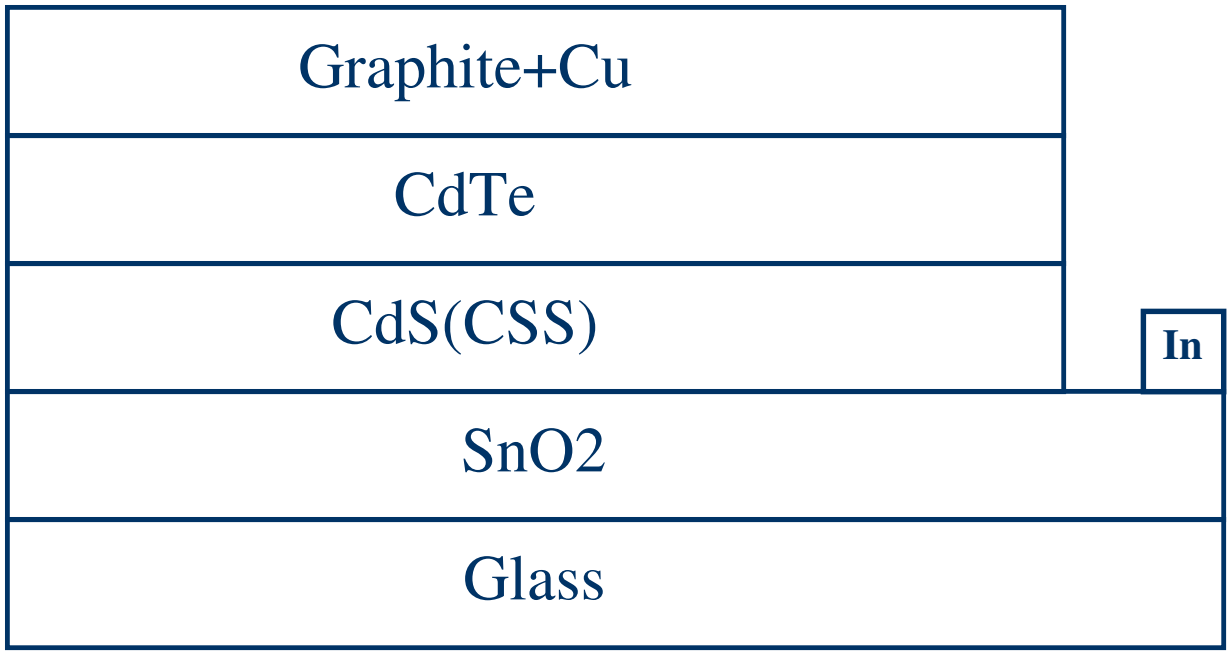


Summary-II

- Increase in sputtered Cu thickness over CdTe eliminates contact rectification
- Increase in Cu thickness also reduces series resistance
- Main junction is not affected initially,irrelevant of Cu thickness except for maximum thickness 80A.
- Optimum Contact Annealing temperature will be around 240 deg C
- Increase in Cu thickness results in reduction in Voc and FF

