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REFLECTIVE MULTILAYER COATINGS WITH DIELECTRIC BARRIERS FOR HIGH CONCENTRATION PHOTOVOLTAICS BY MID FREQUENCY DUAL MAGNETRON SPUTTERING

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Introduction

First-surface mirrors based on reflective multilayer coatings on polycarbonate substrate have been developed and tested for use as primary optics in high concentration photovoltaic (HCPV) systems. These coatings must provide high reflectance properties over a wavelength range between 300 and 1800 nm, where multijunction cells are significantly active for PV generation [1] . Additionally, a good ageing resistance to UV radiation and high humidity/temperature conditions must be achieved [2] .

Experimental details

Coating development

- Silver, aluminium and Ticusil® (titanium, copper and silver alloy) films were developed on polycarbonate substrate and protected with either SiO_2 or Si_3N_4 layers.
- Effect of substrate roughness and multilayer mirrors were previously designed using CODE software.[3] .
- Reflective and protective films were grown by sequential sputtering deposition DC and by reactive mid frequency dual magnetron sputtering, respectively.

Characterization

- Refractive index of SiO_2 and Si_3N_4 was obtained from spectroscopic ellipsometry over a 200-1000 nm range. Fitted using Cauchy dispersion equation.
- Total and diffuse reflectance spectra were obtained from UV-Vis-NIR spectrophotometer with a 150 mm integrating sphere. Specular reflectance spectra result from calculation.

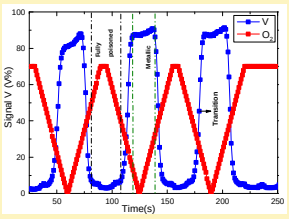
Accelerated ageing

- Durability of the developed mirrors was evaluated through damp heat and UV exposure tests following the IEC 62108 standard.
- Damp heat test: 1000h exposure at 85° C and 85% RH .
- UV test: 1270h exposure to 340nm lamps at 60° C.

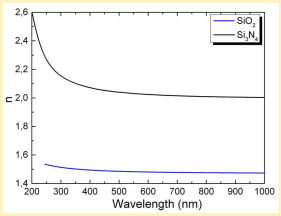
Results

Dielectric layers growth by reactive MF-DMS

- Transition of process from metallic to poisoned mode. Transition occurs very rapidly requiring the use of feedback control to hold the process in the transition state.
- Refractive index extracted by spectral ellipsometry measurements of dielectric layers (SiO_2 and Si_3N_4) growth in transition state.



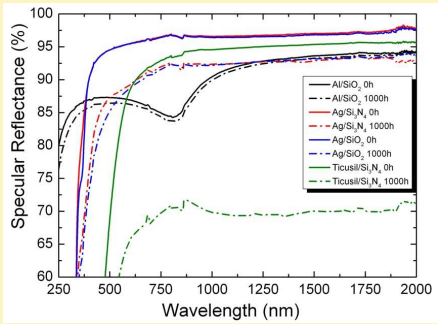
Target poisoning during reactive sputtering



Spectral refractive index of dielectric layers growth in transition mode

Specular reflectance

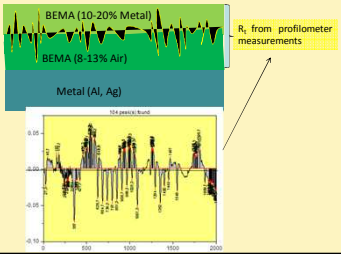
- Specular reflectance is, by design, the most relevant magnitude for a concentrating PV system.
- Initial samples show very low values of diffuse reflection.
- Specular R values higher than 89% were found for Al/SiO_2.
- Ag/SiO_2 and Ag/Si_3N_4 showed specular reflectance values up to 96% as deposited.
- Ticusil®/Si_3N_4 R values considerably lower.

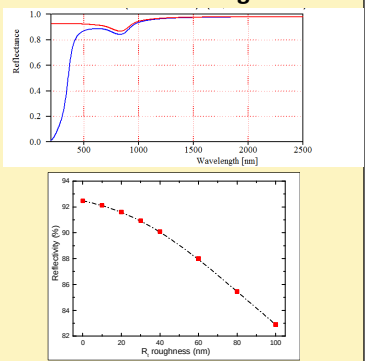


Specular reflectance values as deposited and after damp heat test

Simulation of Reflectance: Effect of substrate roughness

- The effect of substrate roughness, extracted from profilometer measurements, on Specular R values was simulated using CODE software.

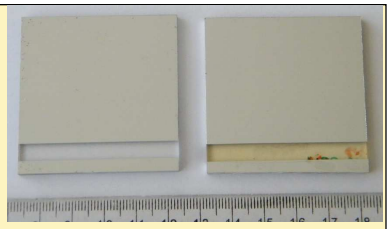




Decrease R% values with increase R_q roughness

Accelerated ageing tests

- Best performance was found for Al/SiO_2 multilayer coatings. Samples were undamaged after damp heat and UV test. Total and specular reflectance remained almost constant.
- Ag and Ticusil® coatings showed delamination and shallow cracking.
- Appreciable decrease in specular reflectance, specially for Ticusil ®.



Al/SiO_2 multilayer films after DH test (left) and UV test (right)

Multilayer	0h		1000h	
	Total	Specular	Total	Specular
Al/SiO_2	89.4	88.2	89.2	87.5
Ag/SiO_2	95.6	94.6	93.7	88.1
Ag/Si_3N_4	96.0	94.8	93.2	88.9
Ticusil®/Si_3N_4	82.2	--	80.0	61.2

Conclusions

- ✓ First-surface mirrors for HCPV applications were designed and deposited on polycarbonate substrate by PVD.
- ✓ Silver, aluminium and Ticusil® reflective layers were grown by DC magnetron sputtering and protected with dielectric SiO_2 or Si_3N_4 films grown by reactive Mid Frequency- Dual magnetron sputtering.
- ✓ Highest initial specular reflectance values up to 95% and 89% were obtained for Ag-based coatings before and after testing. In the case of Al, only a slight decrease less than 1% was observed from initial 88% after acelerated ageing tests.
- ✓ Further research needed to meet the demanding durability requirements of HCPV application with high reflectance values.

References

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Acknowledgements

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