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Title(English)	Study of Light-Trapping Approaches for Silicon-Based Thin Film Solar Cells
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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	電子物理工学　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（Philosophy）
学生氏名： Student's Name	Bancha Janthong	指導教員（主）： Academic Advisor(main)	小長井　誠　教授
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis presents the results of research on light-trapping approaches applied to silicon-based thin film solar cells including a-Si:H/µc-Si:H tandem solar cells. Experimental and theoretical study of the effects of light-trapping approaches, i.e. introduction of optical layers; intermediate layer (IL) inserted between component cells, intermediate layer with function of n-top layer (nIL), n-bottom layer with function of ZnO back reflective layer (nBRL), front anti-reflection layers inserted between glass/ TCO (FAL) and between TCO/p-layer interface (FALp) as additional refractive-index matching layers, as well as, development of double-textured conductive zinc oxide coated on white glass substrates, on the performance of silicon-based thin film solar cells was performed. The numerical analysis of IL, nIL, nBRL, FAL and FALp was also systemically conducted using both of simulators called "OPTICAL" and "ASA" (Advanced Semiconductor Analysis). Firstly, optical calculation using OPTICAL simulator was carried out to find the optimal optical properties of optical layers used in this study, corresponding to different function purposes. Also, theoretical analysis using ASA simulator was provided in order to comprehend and confirm the effect of each optical layer on solar cell performance. Secondly, Different silicon oxide (SiO_x) films have been characterized and optimized for applying to several solar cells as optical layers with those of individual function purposes. N-type hydrogenated silicon oxide (SiO_x:H) films were prepared and optimized by using RF-PECVD technique from a mixture of SiH_4,H_2,CO_2 as a reactant gas and PH_3 as a doping gas. Optical, electrical, and structural properties of the deposited n-SiO_x:H films were investigated by optical band gap (E_{04}), refractive index (n) , in-plan conductivity (σ), Raman spectrum and XPS measurement. By optimizing deposition condition parameters, the SiO_x:H films with considerable optical and electrical properties, i.e. sufficient high conductivity and preferred low refractive index, were obtained and then inserted into a-Si:H top/µc-Si:H bottom cell interface as an IL. It was found that this SiO_x:H IL was effective to be applied into the tandem solar cells. Moreover, a-Si:H/ µc-Si:H tandem solar cells with novel structure were for the first time proposed as a candidate to lower the optical losses and thus increase the solar cell performance. By using the optimum n-SiO_x:H layer instead of n-µc-Si:H/ZnO back reflector for a µc-Si:H solar cell as a nBRL, the spectral response in the long wavelength could be improved and then Jsc was relatively

increased up to 4.4%. Similarly, for the novel a-Si:H/µc-Si:H solar cell structure using the proper dual-functional n-SiO_x:H layers as a nIL and a nBRL, the relative improvement in current density (J_{sc}) by 9% was obtained and therefore the initial efficiency as high as 11.9% was achieved. These results approved that the first layer of newly developed n-SiO_x:H layers (nIL) can work as an n-top layer and also be functioned as an IL at the same time. Whereas, the second n-SiO_x:H layer (nBRL) can work as both an n-bottom layer and a ZnO back reflective layer. As a result, the reduction in optical losses could be obtained. Furthermore, these novel solar cell structures are beneficial for mass production since they were further simplified. Thirdly, intrinsic a-SiO_x films were characterized and optimized by measuring optical properties such as transmittance, reflectance, and haze value for use as a FAL in µc-Si:H solar cells. The µc-Si:H solar cells with the optimized a-SiO_x FAL were fabricated to compared the ones without FAL. By inserting this novel optimized a-SiO_x FAL with n of ~1.75 into the glass/ZnO interface of the µc-Si:H solar cell, J_{sc} could relatively be increased by about 5%, especially in the 550-950 nm region. Also, this optimized FAL did not deteriorate the properties of the ZnO layer because no significant changes in V_{oc} and FF were observed. As a result, the cell with an efficiency of 8.28% could be realized. Finally, W-textured ZnO:B films, with a very high haze value and greater angular distribution function (ADF), coated on white glass were successfully developed by MOCVD technique. Effects of glass-etching time on the morphology and optical properties of the substrates was investigated to explore the optimal properties for use as a front TCO contact in solar cells. It was found that the surface morphology of ZnO:B films deposited on white glass samples was mountain-chain-like double texture, while the one deposited on soda-lime glass samples showed cauliflower-like double texture. The mountain-chain-like double texture had higher haze value over the whole wavelength region than the conventional cauliflower-like double texture and a feature size larger than 10 µm were obtained with longer RIE etching times. By applying these white glass substrates into novel a-Si:H/µc-Si:H tandem solar cells, the short-circuit current density J_{sc} could be increased by 1mA/cm^2, corresponding to improved spectral response in the long wavelength region (>500 nm). Consequently, the initial efficiency could be increased up to 13.3 % (Voc=1.42 V, Jsc=13.44 mA/cm^2, FF=0.703). Therefore, the ZnO:B films deposited on this etched white glass cloud be considered as a promising substrates for use as front transparent contact layers in silicon-based thin film solar cells.