Influence of film formation on interface morphology of silicon thin film solar cells prepared on randomly textured substrates

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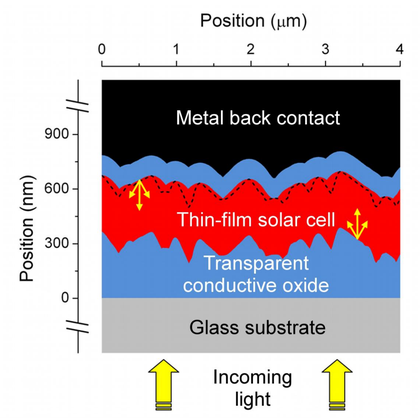
Motivation

- Randomly textured transparent conductive oxides (TCO) are widely used to improve the incoupling of light in the solar cell and diffract/scatter the incident light
- Because silicon solar cells are very thin, the roughness of the front contact propagates through the layer stack, creating a rough metal back contact
- Interaction of light with rough metal interfaces can result in enhanced light scattering and diffraction, but also in an enhanced optical absorption within the metal/dielectric interface
- Optical losses and quantum efficiency depend on the textures of the back contact and optical properties of the metal/dielectric interface
- Accurate modeling of the back contact textures allows for prediction of solar cell performances based on the front contact textures

Surface coverage algorithm

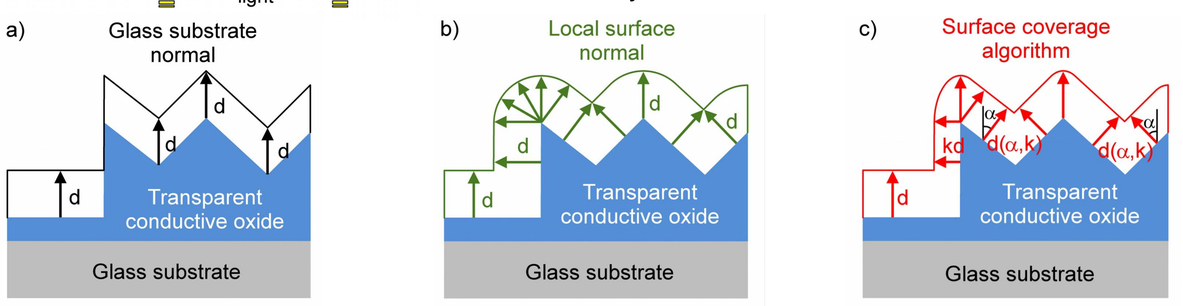


- Measurements by Atomic Force Microscopy (AFM) show significant differences between front and back contact morphology of silicon thin film solar cells
- Different approaches to model back film morphology

  (a) in direction of glass substrate normal and

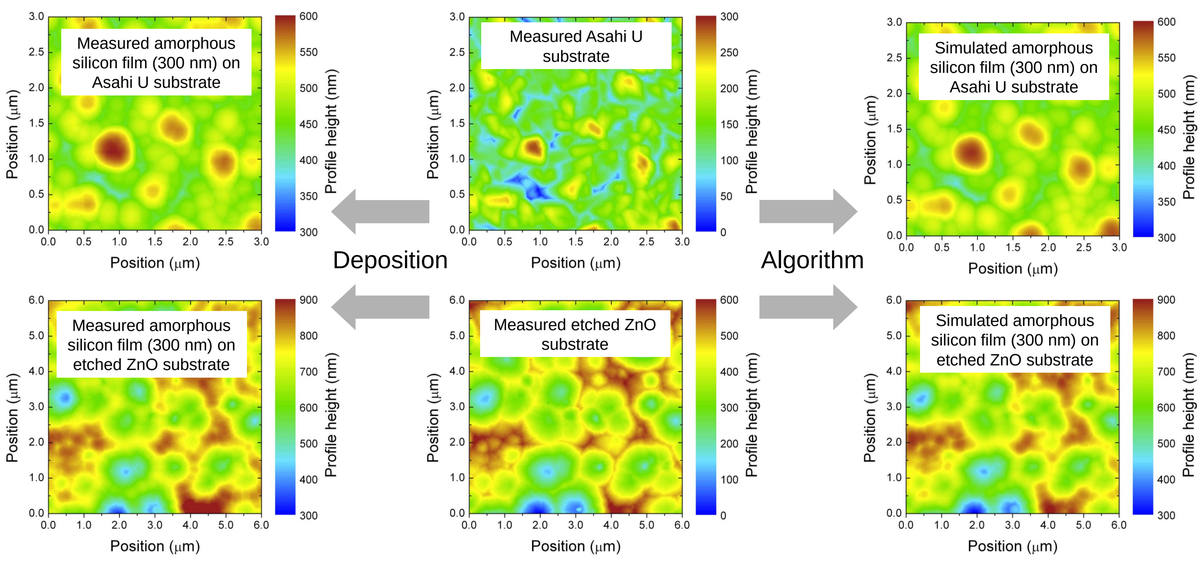
  (b) in direction of local surface normal

