VO2/ZnS core-shell nanoparticle for the adaptive infrared camouflage application with modified color and enhanced oxidation resistance

Publication date: March 2018

Source: Solar Energy Materials and Solar Cells, Volume 176

Author(s): Haining Ji, Dongqing Liu, Chaoyang Zhang, Haifeng Cheng

VO2 has attracted extensive attention as an adaptive camouflage material due to its structural change during the metal-insulator transition (MIT) at 68°C, which can fast respond to ambient temperature and actively modulate infrared emissivity. However, the thermal instability and undesirable color have restricted its applications in multi-spectral camouflage. In this study, the VO2/ZnS core-shell nanoparticles were synthesized via a homogeneous precipitation method. The VO2 nanoparticle core exhibited a remarkable infrared emissivity modulation ability in the mid-wavelength and long-wavelength thermal atmospheric windows. The ZnS shell, as an infrared transparent material, not only modified the color of VO2 nanoparticle from unpleasant blue-black to gray-green that adapts to visible camouflage in the woodland background, but also significantly enhanced the oxidation resistance. This is the first report of such a single nanoparticle structure with both variable infrared emissivity and desirable color that offer significant potential for multi-spectral camouflage application.

Graphical abstract

Polycrystalline CdTe photovoltaics with efficiency over 18% through improved absorber passivation and current collection

Publication date: March 2018

Source: Solar Energy Materials and Solar Cells, Volume 176

Author(s): Amit H. Munshi, Jason M. Kephart, Ali Abbas, Tushar M. Shimpi, Kurt L. Barth, John M. Walls, Walajabad S. Sampath

Sublimated thin-film CdTe photovoltaic devices with conversion efficiencies over 18% and a fill-factor greater than 79% have been repeatedly obtained using high-rate fabrication processes on commercial soda-lime glass substrates used in CdTe modules. Four major improvements to the device have enabled an increase in efficiency from a baseline of approximately 12–18.7%: 1) A sputtered multilayer metal-oxide anti-reflection layer; 2) total replacement of the CdS window layer with a higher bandgap
sputtered Mg$_{x}$Zn$_{1-x}$O (MZO) window layer; 3) deposition of the CdTe layer at a higher thickness and substrate temperature; and 4) an evaporated tellurium back-contact. This work describes the effect of these changes on the device performance and film microstructural characteristics using various methods. Multiple devices with comparable high efficiency have been fabricated and demonstrated using methods described in this study, yielding very high efficiencies for CdTe polycrystalline thin-film photovoltaics using deposition processes and equipment in a university setting.

Graphene nanoplatelets as an anticorrosion additive for solar absorber coatings
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Ervin Šest, Goran Dražič, Boštjan Genorio, Ivan Jerman

Efficiently transforming solar energy into heat requires an understanding of spectrally selective coatings at the atomic, molecular, corrosive and spectrally selective levels. Here, experiments were conducted and analyzed to rationalize and ultimately understand the complex behaviours of spectrally selective coatings in corrosion environments. By exploring reactions that modify graphene nanoplatelets, the preparation of stable dispersions, the incorporation in sol-gel binder, and the preparation of spectrally selective coatings, we demonstrated that (i) a successful graphene nanoplatelet modification is important for their incorporation into binders as sol-gels, (ii) the modified products do not influence the optical properties of the coatings, (iii) incorporating nanoplatelets drastically improves corrosion resistance, and (iv) thinner coatings can be used to achieve the same anticorrosion properties as other treatments. We believe this experimental insight provides a pathway for the rational design of stable spectrally selective paint coatings that are urgently needed for the development of a new generation of reliable and affordable absorber coatings for efficient solar energy harvesting.

