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Simulation and Measurement of Angle Resolved Reflectance from Black Si Surfaces

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Experimental specular and total reflectance as a function of incident angle. The average reflectance in the wavelength range 300-1000 nm and the value at a wavelength of 550 nm are shown (left). The specular reflectance at incident angles from 50-85° is shown to the right.

Concept

Sunlight

Black Silicon nanostructures suppress AM1.5G weighted, average reflectance from solar cell surfaces to less than 1%.

Nanostructures are fabricated by means of maskless reactive ion etching (RIE) using SF6 and O2 plasma.

Simulation Method

The nanostructure topology is modelled as a graded refractive index, Λ is a nonlinearity parameter. The index shape function was defined as \( n(z, h, L) = \text{ln}(1 + z/L)/\text{ln}(1 + h/L) \) in case of a non-linear index profile and \( n(z, h, L) = z/h \) in case of a linear index profile; here the parameters \( L = 10 \text{ nm} \) and \( h = 300 \text{ nm} \) were used.

Simulation Result

Simulated reflectance as function of incident angle at a wavelength of 550 nm for surfaces with nanostructures of 300 nm in height in case of (a) linearly graded refractive index and (b) non-linearly graded refractive index. The insets in (a) and (b) show the simulated reflectance at incident angles of 0-70°. The non-linear profile yields the lowest reflectance; below 1% for angles up to 45°.

Conclusion

Angle-resolved reflectance from nanostructured Si surfaces realized by maskless RIE texturing has been simulated and measured. In both simulation and experiment the specular reflectance is below 10% at incident angles below 65° and below 1% at incident angles below 45° in the case of non-linear graded refractive index. From the simulation results the non-linear graded refractive index yields lower reflectance than the linearly graded refractive index.