IR to UV ellipsometric characterization of silicon nitride thin films on textured Si wafers

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1 Our message
The film thickness and optical constants can be determined for all the presented textures as well as a virtual void fraction.

New method for measuring thickness in structured c-Si substrates.

The effective dielectric function of SiNx decreases depending on the texture. This can be described by an effective medium approximation consisting of a fully dense SiNx film and void optical constants.

IR data of the chemical bond mode amplitude and resonance energy distribution suggests a change in the chemical composition of the films in dependence on the texture.

Introduction

Minimize optical losses in solar cells

Trapping of light techniques:

Surface texturization [1] Anti-reflecting films

Silicon nitride Model Dielectric Function

Infrared (IR) Near-IR to UV

Photon and chemical bonds

Fundamental bandgap and higher energy transitions

Silicon nitride window

Samples: PECVD grown SiNx films on textured Si wafers

<table>
<thead>
<tr>
<th>Name</th>
<th>Wafer type</th>
<th>Wafer treatment</th>
<th>Substrate morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-Alk</td>
<td>crystalline-Si</td>
<td>Abiited etched</td>
<td>Alibted etched</td>
</tr>
<tr>
<td>m-Alk</td>
<td>crystalline-Si</td>
<td>Alibted etched</td>
<td>Alibted etched</td>
</tr>
<tr>
<td>m-Acid</td>
<td>Multi-crystalline-Si</td>
<td>Acid etched</td>
<td>Acid etched</td>
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<tr>
<td>m-Asscut</td>
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<tr>
<td>m-Alkaline</td>
<td>Multi-crystalline-Si</td>
<td>Acid etched</td>
<td>Acid etched</td>
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</tbody>
</table>

UV-VIS: New measurement method and texture effects

Experimental ( ) and best match (dotted) ellipsometric parameters using an EMA to describe the SiNx optical constants and texture effects. The spectra are fitted with respect to the reference sample spectrum for a better clarity.

Problem: Low light reflection and data loss!

Reflectance ( ) and extinction coefficient data ( ) of the point extracted (solid line) for the investigated samples.

IR: Chemical bond modes and texture effects

While in the NIR-UV spectral range the EMA provides good description of the experimental data. The EMA offers a poor description for the IR spectral range. This apparent contradiction appears because the IR spectral range is also sensitive to the film's morphology. A polynomial fit in the IR spectral range no modes exist and the dispersion merely depends on the higher energy electronic transitions.

The EMA obtained from the UV-VIS and IR analysis present both a decrease of the real and imaginary parts. This effect is addressed to the texture of the samples. This can be approximated by the shape of the spectrum with a Gaussian function. The shape of the spectrum suggests changes in the chemical composition of the films from sample to sample.

Results and Discussions

UV-VIS: New measurement method and texture effects

Non-standard measurement geometries for pyramidal textured nano-crystalline-Si wafers

Apical Lateral

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

Effective medium approximation (EMA) vo parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>m-Alkaline</th>
<th>m-Asscut</th>
<th>m-Acid</th>
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<tbody>
<tr>
<td>n</td>
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<td>2.59</td>
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<tr>
<td>k</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Refractive index ( ) and extinction coefficient data ( ) of the point-by-point extracted (solid line) and best match calculation (dotted line) for the investigated samples.

Chemical modes

Gaussian oscillator model

Changes in the chemical bond modes amplitude and resonance energy parameter values suggest changes in the chemical composition from substrate to substrate. Mode assignment after references [2-4].

References


Thickness results

Thickness results plotted versus deposition steps for the different textured wafers obtained from the UV-VIS ( ) and IR ( ) ellipsometry data analysis.