Hydrogenated Silicon Absorber Layers for Thin Film Solar Cells Deposited From Hydrogen Diluted Silane Using a Layer-by-Layer Approach

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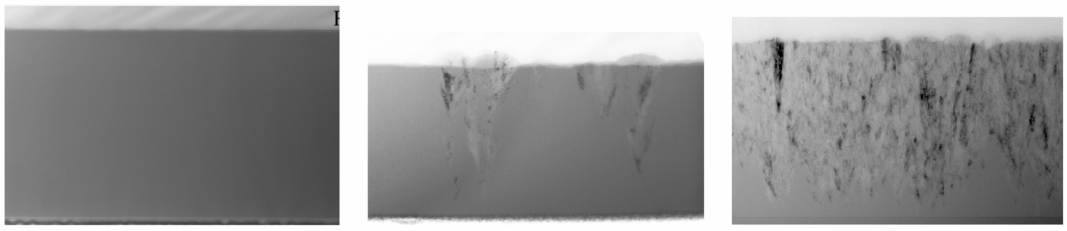
Introduction

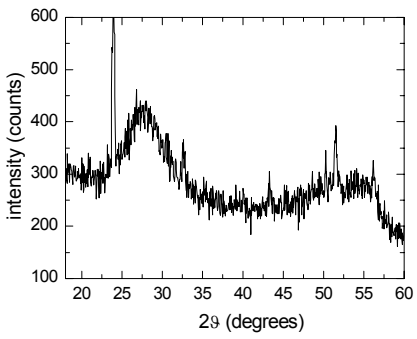
- Dilution of silane source gas with hydrogen is beneficial for stability of the solar cell absorber layer
- Increasing dilution ratio R=[H_2]/[SiH_4] results in reduced thickness of the amorphous 'protocrystalline' layer
- For high R phase control techniques are required to obtain a sufficient thickness for application as solar cell absorber layer

Structural phase evolution

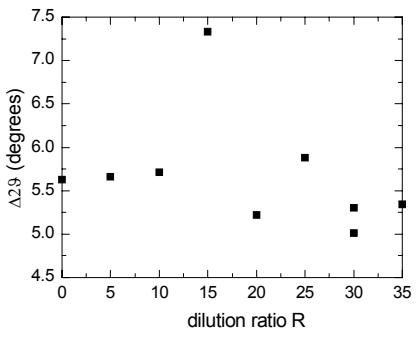


- TEM images of 1 μm thick Si:H films deposited at different R. From left to right: R=20, R=25 and R=30

X-Ray diffraction

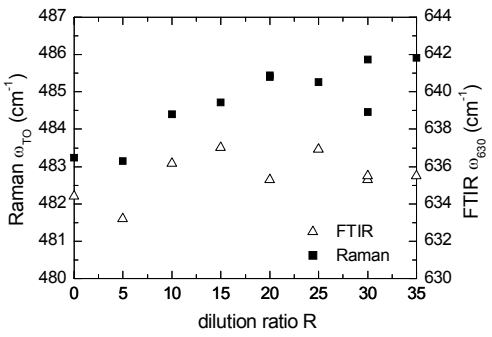


- a-Si-H films on were deposited on c-Si with varying dilution ratio R=[H_2]/[SiH_4]
- XRD spectra recorded as a function of diffraction angle 2ϑ



- Full-width at half maximum (FWHM) was determined for the first diffraction peak
- Lower FWHM values are obtained at increased hydrogen dilutions

Raman and FTIR



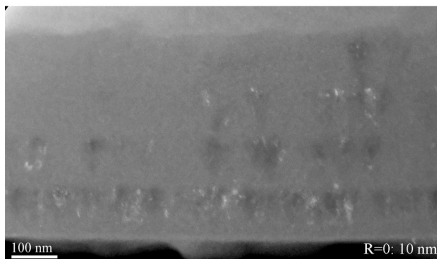
- Raman reveals a shift of the TO mode from 483 cm^{-1} to 486 cm^{-1}
- FTIR 630 cm^{-1} peak analysis: hydrogen content increases up to 16%. No trend observed regarding the peak position

