論文 / 著書情報
Article / Book Information

題目(和文)	シリコンヘテロ接合太陽電池応用に向けたSiH4-freeプロセスとしてのスパッタ法に関する研究
Title(English)	Study of sputtering technology as a SiH4-free process for silicon heterojunction solar cells
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子系 エネルギー	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（ 工学 ）
学生氏名： Student's Name	白取優大		指導教員（主）： Academic Supervisor(main)	宮島 晋介	
			指導教員（副）： Academic Supervisor(sub)		

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Photovoltaic power generation is expected to be one of the solutions to recent environmental and energy issues. Most of the market share is occupied by crystalline silicon (c-Si) solar cells. A silicon heterojunction (SHJ) solar cells, one of the structures of c-Si solar cells, have achieved very high conversion efficiency. However, the current fabrication process of SHJ solar cells require additional costs for safety system due to the use of CVD with hazardous gases such as SiH_4. In this thesis, the development of SiH_4-free fabrication process of SHJ solar cells is presented.

First of all, i-a-Si:H passivation layer was deposited by the FTS method, which is a low-damage sputtering technique. It was found that the sputtering power is a key factor in achieving high quality passivation. High quality i-a-Si:H film was obtained when the sputtering power is high, while the damage to the substrate was extremely small when the sputtering power is low. Based on these results, a 2-step deposition technique was proposed. The i-a-Si:H deposited by using the 2-step deposition technique showed a passivation quality comparable to that of the passivation layer deposited by the conventional PECVD method. Additionally, a deposition rate of about 15 nm/min was achieved by using the 2-step deposition technique. This is first report of sputtered i-a-Si:H (about 5 nm) with such high deposition rate and high passivation quality.

The sputtered p-type and n-type layers were also investigated. For the deposition of p-a-Si:H and p-μc-Si:H, a highly B doped Si sputtering target was used. It was found that the high boron concentration over oxygen concentration in the p-a-Si:H is required to achieve high conductivity. It was also found that RF power and substrate temperature strongly affect the p-a-Si:H film quality. The sputtered p-a-Si:H with a thickness of about 10 nm showed a conductivity larger than 10^{-3} S/cm, and this conductivity is the highest in the sputtered p-a-Si:H with this thickness reported so far. For the n-a-Si:H deposition, we used a low-resistivity n-type monocrystalline silicon sputtering target. The n-a-Si:H deposited with this target showed a relatively high conductivity of about 10^{-3} S/cm. We fabricated sputtered n-a-Si:H/n-c-Si hetero-structure to investigate a potential of sputtered n-a-Si:H as BSF structure in SHJ solar cells. The detail analysis of the sputtered n-a-Si:H/n-c-Si contacts suggests that n-a-Si:H/low work function electrode has a potential of BSF structure in SHJ solar cells.

SHJ solar cells with the i-a-Si:H passivation layer and the p-type layers deposited by sputtering were fabricated. It was found that the thickness control of the i-a-Si:H passivation layer is very important for the SHJ solar cells with the passivation layer deposited by FTS. Finally, a conversion efficiency of 17.4% was achieved for a SHJ solar cell with FTS-deposited i-a-Si:H by optimizing the thickness of the i-a-Si:H passivation layer. This indicates that passivation quality of i-a-Si:H passivation layer deposited by FTS is comparable to that of passivation layer deposited by conventional PECVD. In the case of SHJ solar cells with sputtered p-layers, it was found that the sputtering power and device annealing processes are important factors to obtain good solar cell performance. By depositing a p-a-Si:H layer with higher conductivity at lower sputtering power and improving the device fabrication process, a conversion efficiency of 14.6% was achieved for a SHJ solar cell with sputtered i-a-Si:H passivation layer and p-a-Si:H layer. This is the first demonstration of SHJ solar cells with sputtered emitter structure.

Finally, III-V materials were investigated as n-type layer materials by device simulation. Initially, properties of sputtered nanocrystalline gallium nitride (nc-GaN) were investigated in detail. Based on the I-V characteristics of fabricated nc-GaN/c-Si devices, a GaN layer model was developed, and device simulations were used to discuss the key factor for the n-type layer in SHJ solar cells. According to our simulation study, the SHJ solar cells with GaN layer shows good solar cell performance if carrier concentration of GaN layer is larger than 5×10^{18} cm^{-3}. Additionally, the device simulation also indicated that the carrier concentration is more flexible when InGaN is used instead of GaN.

Overall, application of sputtering method to the fabrication process of SHJ solar cells was investigated. The sputtered passivation layer and p-type layer showed good performance at the device level. Additionally, it was found that sputtered n-type layer has potential as the n-type layer of SHJ solar cells. These results indicate that the sputtering method is promising for the SiH_4-free fabrication process of SHJ solar cells.