Graphical abstract

Enhanced fatigue resistance of suppressed hysteresis in perovskite solar cells by an organic crosslinker
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Chang-Keun Lim, Qi Li, Tianmu Zhang, Tim Thomay, Alexander N. Cartwright, Mark T. Swihart, Paras N. Prasad

With record power conversion efficiencies of hybrid perovskite solar cells now exceeding 20% under laboratory conditions, improvements in stability of the cells under real-world working conditions are now key requirements for their commercial success. Here, we present a novel strategy to reduce penetration of humidity and oxygen into perovskite films via incorporation of a diammonium glycol. The two ammonium groups of this molecule allow it to serve as a crosslinker in the structure, bridging...
two unit cells within a crystallite or even across a grain boundary. In a planar heterojunction solar cell containing PCBM as an electron transport layer, the power conversion efficiency of the cell with ~0.1% diammonium glycol in the absorber layer was 13.96%, slightly exceeding that of the glycol-free device (13.53%). Most importantly, the glycol-free device exhibited the typical growth in hysteresis with performance degradation, but hysteresis remained suppressed in the device doped with diammonium glycol, even as its overall performance deteriorated. Furthermore, the chemical stability of the unpackaged device under continuous AM1.5G illumination at ambient conditions was substantially improved relative to the glycol-free device. Formation of PbI2 was significantly suppressed, which could minimize release of toxic Pb ions.

**Graphical abstract**

![Graphical abstract](image)

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**Evaluation of thermal physical properties of molten nitrate salts with low melting temperature**

Publication date: March 2018  
**Source:** Solar Energy Materials and Solar Cells, Volume 176  
**Author(s):** Peng Zhang, Jinhui Cheng, Yuan Jin, Xuehui An

NaNO3–KNO3 (60–40wt%, Solar salt) has been used as medium for TES and HTF in the CSP system. One of the key challenges using Solar salt is its high melting temperature, which may freeze and block the pipeline. In this work, a novel eutectic nitrate molten salt of the LiNO3–NaNO3–KNO3–CsNO3 system with low melting temperature of 368K is designed using Calphad method. Its thermal physical properties, as well as that of Solar salt, LiNO3–NaNO3–KNO3, NaNO3–KNO3–CsNO3, NaNO3–KNO3–Ca(NO3)2, and LiNO3–NaNO3–KNO3–CsNO3–Ca(NO3)2 molten salts are comprehensively determined and evaluated for better understanding their thermal storage and heat transfer performances, such as the melting temperature, thermal stability, specific heat capacity, thermal diffusivity, density and viscosity. The energy storage capacities and figures of merit of the six molten nitrate salts are calculated based on their thermophysical properties to evaluate their TES and HTF performances. This work not only provides the basic engineering data for CSP system, but is useful for choosing media of TES and HTF.

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**Experimental study on the specific heat and stability of molten salt nanofluids prepared by high-temperature melting**

Publication date: March 2018  
**Source:** Solar Energy Materials and Solar Cells, Volume 176  
**Author(s):** Xia Chen, Yu-ting Wu, Lu-di Zhang, Xin Wang, Chong-fang Ma

Molten salt is an important heat storage and heat transfer medium in solar thermal power generation technology due to its high heat capacity, wide working temperature range, and low cost. Adding nanoparticles (usually by the two-step method with ultrasonic dispersion) can increase the specific heat of molten salt. Thus, the molten salt nanofluids can increase the heat capacity and decrease the heat
storage cost of a solar thermal power generation system. However, nanoparticles are easy to agglomerate in the molten salt; moreover, after agglomeration, the performance of molten salt nanofluids is degraded. A two-step method with high-temperature melting in preparing molten salt nanofluids is proposed in this paper. Molten salt nanofluids were prepared by high-temperature melting. The base solution was a low-melting point molten salt and the nanoparticles were SiO₂ with a diameter of 20nm. The specific heat was measured and the nanoparticle dispersity was analyzed. The stability of the molten salt nanofluids was studied, and the results were compared with those prepared by ultrasonic dispersion. The average specific heat of molten salt nanofluids prepared by high-temperature melting was 1.789J/(g·K), which was close to that of molten salt nanofluids prepared by ultrasonic dispersion and 16.4% higher than that of pure molten salt. The molten salt nanofluids prepared by ultrasonic dispersion showed poor thermal stability under high-temperature conditions, and the average specific heat decreased by 8.5% after only 200h. The thermal stability of molten salt nanofluids prepared by high-temperature melting showed a highly stable performance in long-time experiments. The variation of specific heat was less than 5% after 2000h under the same high-temperature experimental condition. The molten salt nanofluids obtained by high-temperature melting showed better stability and long performance than those obtained by ultrasonic dispersion. Therefore, the two-step method with high-temperature melting is stable and reliable for preparing molten salt nanofluids.