III.Cu on CdS

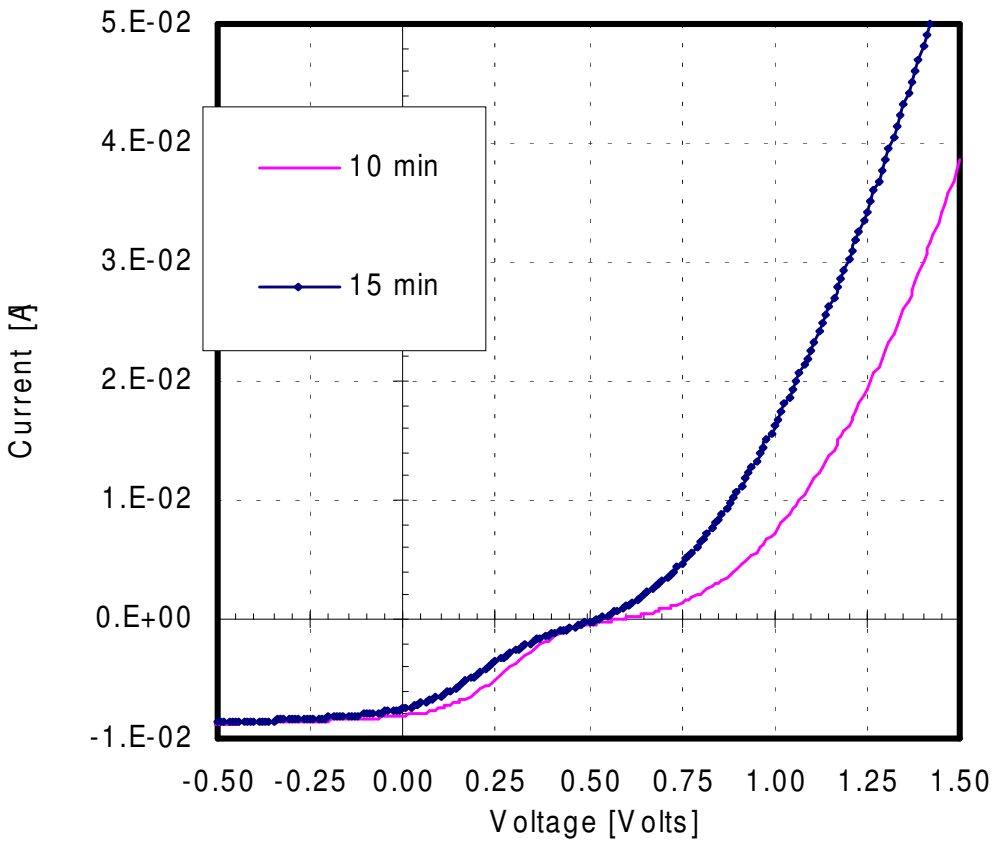
Note:CdCl2 treatment is done after CdTe deposition
CuCl treatment or Cu Sputtering is done over CdS prior to CdTe deposition



