Engineering of the Ideal a-Si:H Layer in Heterojunction Solar Cells

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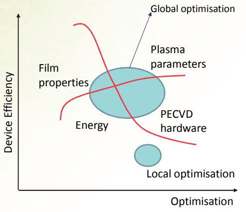
研究の目的 Purpose of Research

In nano-scale fabrication, plasma deposition process requires the precise control of species in the plasma.

- Different PECVD systems (i.e. geometries, power levels, RF, MW, ETPECVD….)
- Film properties are determined by plasma and surface based parameters.
- Plasma properties are universal across deposition systems.
- Inconsistent film properties make it difficult to transfer research devices to industry.



Internal plasma properties of each species (radical and ion density, their energies and trapping probability) can allow for precise control of deposition material.

実験 Experimental Details

5nm hydrogenated amorphous silicon (a-Si:H) layers were deposited in a parallel-plate PECVD system.

The influence of deposition conditions from an optical and structural stand-point for a-Si:H were investigated for their role in the passivation of crystalline silicon (c-Si) surfaces.

a-Si:H layer composition, electronic and optical properties measured by FTIR, RAMAN, XRD, multispectral ellipsometry, and QSSPC/PCD.

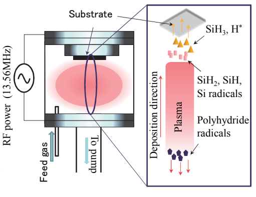
Surface reactions induced by plasma are by simulation.

$$\tau_d = \frac{p\Lambda_0^2}{D} + \frac{2l_o s}{\sqrt{8kT/_{\pi M}}}$$

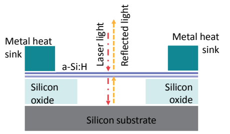
$$\Lambda_0^{-2} = \left(\frac{\pi}{L}\right)^2 + \frac{2.405}{R^2}$$

p = Pressure
s = Trapping probability
L = Length of the deposition chamber
R = Radius of the deposition chamber
T = Temperature of plasma radical

M = Mass of plasma radical
Λo = Geometrical diffusion length determined by deposition chamber structure
D = Diffusion length of Hydrogen
*l*o = Volume to surface area ratio of chamber

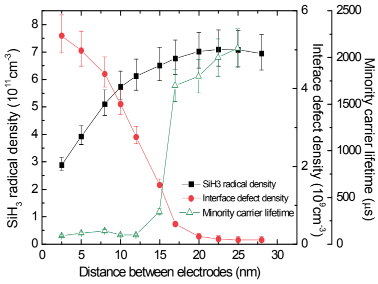


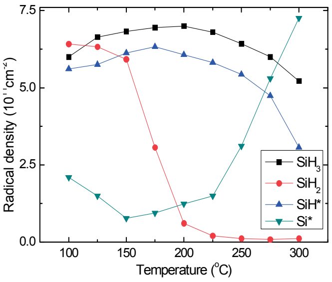
Plasma dynamics during deposition in *rf* with DC bias.



Method of absorption/scattering analysis

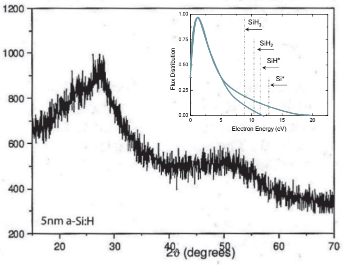
結果と考察 Results and Discussion



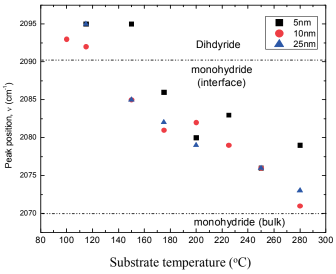


Plasma quality and ion/radical energies at deposition surface influence both abstraction and chemisorption processes of SiH_3 radicals, ultimately affecting passivation quality.

Composition of the a-Si:H layer can be determined by the uptake of key plasma-based radicals, influenced by temperature, *rf*-power, and partial pressure.



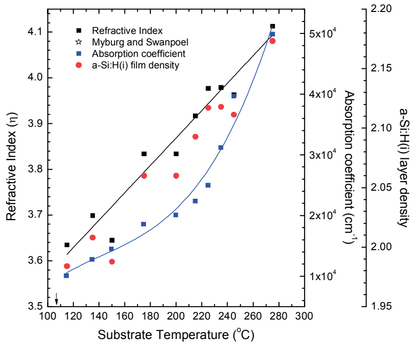
XRD analysis identifies no crystallite formation or transitioning states occur with increased process temperatures up to 280°C, when stable monohydride a-Si:H was deposited by ML-PECVD and standard PECVD.



The shift in high-frequency hydride stretching mode with increasing temperature when correlated with S_{eff} indicates that drifting outside the local optimization may lead to lower quality a-Si:H layers

Optical profile for refractive index and absorption coefficient (633nm) of 5nm a-Si:H(i) deposited between 100°C and 300°C.

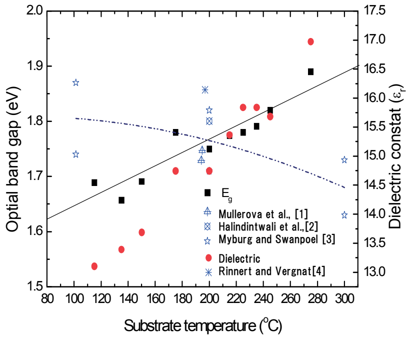
Correlated with previous IR spectroscopy measurements, an upward trend is established that demonstrates a clear increase of refractive index and absorption coefficient in the absence of microvoids.



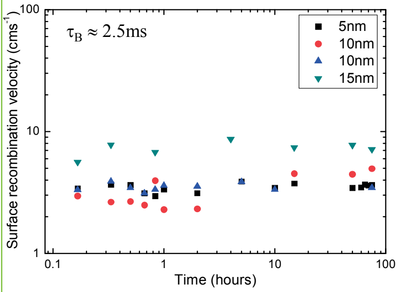
The proportional increase in the density of the thin film layers with temperature was unexpected given that the density of a-Si:H had been thought to decrease with temperature according to the literature; whereas, decreases in density of a-Si:H layers (below 300°C) are more consistent with increased microvoid concentration. Increases in density (up to 300°C) are consistent for optimised amorphous material, prior to any phase transition.

Importantly E_g exhibits a distinct improvement with increases in the anneal temperature between 100°C and 300°C, contrary to the literature. The observed blue-shift relates well to the increase in density of the a-Si:H(i) layer with higher anneal temperatures.

Above 300°C, changes in E_g are influenced by transition states.



結論 Importance for solar cells



The long term stability of the a-Si:H layers during thermal annealing are observed by their low surface recombination velocities.

High stability is apparent for all a-Si:H layers annealed at 250°C in excess of 100 hours.

Long term stability and performance can be guaranteed by careful analysis of deposition conditions.

Although ML-PECVD adds reliability to the a-Si:H deposition compared to standard PECVD, further improvements to the efficiency and stability of a-Si:H/c-Si heterostructures remains available.

結論 Conclusions

- The structural profile for density in thin 5 nm and 10 nm a-Si:H(i) layers containing no micro void fraction has demonstrated a basis for deposition of high quality deposited layers. The optical and electronic properties are shown to be dependent on the hydrogen content, and density, influenced by the composition of radicals within the plasma
- In nano-fabrication, precise spatio-temporal control of radical density and energy within the vicinity of the deposition surface represents a solution to large area fabrication of ideal solar cells.

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