Characterizing AntiReflection Coatings on Textured Mono-Crystalline Silicon with Spectroscopic Ellipsometry

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Our message

Film thickness and optical constants (n & k) can be determined from textured monocrystalline and multi-crystalline silicon.

New measurement geometries (apexial or lateral) required for pyramid-structures of alkaline-etched mono-crystalline silicon.

Tilted Lateral geometry separates measurement beam from pyramid facets and surrounding bus lines.

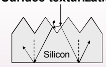
Pyramid coverage determines preferred measurement geometry.

Scattering-Matrix approach models interaction of light beam with textured, scattering surface.

Introduction

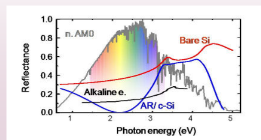
Light Trapping techniques to minimize optical losses in solar cells

1. Surface texturization



2. Anti-reflecting films

$$d_{AR} = \lambda / 4n(\lambda)$$

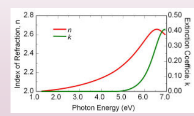


Silicon nitride Model Dielectric Function

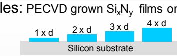
Near-IR to UV

Fundamental bandgap and higher energy transitions

Tauc-Lorentz oscillator



Samples: PECVD grown Si_xN_y films on textured Si

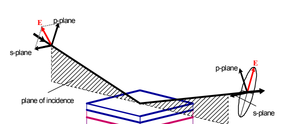


Name	Wafer type	Wafer treatment	Substrate morphology
Reference	crystalline-Si	Polished (no texture)	15 cm
c-Alk	crystalline-Si	Alkaline etched	20 µm
m-Alk	Multi-crystalline Si	Alkaline etched	50 µm
m-Acid		Acid etched	50 µm
m-Ascut		As-cut	20 µm

Results and Discussions

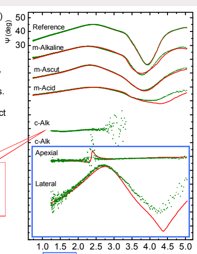
New measurement method and texture effects

(a) Standard geometry



Standard Ellipsometry measurement geometry collects the specular reflection from a smooth, flat surface.

Experimental (······) and best match (——) ellipsometric parameter ψ data using an EMA to describe the Si_xN_y optical constants and texture effects. The spectra are shifted with respect to the reference sample spectrum for a better clarity.

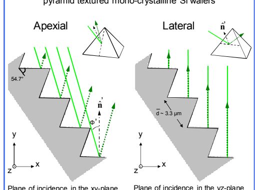


Problem: Low light reflection and data loss!

Solution

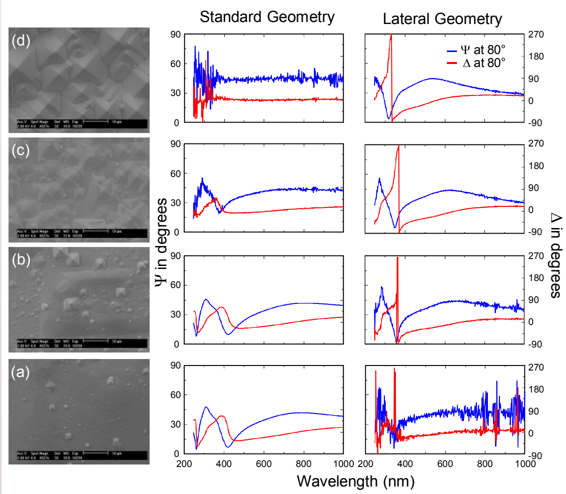
Spectroscopic Ellipsometer configured with special sample tilt- and rotation to align pyramid-facet normal with measurement beam (Lateral geometry)

Non-standard measurement geometries for pyramid textured mono-crystalline Si wafers



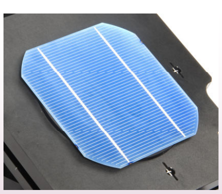
Each pyramid facet acts as an independent sample with same properties. The beam diameter of ~ 2 mm illuminates a large number of pyramids sharing the same orientation.

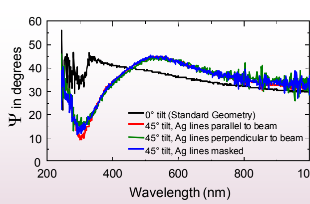
Pyramid Surface Coverage



Standard and tilted Lateral geometry SE measurements from samples with varying etch conditions. SEM graphs from each sample show the development in pyramid texture with increasing etch time (from bottom to top). As coverage increases, the standard measurement no longer provides signal to determine the AR coating properties – instead, that information switches to the lateral geometry.

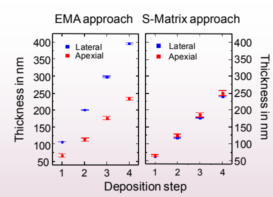
Measuring in Presence of Bus Lines

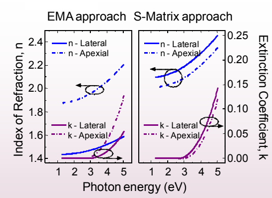




Measurement from standard geometry shows flat Ψ spectra indicative of metal bus lines. All tilted measurement spectra contain interference oscillation from SiNx AR coating. Additionally, all tilted data are the same regardless of whether Ag bus lines are masked or oriented in a specific direction. Light reflected from bus lines is scattered away from the detector for the lateral tilted measurement geometry.

Thickness and Optical Constants for AR Coating





EMA modeling approach results in a large discrepancy in both optical constants and thickness of SiNx AR coating between apexial and lateral measurements. The Scattering-Matrix (S-Matrix) approach improves consistency between measurements and better describes the interaction of light with textured surfaces.

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