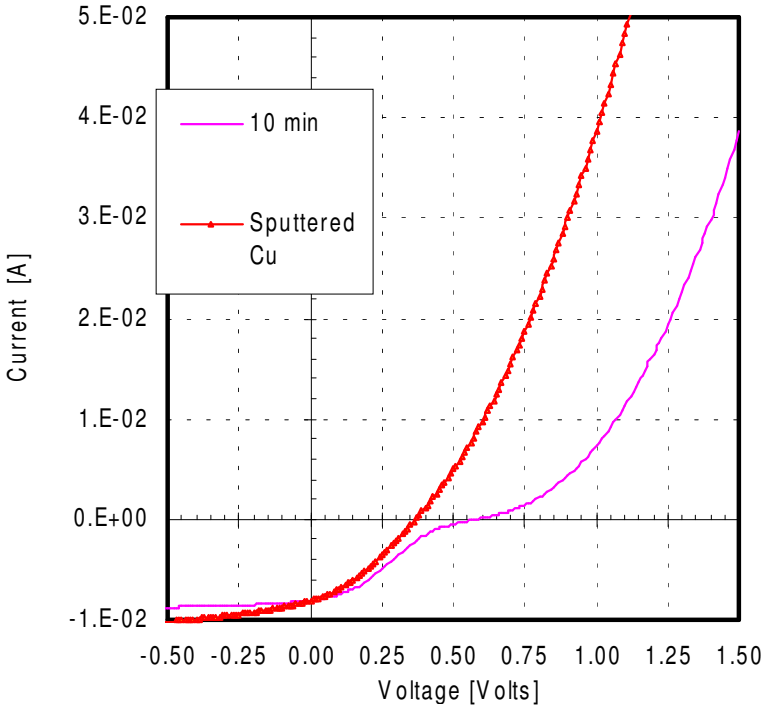
Process Condition

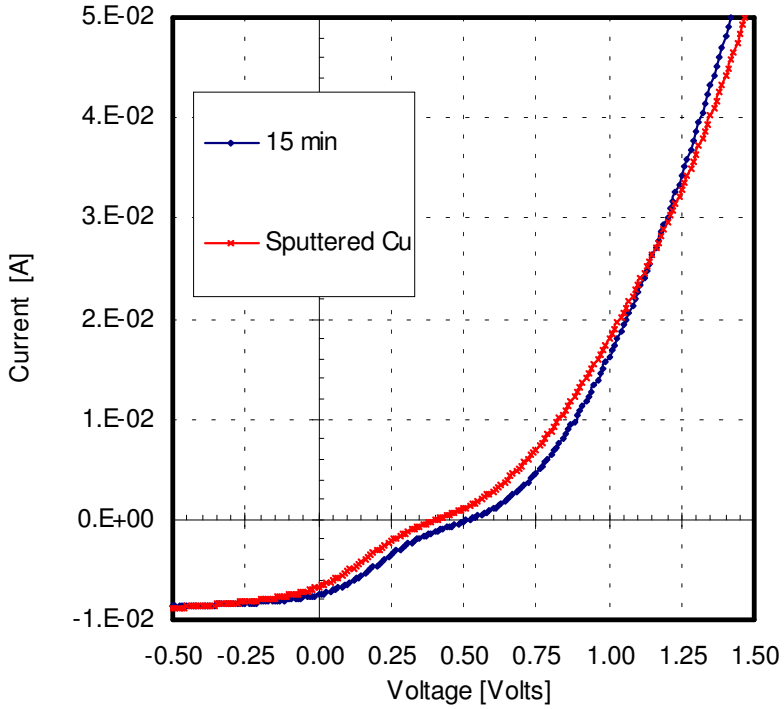
- SnO_2 is Bi Layer(Low and High conductivity)
- CdS is done by CSS.
- CdTe is done by CSS
- For all samples CdTe thickness is about 5 micro m
- Annealing after $CdCl_2$ treatment is done at 390 deg C for 25 min
- Contact Annealing is done for 25 min