Increased MRO

- Narrowing of the FWHM of the XRD first diffraction peak and the shift of the Raman TO peak position to higher wave numbers has been linked to an improved structural order of a-Si:H
- The medium range order (MRO) of the films increases with hydrogen dilution
- No evidence for crystallites embedded in the amorphous film, since the FTIR 630 cm^{-1} peak does not shift to 620 cm^{-1}, which would indicate mono hydride bonding on c-Si

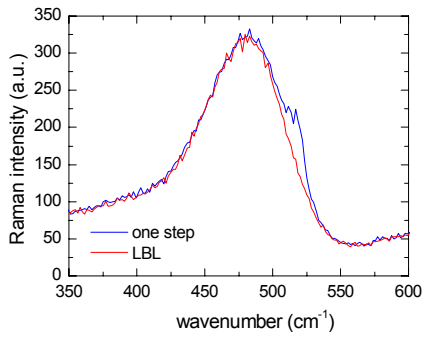
Layer-by-layer process

- To benefit from increased stability of a-Si:H deposited using high hydrogen dilution the transition to the microcrystalline phase should be avoided
- Layer-by-layer (LBL) approach is proposed in which thin interlayers of pure silane are applied to suppress the crystalline growth
- Solar cell was fabricated with LBL absorber layer at R=40
- Suppression of crystalline growth evident from comparison with one-step R=40 solar cell.

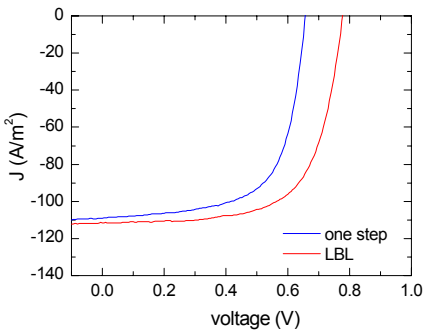


- Example LBL stack, crystalline growth is suppressed using three interlayers from pure silane
- The film becomes more amorphous in the growth direction

Layer-by-layer solar cell

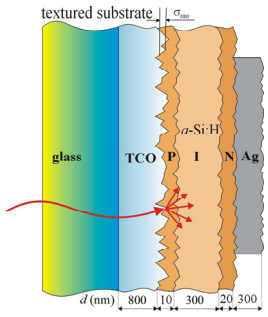


- Raman spectra recorded through n-layer of solar cell device
- LBL absorber layer is amorphous

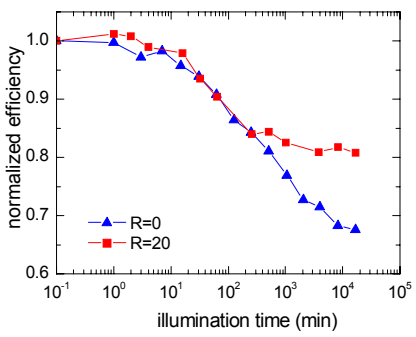


- I-V curves measured under standard illumination conditions
- V_{OC} of LBL cell is improved

One-step solar cell: increased stability at R=20



- Results of accelerated degradation experiment on solar cells with R=20 and undiluted (R=0) absorber layers.
- Increased stability for R=20



- Normalized efficiency as a function of illumination time for solar cells deposited with and without hydrogen dilution

Conclusions

- XRD first diffraction peak narrows with increasing hydrogen dilution
- Raman TO peak shifts to higher wavenumbers with increasing hydrogen dilution
- Films grown at increased levels of hydrogen dilution show improved medium range order.
- No evidence for embedded crystallites from FTIR data.
- Improved stability of solar cell with R=20 absorber layer confirmed
- LBL process applied successfully to obtain amorphous absorber layer at a high dilution ratio that would normally result in microcrystalline phase