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COMPOSITE THIN FILM SELECTIVE ABSORBER COATINGS FOR SOLAR THERMAL APPLICATIONS

by

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Abstract

This thesis presents the results of theoretical and experimental work on thin film selective absorbers for flat plate solar collectors.

A computer simulation tool, based on the use of effective medium models employing a Bruggeman formalism, has been developed to enable the design of composite selective absorbers. The design tool has been validated by experimental work and has been used further to investigate systematically key coating design parameters with the objective of optimising selective absorber performance. The key design parameters are the compositional gradient and number of individual layers within the coating, the composition and metal volume fraction, overall film thickness and the respective influences of antireflection and metal base layer coatings. Particle size and orientation within the absorber are not considered.

Graded index composite metal:dielectric selective absorbers have been prepared by DC and RF magnetron sputtering. A simplified film structure which minimises the number of layers within the absorber whilst maximising absorptance by optical interference has been designed and prepared. It is shown that for high metal volume fractions greater than 0.6, a 4-layer graded index film outperforms all other designs.

A number of metal:dielectric systems have been considered. New results are presented for $Ni:SiO_2$ and the previously unstudied $V:Al_2O_3$ systems. Experimental and theoretical results are in good agreement. $V:Al_2O_3$ films outperform $Ni:SiO_2$ films because of the higher metal refractive index. Spectrally selective solar absorbers of $V:Al_2O_3$ with metal volume fraction in the range 0.6 - 0.8 and thickness 150 - 250 nm with AR coatings are capable of solar absorptance > 0.97 and thermal emittance < 0.05. Excellent solar and thermal performance is also obtained for $Ni:SiO_2$ with $\alpha > 0.95$ and $\varepsilon < 0.13$. The design tool has also been used to investigate the optical properties of other metal:dielectric absorbers employing Ni, Co, Cr and W respectively in different dielectric hosts and the optical conditions and parameters are consistent with the results obtained for the experimentally prepared $V:Al_2O_3$ and $Ni:SiO_2$ films. As such the work contains important generic elements for the future design of composite selective absorbers of the metal:dielectric class.