Effect of CuCl Treatment on CdS

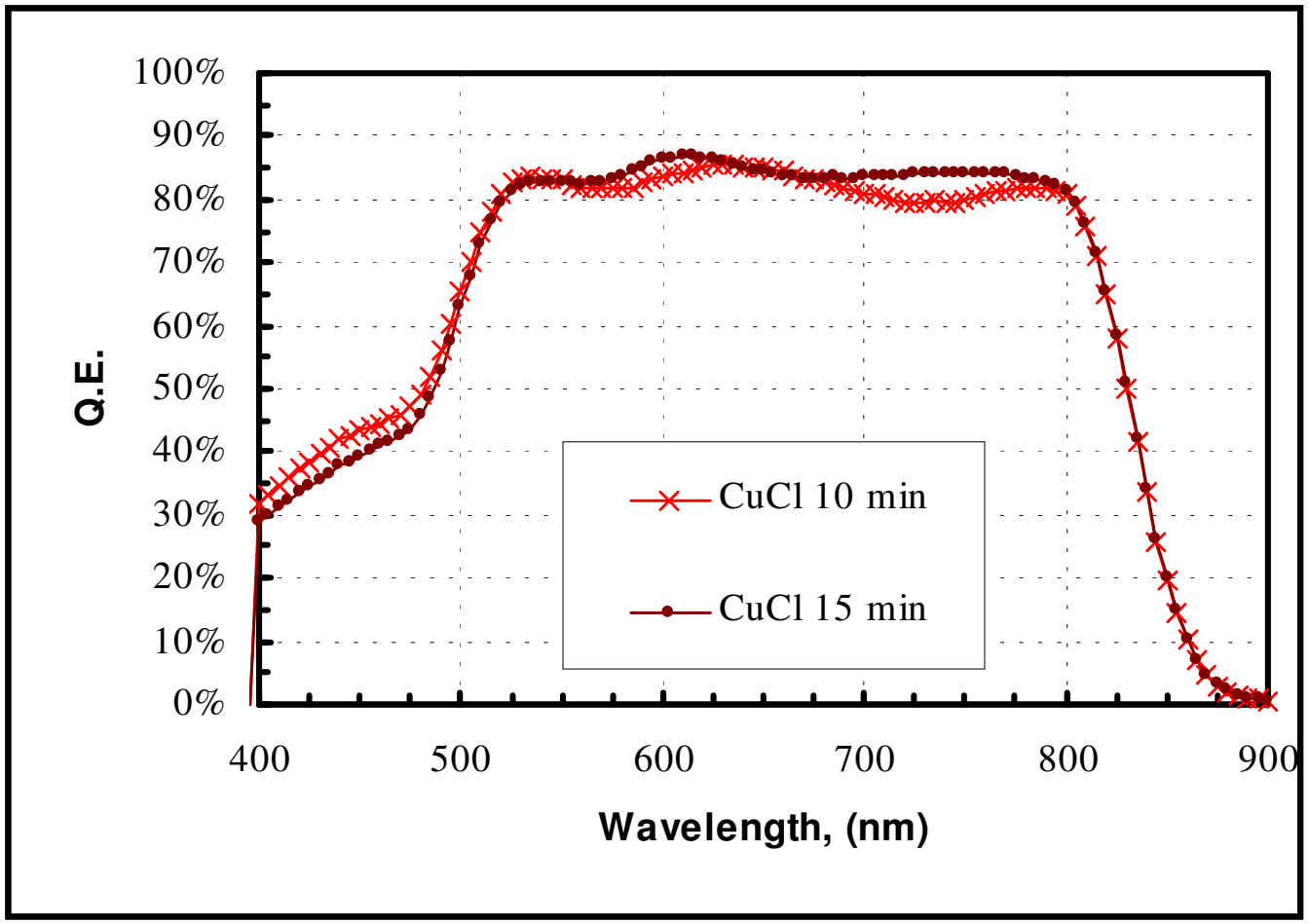


Effect of Cu Sputtering on CdS

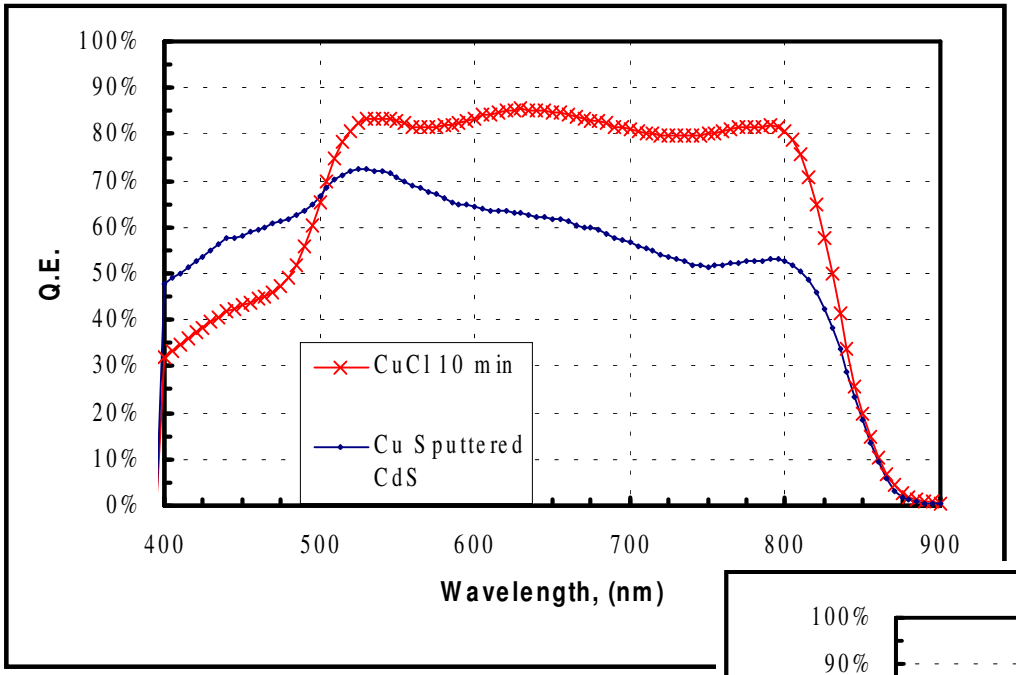


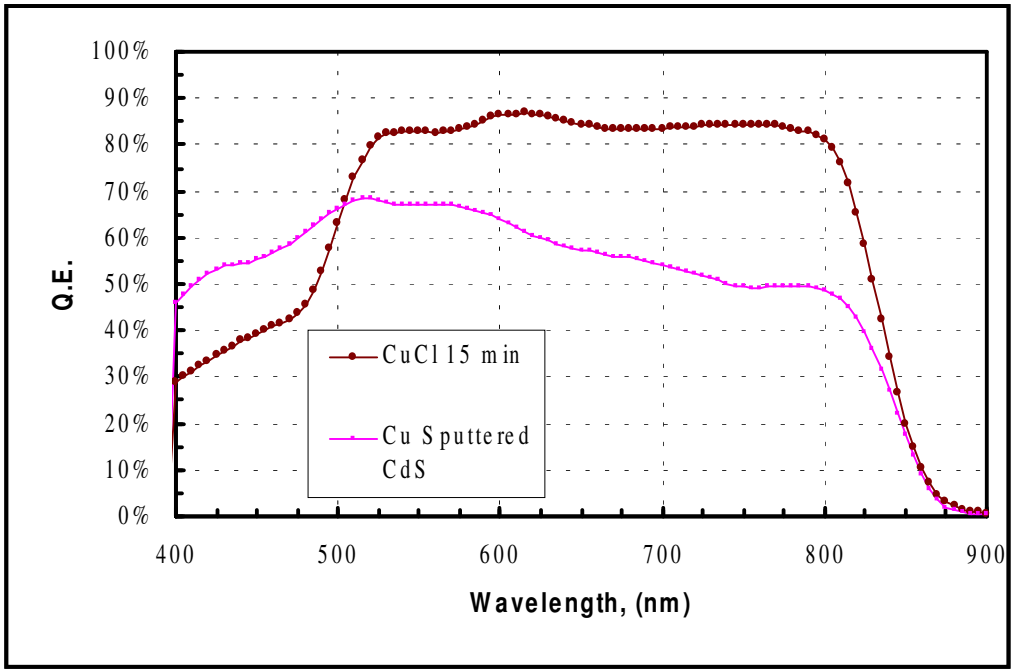


Effect of CuCl Treatment on CdS



Effect of Cu Sputtering (10A) on CdS





Summary-III

- Cu content directly in interface greatly affects the device performance,though Research is going on to optimize the process conditions for better results.
- Previous stability results indicate better stability performance for device which are CuCl treated directly in junction.