  (c) directional film formation. Direction defined by direction factor (k), which can be varied from 0 and 1
- Direction factor for amorphous silicon k=1, direction factor for microcrystalline silicon k=0.75



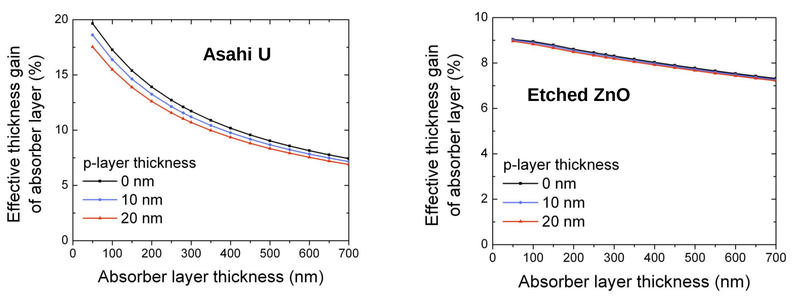
Amorphous silicon films and solar cells

Morphologies of amorphous silicon films on Asahi U and etched ZnO substrate were measured and simulated



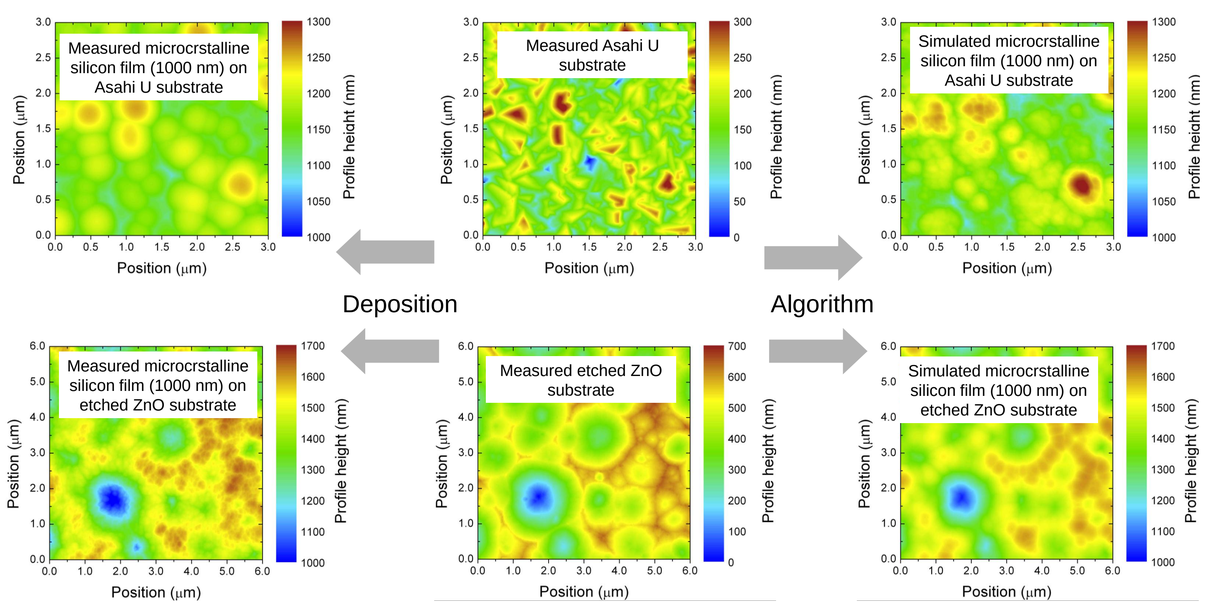
- Influence of substrate morphology on amorphous silicon film growth was investigated.
- Only AFM scan of the substrate and nominal film thickness were used as input parameters