Atomic-layer-deposited buffer layers for thin film solar cells using earth-abundant absorber materials: A review
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Soumyadeep Sinha, Dip K. Nandi, Soo-Hyun Kim, Jaeyeong Heo

Atomic layer deposition (ALD) is not just a thin film deposition technology limited to the semiconductor IC industries to grow high-k gate dielectric or a Cu diffusion barrier layer. In recent times, it has found plenty of applications in the field of renewable energy due to its precise thickness control up to few angstroms and its unique feature of conformal and uniform coating on any randomly shaped 3D structure. ALD has far-reaching applications in this field, including electrochemical storage, fuel cells, solar photovoltaics (PV), and catalysis for water splitting to produce H₂ as a green fuel. In solar PV technology, ALD is now being extensively used as an efficient tool to deposit surface passivation layers, absorber or sensitizer, transparent conducting oxide, and barrier and buffer layers in several kinds of solar cells. Out of all the different layers associated with a solar cell, ALD is majorly used for the development of a very thin n-type buffer layer. This review article presents a systematic chronological study on such ALD-grown buffer layers for thin film solar cells (TSFCs). The study is carried out in detail based on different earth-abundant absorber materials, such as Cu₂ZnSn(S,Se)₄ (CZTSSe), Cu₂O and SnS, for which ALD is successfully used to deposit the buffer layer.
A method for generating a solar reflective blue-grey paint coating with yellow-green luminescence that is cost-effective, industrially scalable, widely applicable, easily repairable, super-non-wetting, self-cleaning, and solar reflective, is introduced. The coating can be manufactured using as-received commercially available materials and following a simple industrial procedure. Grinding the coating surfaces using emery papers with appropriate grit numbers can readily yield appropriate surface roughness, generate suitable micro-grooves and expose micro- and nano-particles on the coating surfaces, thus endowing the coating surfaces with super-non-wettability and self-cleaning property. The surface free energy of the coating only depends on the dispersive component and both the Lewis acid component and the Lewis base component are 0 mN/m. The solar reflective blue-grey coating with solar reflectance of 0.808 can yield a cooling effect of 22.6 °C relative to a flat or low-sloped concrete roof on a typical clear summer sunny day. It emits yellow-green luminescence during the night, thus decorating the buildings to some extent when applied to the external walls of buildings. Although the super-non-wettability of the coating surfaces might be destroyed mainly by the periodic spraying of water (simulated by 400h of artificial accelerated weathering tests), the super-non-wettability and the self-cleaning property can be completely re-established after roughening the weathered coating surfaces using emery papers with appropriate grit numbers. In terms of optical properties, the solar reflective blue-grey coating with yellow-green luminescence has good resistance to artificial accelerated weathering.
Design of high-temperature solar-selective coatings based on aluminium titanium oxynitrides. Part 1: Advanced microstructural characterization and optical simulation

Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176

Aluminium titanium oxynitrides were studied as candidate materials for high temperature absorbers in solar selective coatings due to their excellent stability and their tuneable optical behaviour. A set of individual $\text{Al}_y\text{Ti}_{1-y}(\text{O}_x\text{N}_{1-x})$ layers with different oxygen content was prepared by cathodic vacuum arc (CVA) deposition. The composition, morphology, phase structure and microstructure of the films were characterized by elastic recoil detection (ERD), scanning and transmission electron microscopy and X-ray diffraction. An fcc phase structure is found in a broad compositional range of $\text{Al}_y\text{Ti}_{1-y}(\text{O}_x\text{N}_{1-x})$. Simultaneously, sample microstructure and morphology undergo systematic changes from a columnar growth to the development of a heterogeneous structure with spherical nanoparticle inclusions when the oxygen concentration is increased. The optical properties were determined by spectroscopic ellipsometry and UV–Vis–NIR and FTIR spectrophotometry. A comprehensive analysis of the film properties allowed an accurate modelling of the optical constants of the $\text{Al}_y\text{Ti}_{1-y}(\text{O}_x\text{N}_{1-x})$ in the whole wavelength range of solar interest (from 190 nm to 25 μm). It points to a transition from metallic to dielectric behaviour with increasing oxygen content. Consequently, it is demonstrated that the optical properties of these $\text{Al}_y\text{Ti}_{1-y}(\text{O}_x\text{N}_{1-x})$ deposited films can be controlled in a wide range from metallic to dielectric character by adjusting the oxygen concentration, opening a huge range of possibilities for the design of solar selective coatings (SSC) based on this material. Complete SSC, including a TiN layer as IR reflector, were designed by applying optical simulations, obtaining excellent optical selective properties of $\eta = 94.0\%$ and $\eta_{RT} = 4.8\%$. 

WCA>159° SA<3° Solar reflectance 0.808 Cooling effect 22.6 °C
Optical properties and failure analysis of ZrC-ZrOx ceramic based spectrally selective solar absorbers deposited at a high substrate temperature

Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Xiang-Hu Gao, Hui-Xia Guo, Tian-Hong Zhou, Gang Liu

A tandem layer structured ZrC-ZrOx/Al2O3 coatings are deposited onto stainless steel (SS) substrates by the sputtering method for solar selective absorbing. The ZrC-ZrOx and Al2O3 layers work as an absorptance layer and an antireflectance layer, respectively. The substrate temperature has an important effect on the optical properties of the coating. With a high substrate temperature (300°C), the SS/ZrC-ZrOx/Al2O3 coatings exhibit a relatively high absorptance of 0.92 and a relatively low emittance of 0.12. The composition, structure, optical properties and surface morphology of the coatings are characterized using SEM, EDS, XPS, Raman, UV–vis–NIR spectrophotometry and Fourier transform infrared spectroscopy. Detailed failure analysis of the SS/ZrC-ZrOx/Al2O3 coatings in vacuum and air is conducted.

Photovoltaic performance of CdS/CdTe junctions on ZnO nanorod arrays

Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176

One-dimensional nanostructures, such as nanorod (NR) arrays, are expected to improve the photovoltaic (PV) response of solar cells with an ultrathin absorber due to an increased areal (junction) density and light trapping. We report on the deposition of CdS and CdTe:As semiconductor thin films on ZnO NR arrays by means of metalorganic chemical vapour deposition (MOCVD). The change in optical properties of the ZnO NRs upon the growth of CdS shell was monitored and compared to the simulated data, which confirmed the presence of strong light scattering effects in the visible and near infrared regions. The PV performance of nanostructured vs. planar CdS/CdTe solar cells (grown using the material from the same MOCVD run) showed similar conversion efficiencies (~ 4%), despite the current density being lower for the nanostructured cell due to its thicker CdS window. A clear improvement in the quantum efficiency was however observed in the near infrared region, resulting from the light trapping by the ZnO/CdS core-shell NR structure. We also showed that reduction of surface defects and use of high absorber carrier density would boost the efficiency beyond that of planar CdTe solar cells. The reported device performance and the direct observation of light trapping are promising towards
Effect of annealing dependent blend morphology and dielectric properties on the performance and stability of non-fullerene organic solar cells
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Mushfika Baishakhi Upama, Naveen Kumar Elumalai, Md Arafat Mahmud, Matthew Wright, Dian Wang, Cheng Xu, Ashraf Uddin
This work demonstrates the influence of annealing temperature on the phase morphology of the polymer-non-fullerene blend and its relationship with the dielectric constants of the blend layer. It is also the first study to report the annealing induced changes in dielectric environment of the active layer blend employing non-fullerene acceptor. Polymer solar cells (PSCs) annealed at 80°C were found to possess optimal blend morphology favourable for efficient charge separation owing to reduced coulomb capture radius and relatively high dielectric constant, resulting in high power conversion efficiency (PCE) of ~11.4%. The high performing devices fabricated at optimized temperature also exhibited superior charge transport characteristics including high recombination resistance (R\text{rec}) which is 31% higher than the non-annealed devices. The effect of intermolecular aggregation induced by the annealing temperature and its relationship with the disorder states in the blend layer, influencing the electron transport properties is also investigated in detail. Furthermore, a month long degradation study investigating the operational stability of the as-developed non-fullerene based PSCs was also performed and analysed.

