Luminescence from poly-Si films and its applications

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Motivation

Current record: 26.1%
Haase et al., SOLMAT 2018, 186, 184.

Source: Melskens et al., IEEE JPV 2018, 8, 373.

poly-Si films also absorb light → could yield PL signal
Formation and microscopic structures

TEM image

Doped poly-Si films contain both amorphous and crystalline phases

Nguyen et al., ACS Appl. Energy Mater. 2018, 1, 6619
PL (1250-1500nm) is from radiative defects in doped poly-Si films
PL from doped poly-Si films

Even 1.3nm oxide layer can block carriers from poly-Si films

Nguyen et al., ACS Appl. Energy Mater. 2018, 1, 6619
Extended to a-Si:H films

Even 1nm oxide layer can block carriers from a-Si:H films

Nguyen et al., ACS Appl. Energy Mater. 2018, 1, 6619
What we have known so far...

1) a-Si DP
2) Poly-Si
3) SiO_x
4) Si <100>
5) 2 nm

2) a-Si:H films have a strong PL emission

3) Carriers in the films cannot move into c-Si substrates with ~1nm oxide present

Why didn’t we see the a-Si:H peak from poly-Si films?
Note: Raman spectroscopy and XRD confirm that the film is still largely in a-Si phase after being annealing.

- Annealed $\rightarrow$ H escapes the film $\rightarrow$ un-hydrogenated a-Si
- Phosphorus diffusion ($>800$ °C) $\rightarrow$ no hydrogen in the film $\rightarrow$ no a-Si:H peak

Truong et al., ACS Appl. Mater. Interfaces 2019, 11, 5554
Hydrogenation in doped poly-Si films (1/2)

We can introduce H atoms into doped poly-Si films

Truong et al., ACS Appl. Mater. Interfaces 2019, 11, 5554
Hydrogenation in doped poly-Si films (2/2)

- We can manipulate the presence of H in poly-Si films

Confirmed [H] by SIMS

SIMS profile

- As diffused
- Hydrogenated

Concentration (cm\(^{-3}\)) vs. Depth (\(\mu\)m)

Note: SIMS background for [H] is \(10^{19} - 10^{20}\) cm\(^{-3}\).

M. Schnabel et al., APL, 112 (2018) 203901

Truong et al., ACS Appl. Mater. Interfaces 2019, 11, 5554
Hydrogen injection effectiveness

Carriers in the films cannot move into c-Si substrates with ~1nm oxide present → Stronger a-Si peak = more hydrogen

Truong et al., Solar RRL, 2019, DOI: 10.1002/solr.201900476
Prediction of pinholes / broken oxide layers

Textured substrate

Possible applications (2/3)
Carrier dynamics in the poly-Si films by time-resolved PL

Possible applications (3/3)
Summary

P-doped poly-Si films:

➢ Amorphous and crystalline phases

➢ Strong sub-bandgap PL

➢ No carrier coupling from these films with an oxide layer

➢ We can inject H into poly-Si films

Hydrogen monitoring, broken oxide/pinholes, TRPL
My students: **Thien Truong**, Mike Tebyetekerwa, Zhuofeng Li, Jessica Wu

ANU: Prof Dan Macdonald, Dr Di Yan and the Si team

NREL: Harvey Guthrey, Steve Harvey, Matt Young, Mowafak Al-Jassim (some TEM and SIMS works)
Hydrogenation in doped poly-Si films: FTIR

Clear Si-H bonds from FTIR

Truong et al., ACS Appl. Mater. Interfaces 2019, 11, 5554
Possible applications

Prediction of pinholes / broken oxide layers
PL from doped poly-Si films

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