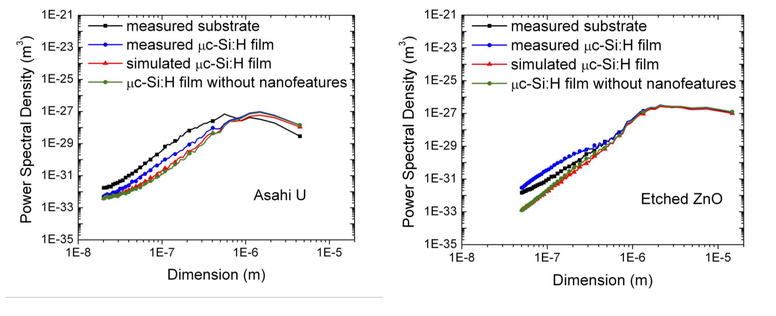
Thickness gain of amorphous silicon films on Asahi U and etched ZnO substrates



- Average thickness of deposited layers is larger than nominal film thickness
- Thickness gain as a function of the film thickness.
- Thickness gain is larger for Asahi U substrate.

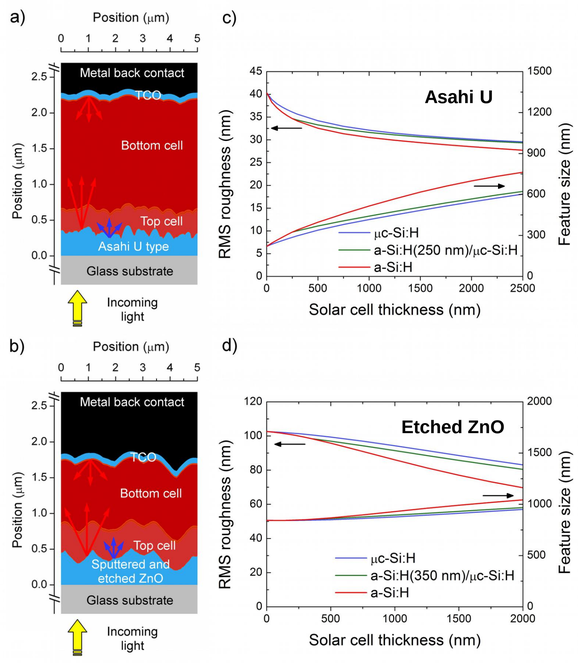
Morphologies of microcrystalline silicon films on etched ZnO and Asahi U substrate were measured and simulated





- Measured and simulated surface morphologies were compared by calculating the Power Spectral Density
- Good agreement for measured and simulated surfaces
- Nanofeatures of microcrystalline silicon films can not be described by growth model

Back contact morphology of silicon tandem solar cells



- Surface coverage algorithm was also used to investigate behavior of micromorph tandem solar cells
- Back contact morphology of tandem solar cell is determined by microcrystalline silicon bottom cell
- Back contact feature size of microcrystalline silicon solar cells is smaller than a-Si, while roughness is larger
- Light trapping properties of microcmoph tandem solar cells depends on the substrate morphology
- Increased thickness of solar cell layers is also present in micromorph tandem solar cells

Summary

- Light trapping in thin film solar cells depends on morphologies of the front and back contact
- Back contact morphology can be accurately predicted by knowing the front contact textures and deposited film thickness
- Calculated morphologies are in excellent agreement with measured back contact morphologies
- Influence of film thickness on back contact roughness and feature size for amorphous, microcrystalline and micromorph tandem solar cell was determined
- Thickness gain of deposited layers is observed
- Optics of thin film solar cells can be predicted by using AFM scans of the textured substrates

References

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