The effect of incidence angle on the reflectance of solar mirrors
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Florian Sutter, Marco Montecchi, Haymo von Dahlen, Aránzazu Fernández-García, Marc Röger
Solar reflectors for Concentrating Solar Technologies require a high reflectance in the terrestrial solar spectrum (280–4000nm). Besides the wavelength, the reflectance of solar mirror materials is also dependent on the incidence angle of the incoming sunlight. The commonly used measurement equipment measures the reflectance at fixed near-normal incidence angles, typically between 8° and 15°. In this work, the annual incidence angle frequency distribution has been calculated for a LS3/Eurotrough-type parabolic-trough collector located at different sites, and for the heliostat field of the solar tower system CESA-1 located at the Plataforma Solar de Almería in Tabernas, southern Spain. It was found that the most frequent incidence angles registered in the solar field are quite higher than the...
ones at which reflectance is measured with state of the art instruments, obtaining mean incidence angles in the range of 28–35° depending on the type and location of the solar field. A methodology to predict the off-normal reflectance of silvered-glass mirrors based on near-normal reflectance and transmittance measurements of the uncoated glass is presented. The complex refractive index of 2, 4 and 5mm thick solar glass and the deposited silver was determined and used to model the solar weighted reflectance of silvered-glass mirrors at different incidence angles. The model was compared to experimental measurements. For this purpose, the Spectral Specular Reflectometer (S2R) has been improved and updated with a polarizer crystal to measure reflectance at perpendicular (s-pol) and parallel (p-pol) polarizations up to incidence angles of θ = 70°. Eight solar mirror materials (three silvered-glass mirrors of different glass thicknesses, two anti-soiling coated glass mirrors, two enhanced aluminum reflectors and a silvered polymer film) have been measured over a broad range of incidence angles and the results have been weighted with the annual incidence angle frequency distribution. The obtained incidence angle-weighted reflectance is a suited parameter to compare the efficiency of solar mirror materials taking into account their use in a specific collector type and location.

Environmental stability of transparent and conducting ITO thin films coated on flexible FEP and Kapton® substrates for spacecraft applications
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): K.P. Sibin, A. Carmel Mary Esther, H.D. Shashikala, Arjun Dey, N. Sridhara, Anand Kumar Sharma, Harish C. Barshilia

Acquiring good adhesion of ITO thin films on polymer substrate is a major concern, especially for space related applications. Delamination of ITO coating on these polymers can seriously damage the spacecraft. This paper presents the development of highly transparent and conducting ITO thin films on as-received and surface treated fluorinated ethylene propylene (FEP) and Kapton® substrates by reactive direct current magnetron sputtering. Stability of the ITO coating on FEP and Kapton® substrates was studied in simulated space environments. Environmental tests such as: relative humidity, thermal cycling and thermo vacuum were performed. Thermo-optical properties and sheet resistance of ITO coated FEP and Kapton® substrates were studied before and after environmental tests. Optimized ITO coating with thickness of ~ 15nm on FEP and Kapton® substrates showed sheet resistance in the range of 2–4kΩ/sq. with high average transmittance and high IR emittance. Adhesion of ITO coating on FEP substrate was improved by Ar plasma etching. X-ray photoelectron spectroscopy and field emission scanning electron microscopic studies of etched FEP substrate showed defluorination and high roughness of the etched surface which helped for better adhesion of ITO coating. We demonstrated that ITO coated plasma etched FEP substrate showed no change in the sheet resistance and thermo-optical properties. Moreover, ITO coated etched FEP substrate showed good environmental stability than ITO coated untreated FEP substrates.

