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題目(和文)	イオン注入とスパッタによるアモルファスシリコンを用いた高効率シリコン太陽電池用パッシベーティングコンタクト
Title(English)	Passivating contacts for high efficiency silicon solar cells fabricated by using ion implantation and sputtered amorphous silicon
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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 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 ）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The objective of this thesis is to demonstrate a cost-reduction process for the fabrication of TOPCon-IBC solar cells. To address the challenges associated with conventional manufacturing processes, a novel process was investigated using ion implantation and sputtering techniques. In particular, the passivation quality of TOPCon structures and the characteristics of TOPCon solar cells fabricated using a unique ion implantation system equipped with a mechanical hard mask were evaluated. Furthermore, to further reduce the manufacturing cost of TOPCon-IBC solar cells, this study is the first in the world to investigate the passivation quality of TOPCon structures by combining a unique ion implantation method with facing target sputtering (FTS) technology, exploring its potential for practical application. Below is a summary of the main findings of this study, organized by chapter.

Chapter 1 discusses the background and objectives of this study, emphasizing the importance of renewable energy and the role of solar power generation. It also provides an overview of the thesis structure and summarizes each chapter. Chapter 2 explains the fundamental principles of solar cells and introduces the latest advancements in high-efficiency crystalline silicon solar cells. Key passivation techniques for suppressing carrier recombination and strategies for reducing the manufacturing cost of TOPCon-IBC solar cells are detailed. Additionally, the chapter explores the use of ion implantation and low-damage film formation through sputtering techniques, along with an explanation of the main measurement methods employed in this study. Chapter 3: The challenges of ion implantation using a plasma immersion ion implantation (PIII) system with a mechanical hard mask were examined in detail. A fundamental evaluation of ion implantation damage and patterning implantation was conducted. It was found that optimizing the ion acceleration energy and dose is crucial for applying the PIII system to crystalline silicon substrates. Additionally, it was discovered that the machining accuracy of the mechanical hard mask for TOPCon IBC solar cells can be significantly improved by using materials with crystalline orientation. The improvement in the characteristics of solar cells fabricated by patterning implantation using a mechanical hard mask was also demonstrated. Chapter 4: A fundamental evaluation of the TOPCon structure fabricated using the PIII system was performed. The study investigated the issue of ion contamination by comparing TOPCon structures fabricated using both PIII

and beamline systems. The results indicated that the PIII system can form TOPCon structures with high passivation quality (iV_{oc} exceeding 740 mV). It was found that the high-temperature annealing process can diffuse undesirable ions, addressing the ion contamination issue. These findings suggest that the PIII system can be used for the fabrication of TOPCon structures with high quality passivation effects. Chapter 5: TOPCon solar cells were fabricated using both PIII and beamline systems, and their device characteristics were compared. While the TOPCon solar cells with n-type substrates fabricated using the PIII system showed slightly inferior characteristics compared to those fabricated using the beamline system, it was suggested that equivalent characteristics could be achieved by optimizing the annealing conditions. For TOPCon solar cells with p-type substrates, the study confirmed that metal contamination in the PIII system significantly deteriorates the electrical characteristics. This indicates the need to control metal contamination when using the PIII system for p-type substrates. However, the PIII system is considered sufficiently adaptable for manufacturing TOPCon solar cells with n-type substrates. Chapter 6: The possibility of reducing the manufacturing cost of TOPCon IBC solar cells by combining sputtering and ion implantation techniques was investigated. It was shown that TOPCon structures with good passivation quality can be formed using FTS and PIII systems. The study discovered that hydrogen blistering occurs when depositing i-a-Si using sputtering, indicating the importance of avoiding hydrogen addition during the i-a-Si deposition. The TOPCon structures with n^{++}-poly-Si fabricated using FTS and PIII systems showed higher passivation quality compared to those fabricated by sputtering alone. The contact resistance was found to be sufficiently low for device applications. Chapter 7 examined the improvement of passivation quality in TOPCon structures fabricated by using FTS and PIII systems. The n^{++}-poly-Si showed high passivation quality (τ_{eff} = 12 ms and iV_{oc} = 725 mV), while the phosphorus deposition in PIII influenced the passivation quality. It was confirmed that a cleaning process is necessary to remove the phosphorus deposition film before annealing in mass production. The surface recombination velocity of p^{++}-poly-Si was found to be below 10 cm/s, suggesting that this passivation quality is suitable for high-efficiency solar cell applications. However, its passivation quality was slightly inferior to that in Chapter 4. This can be improved by changing the SiO_2 formation method to thermal oxidation. Finally, the contact resistance was demonstrated to be sufficiently low, confirming its feasibility for device applications.