論文 / 著書情報
Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
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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　（　工学　）
学生氏名： Student's Name	平井　義晃	指導教員（主）： Academic Advisor(main)	山田 明　教授
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Recently, issues of energy consumption and environment have become serious. In such a situation, solar cells bas been paid attention. Cu(InGa)Se_2 (CIGS) which has a high absorption coefficient and a tunable bandgap is promising material for the absorber layer of solar cells. High efficiency CIGS solar cells are expected for bandgap of 1.4 eV, accordingly a Ga content of 70%, because of the matching of sunlight spectrum. However, efficiency decreases with increasing Ga content. In order to increase efficiency of CIGS solar cells with high Ga content, this thesis focused both on an electron barrier near the surface of CIGS and on the recombination process at CdS/CIGS interface.

One problem is a deep notch in the conduction band profile caused by the low diffusivity of Ga atoms compared to In atoms during preparation of CIGS thin films using a three-stage method. To overcome this issue, a five-stage method was conducted. By increasing segments of preparation process, suppressing segregation of In and Ga atoms in CIGS films was attempted. As a result, the depth of the notch decreased from 0.23 to 0.11 eV, compared with the three-stage method. An improvement in the conduction band profile yielded an increase of efficiency from 8.7 to 11.2%. However, V_{OC} was still low owing to formation of flat conduction band profile at the Mo back contact side. In order to form graded conduction band profile at the Mo back contact side while keeping the shallow notch, promotion of Ga diffusion during the three-stage method by raising preparation temperature was attempted. Preparation at a temperature of 640 ^{o}C during the second and the third stage was conducted, resulting in a notch depth of 0.07 eV and the conduction band grading around the back contact side. Further improvement in the conduction band profile yielded an efficiency of 12.9% with a V_{OC} of 0.677 V. However, V_{OC} was still lower than the expectation, although it increased as compared to the case of the typical three-stage method.

To disclose effects of the conduction band profile on solar cell performance, numerical evaluation was carried out at the condition that an average bandgap of CIGS was 1.4 eV, employing wxAMPS. Simultaneously, because the CdS/CIGS interface recombination was taken into account in the numerical evaluation, effects of suppressing the interface recombination on solar cell performance were also evaluated by focusing on the valence band offset (ΔE_V) at the CdS/CIGS interface. The evaluation of conduction band profiles revealed that efficiency was increased from 14.0 to 17.0% by forming the deep notch at the vicinity of surface, compared with the case of the flat conduction band profile. This result indicated that increasing efficiency was difficult by only improvements of conduction band profile and suggested that suppressing recombination at CdS/CIGS interface was important. Therefore, it was evaluated that the effects of ΔE_V at the CdS/CIGS interface by varying the bandgap of CIGS with a flat conduction band. As a result, increasing ΔE_V contributed to suppression of the recombination at the CdS/CIGS interface. Subsequently, an efficiency above 22% was obtained by increasing ΔE_V up to 0.3 eV when the bandgap was set close to the estimated bandgap to obtain the highest efficiency due to the matching of the sunlight spectrum. Additionally, an efficiency of 23.4% was obtained in the case of the single-graded conduction band profile. Moreover, an efficiency of above 25% was obtained by decreasing the defect density in the CIGS layer one third.

Taking the result of numerical evaluation into account, it was evaluated the effect of ΔE_V at the CdS/CIGS interface on solar cell performance, especially V_{OC}. In this study, incorporation of ZnSe thin-films into the CdS/CIGS interface was conducted. At first, ZnSe thin-film was deposited onto $CuInSe_2$ by ALD-like process in the chamber which is equipped with not only Cu, In, Ga, and Se but Zn Kunudsen cell in order to confirm the formation of ZnSe thin-films and investigate the deposition rate of ZnSe thin-films. Then, it was found that the layer by layer deposition of ZnSe thin-films was conducted. As a result of incorporation ZnSe thin-film into the typical solar cell structure, a V_{OC} of 0.792 V was obtained by increasing the ZnSe thickness up to 50 nm. Moreover, efficiency of CIGS solar cells with a Ga content of approximately 0.68 was increased up to 14.8% by modifying preparation condition of ZnSe thin-films. This result agreed with the result of numerical evaluation. Therefore, it is possible that an efficiency of above 22% is obtained by further understanding of the ΔE_V effect and optimizing preparation method of ZnSe thin-films. Subsequently, it is believed an efficiency of above 25% is realized by forming the single-graded conduction band profile and reducing the defect density in the CIGS with high Ga content, using CIGS absorbers with high Ga content.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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