Facile synthesize VO2 (M1) nanorods for a low-cost infrared photodetector application
Publication date: March 2018
Source: Solar Energy Materials and Solar Cells, Volume 176
Author(s): Jiwei Hou, Zhongping Wang, Zejun Ding, Zengming Zhang, Jianwu Zhang

Infrared photodetector is an important technology for both civilian and military applications. However, conventional commercial detectors generally require complex designs, expensive devices and cumbersome procedures. In this work, monoclinic phase VO2 (M1) nanorods (NRs) with metal-insulator transition properties were synthesized through a low-temperature hydrothermal reaction and
subsequent annealing. The evolution of vibrational modes of VO$_2$ (M1) NRs have been observed using Raman and IR spectroscopies during the structural phase transition. In addition, a high-sensitivity infrared photodetector based on a network of the VO$_2$ (M1) NRs was fabricated with a low-cost method, and the electron transfer processes in nanorod (NR) networks has been discussed. The device exhibited high photosensitivity, excellent stability, and reproducibility in atmospheric condition at room temperature.

**D-mannitol for medium temperature thermal energy storage**

Publication date: March 2018  
**Source:** Solar Energy Materials and Solar Cells, Volume 176  
Author(s): Ahmad Mojiri, Nikola Grbac, Brendan Bourke, Gary Rosengarten

D-mannitol is a sugar alcohol with a melting temperature of approximately 167°C. It has been identified as a phase change material for storing heat at a temperature range of about 150–180°C. The outcome of the published research on its applicability for this purpose is inconsistent and sometimes contradictory. We identified that there is a need for further study on the material to overcome such uncertainty. Thus we conducted a series of thermal measurements to quantify its properties and suitability for a phase change thermal storage. Our differential scanning calorimetric measurements showed that the material has a melting temperature of 167°C and fusion heat of 297kJ/kg. However, our accelerated thermal cycling test revealed that this value decreases logarithmically to 249 and 240kJ/kg after 100 and 200 cycles respectively. The material shows a significant level of sub-cooling in DSC measurement with a solidification temperature of approximately 110–120°C which can render the material unsuitable for thermal storage purposes. However, our secondary measurement with a large quantity of D-mannitol shows that such level of sub-cooling is unlikely to occur in a macro-scale sample. We built and tested a thermal storage system containing 3.8kg of D-mannitol to investigate its performance in larger quantities and evaluate the heat transfer properties of the heat exchanger mechanism in the storage system. We show that the material releases significant heat when it is cooled down to 150°C which means implies the occurrence of solidification at a temperature above 150°C.

**Enhancing spectrally selective response of W/WAlN/WAlON/Al$_2$O$_3$ – Based nanostructured multilayer absorber coating through graded optical constants**

Publication date: March 2018  
**Source:** Solar Energy Materials and Solar Cells, Volume 176  
Author(s): Atasi Dan, Arup Biswas, Piyali Sarkar, Sanjay Kashyap, Kamanio Chattopadhyay, Harish C. Barshilia, Bikramjit Basu

In the field of concentrating solar power (CSP) technologies, multilayer absorber coatings are widely being investigated. The spectral properties of selective coatings can be tailored by carefully adjusting the composition and thickness of each layer. Based on the extensive analysis using the transmission electron microscopy (TEM), phase modulated spectroscopic ellipsometry along with computational study, we demonstrate how we can engineer the optical constants (refractive index and extinction coefficient) of individual layer to successfully achieve the spectrally selective properties in W/WAlN/WAlON/Al$_2$O$_3$ –based multilayer absorber coating. This coating exhibits a high absorptance of 0.958 and a low emittance of 0.08. The spectroscopic ellipsometry study confirmed the variation in metallic and optical properties of single layer of WAlN, WAlON and Al$_2$O$_3$ films, deposited on stainless steel substrates. This study also revealed the presence of intermediate layers of 26% WAIN – 74% WALON at WAIN/WALON interface and 60% WALON – 40% Al2O3 at WALON/Al2O3 interface. The Tauc - Lorentz dispersion model could effectively interpret the ellipsometry data of single layers of WAIN and Al2O3,
while Cauchy absorbent model was useful for WALON coating. Bruggeman effective medium approximation was used to describe the optical functions of intermediate layers. Investigation on optical constants reveals that the refractive index and extinction coefficient of each layer decrease from substrate to surface. The computational predictions of the reflectance properties corroborate well with the experimental results. In summary, the careful engineering of the optical properties in W/WAlN/WAlON/Al₂O₃ enables it to be an exceptional spectrally selective absorber coating.