Measurement Automation

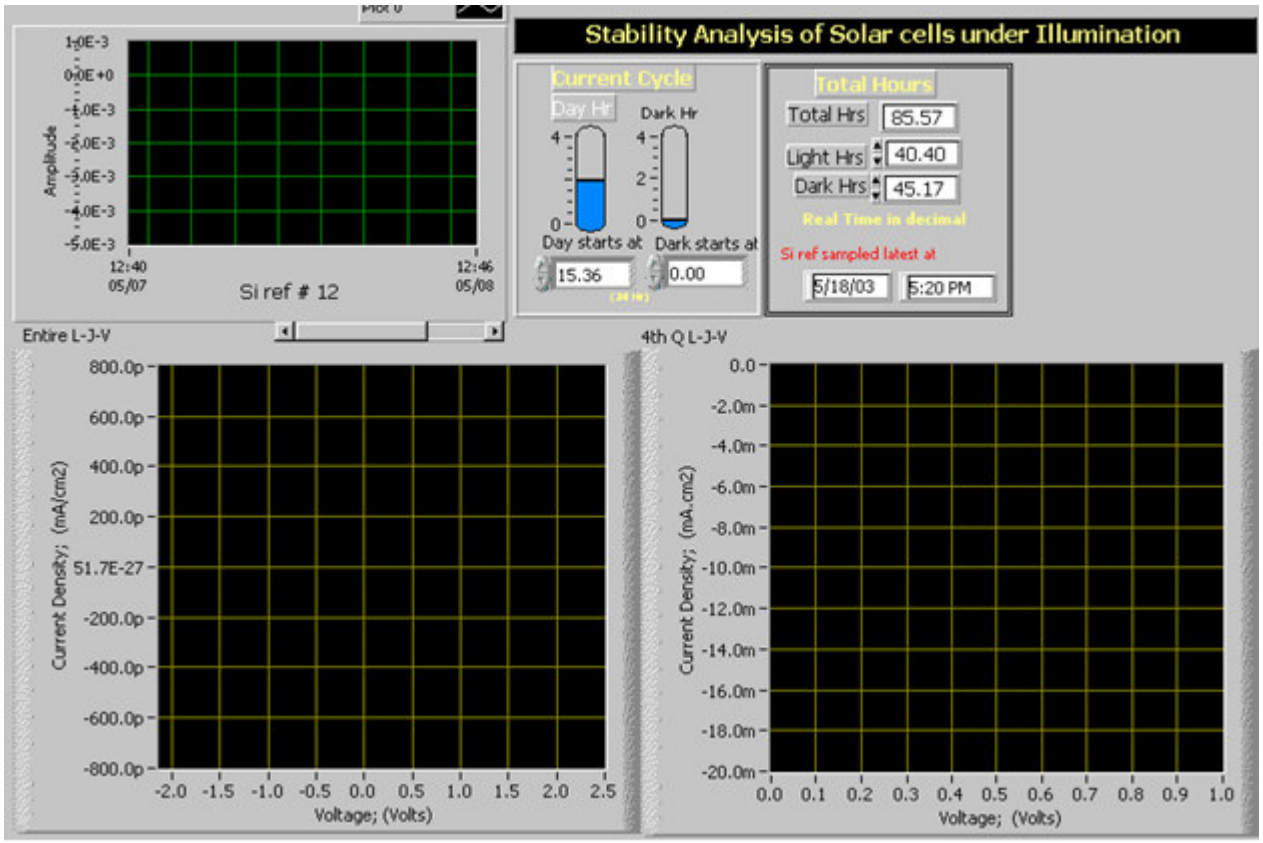
Hardware

- Setup for 48 cell configuration
- Each cell can be configured in different stress conditions- e.g.-O.C,S.C,F.B,R.B,Max.Load,etc
- Cells will not be in stress condition for negligible time(in seconds) only during measurement of that cell
- Costs 1/10th that of commercial alternatives which don't have features for stability testing
- Risk Management
    - Complete isolation of faulty part,AC to DC converter,Opto couplers
- General purpose PCBs