**Improvement in ultra-thin hydrogenated amorphous silicon solar cells with nanocrystalline silicon oxide**

Publication date: March 2018  
**Source:** Solar Energy Materials and Solar Cells, Volume 176  
Author(s): Jia Fang, Baojie Yan, Tiantain Li, Changchun Wei, Qian Huang, Xinliang Chen, Guangcai Wang, Guofu Hou, Ying Zhao, Xiaodan Zhang  
Ultra-thin a-Si:H p-i-n solar cell has been proposed as advance to form three-dimensional structures on nano-structured substrates for achieving optically thick and electrically thin solar cells. However, over the years, although extensive studies have been carried out, no high efficiency was achieved yet. We found that not only the short circuit current density (J_{sc}) decreases, but also the open circuit voltage (V_{oc}) and fill factor (FF) decreases with the reduction of i-layer thickness, which is opposite to the expectation. We investigated the possible root-causes for this unusual phenomenon and speculated the direct recombination of the electrons in the n-layer and the holes in the p-layer by tunneling through the thin i-layer is the main reason for the reduced V_{oc} and FF in ultra-thin solar cells. Furthermore, the absorption in the doped layers is the most critical limitation for ultra-thin silicon solar cell efficiency because the doped layer thickness becomes comparable to the intrinsic layer. To resolve this issue, we used nanocrystalline silicon oxide (nc-SiO\textsubscript{x}:H) doped layers with a wide bandgap to reduce the parasitic absorption in the doped layers and the highly asymmetric conductivity improves the carrier collection and made a significant improvement in the cell efficiency. We achieved 8.79%, 7.65%, and 5.32% efficiencies with the i-layer thickness of only 70nm, 50nm and 20nm, respectively, which are the highest ones in ultra-thin silicon solar cells.

**Graphical abstract**

**Al-doped VO\textsubscript{2} films as smart window coatings: Reduced phase transition temperature and improved thermochromic performance**

Publication date: March 2018  
**Source:** Solar Energy Materials and Solar Cells, Volume 176  
Author(s): Chunhui Ji, Zhiming Wu, Xuefei Wu, Jun Wang, Jun Gou, Zehua Huang, Hongxi Zhou, Wei Yao, Yadong Jiang
In the pursuit of energy efficient materials, vanadium dioxide (VO$_2$) based smart coatings have gained much attention in recent years. In this paper, we investigate Al-doped VO$_2$ films as thermochromic coatings on glass substrates by DC magnetron sputtering. It is found that adding Al$^{3+}$ ions into VO$_2$ films can generate groups of polygonal grains and nanowire clusters, apart from routinely reducing the valence and decreasing the grain size, through XRD, XPS, Raman shift and SEM results. For optical properties of Al doped films, a blue-shift of absorption edge in transmittance spectra has been introduced, which can significantly improve the luminous transmittance. Further, largely reducing phase transition temperature and enhancing solar modulation ability are also achieved. After carefully analyzing the relationship between the film characterizations and optical performance, we attribute the advanced theromochromic properties to the generation of nanowire clusters by the depositing conditions and the transformation effect of Al dopants. Such good thermochromic performances obtained by Al doping obviously overcome the drawbacks of undoped VO$_2$ films for practical application. This work provides a considerable and new method of optimizing thermochromic properties of VO$_2$ films as smart window coatings.

**Graphical abstract**