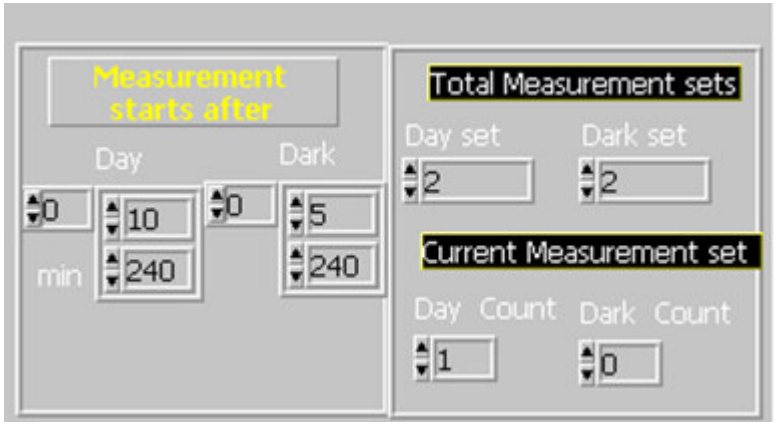
Software

- Developed in LabView®

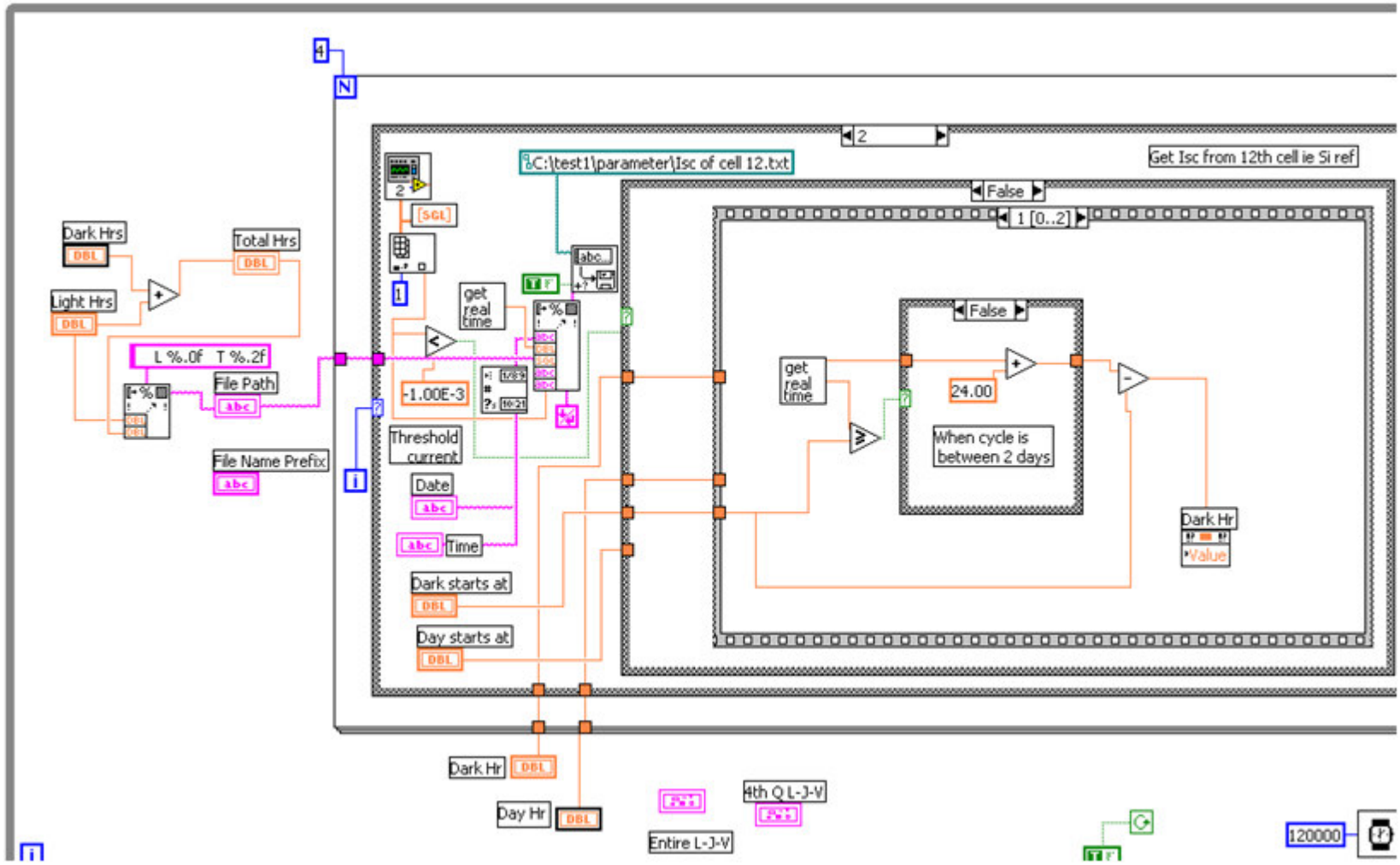
Front Panel of Main VI



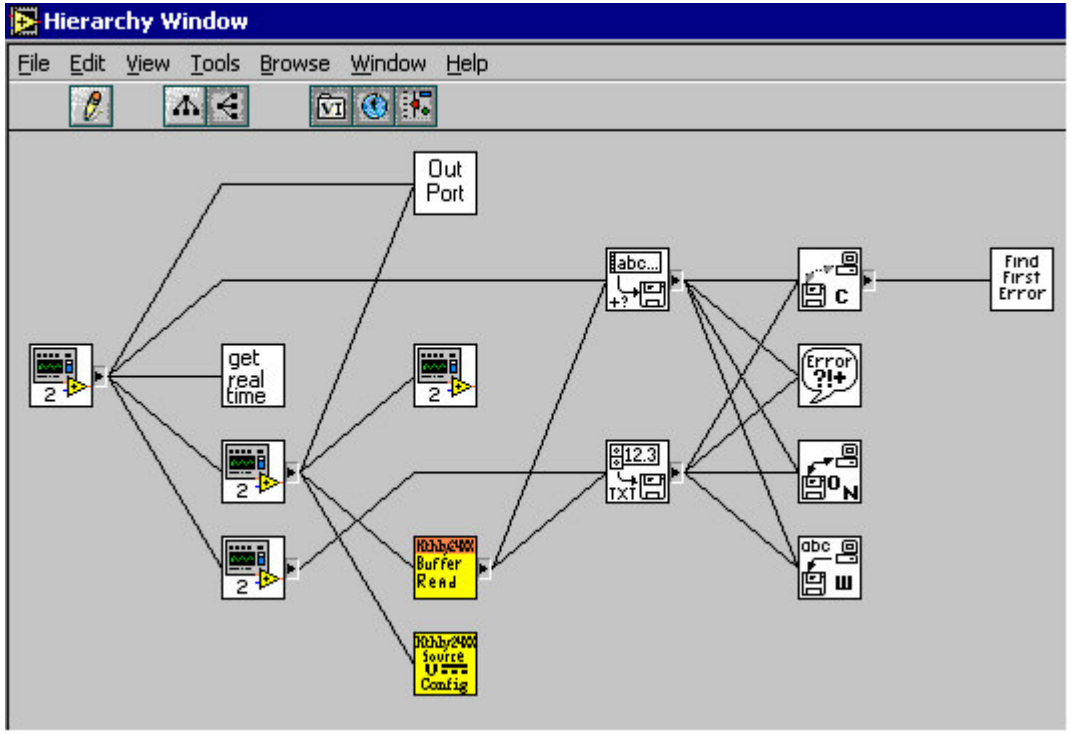
User Defined Measurement Frequency



Snap Shot of Block Diagram of Main VI



Hierarchy of Sub VIs



Features:

•Day-Night Cycle Monitoring and Data Logging

- Timer synchronized with real time Day-Night Cycle
- Error Handling
  - No measurements during system failure
  - Error handlers for keithley ® Source meter
  - Day Transition Monitoring
- Millisecond accuracy in predicting actual light soaked Hours,dark Hours, and Total Hours that the cells are inside.
- User Defined measurement frequency to suit log scale requirement.
- Well Structured complete Parameter and Data storage for easy retrieval and plots.
- Real time Data Display for monitoring
- Risk Management
  - Back up scheduling,Timer logging,Backup VI Files,Optimized to avoid memory leakage,Code protection

Temperature and RH Loggers

- Model OM-44 is a four channel datalogger that measures temperature and relative humidity (internal sensors) and also up to two external signals which can be external temperature probes, 4 to 20 mA signals or 0 to 2.5 Vdc signals.

- 1/10th of PCI based loggers cost

- Can be placed anywhere and software available for data offload and reconfiguration

- Date and Time storage

Summary-II

Measurement Automation helps in

- Consistency,accuracy in measurement
- No change in Stress Condition
- Data logging and Continuous Monitoring Stress temperature,humidity, and stress period
- Massive Well Structured Data collection