Extended Abstracts of the 2016 International Conference on Solid State Devices and Materials, Tsukuba, 2016, pp349-350

G-6-01

Effect of Anti-Reflection Coating on the Crystallization of Amorphous Silicon Films by Flash Lamp Annealing

Yuki Sonoda and Keisuke Ohdaira (JAIST)
E-mail:s1530024@jaist.ac.jp

Abstract

We succeed in decreasing the fluence of flash lamp pulse required for the crystallization of electron-beam-(EB-) evaporated amorphous silicon (a-Si) films by using silicon nitride (SiN_x) anti-reflection films. The anti-reflection effect of SiN_x is confirmed not only when SiN_x is placed on the surface of a-Si and FLA is performed from the film side but also when SiN_x is inserted between glass and a-Si and flash pulse is supplied from the glass side. We also quantitatively confirm, by calculating actual absorbed energies using reflectance spectra, that the reduction in the fluence of flash lamp pulse for the crystallization of a-Si films owes the anti-reflection effect of SiN_x.

1. Introduction

In recent years, solar power generation is expected as the solution of environmental problems and high power demand. Although the mainstream of current solar cells is wafer-based Si solar cells, their fabrication is not cost-effective since a lot of energy and processes are required. Research on polycrystalline Si (poly-Si) thin film solar cell has thus been conducted to decrease manufacturing cost. Poly-Si films can be formed by crystallizing amorphous Si (a-Si) films by rapid heat treatment with high productivity. We have so far investigated flash lamp annealing (FLA), millisecond-order discharge from Xe lamps, as the method of crystallizing µm-order-thick a-Si films [1]. In particular, the utilization of electron-beam- (EB-) evaporated a-Si films results in the formation of poly-Si films consisting of several tens of µm-long large grains due to the emergence of liquid-phase explosive crystallization during FLA [2]. Although this feature is favorable for the application of the flash-lamp-crystallized poly-Si to solar cells, EB-evaporated a-Si films need more fluence for crystallization than a-Si films formed by other methods [2]. The fluence of flash pulse may be reduced if the loss of flash lamp pulse light is minimized by suppressing optical reflection.

In this study, we have attempted to utilize silicon nitride (SiN_x) films to reduce the fluence of flash lamp pulse light. The effect of the addition of SiN_x anti-reflection films is confirmed also by estimating energy actually absorbed in a-Si films by using optical reflectance spectra of a-Si structures.

2. Experimental

We used EB-evaporated a-Si structures schematically shown in Fig. 1. The a-Si films consist of a 35 nm-thick n^+ a-Si layer deposited by plasma-enhanced chemical vapor deposition (PECVD), a 2 µm-thick p-type EB-evaporated a-Si film, and 100 nm-thick EB-evaporated p^+ a-Si layer. Some of the samples have PECVD SiN_x anti-reflection films with a thickness of 70–80 nm (Fig. 1(a)). We also prepared samples with a 85 nm-thick SiN_x film deposited by catalytic chemical vapor deposition (Cat-CVD) on the stacked a-Si films (Fig. 1(d)). We measured optical reflectance spectra of these a-Si structures in order to estimate energies actually absorbed in the a-Si films. We performed FLA to these a-Si structures. Pulse light was suppled from the glass side for glass/SiN_x/a-Si and glass/a-Si structures (Figs. 1(a) and (b)) and from the a-Si side for a-Si/glass and SiN_x/a-Si/glass structures (Figs. 1(c) and (d)). FLA was performed using pulse light at fluences of 7–19 J/cm^2 with 7 ms duration in Ar atmosphere under the preheating of the samples at 500 °C. Only one shot of flash lamp irradiation was performed for each sample. We evaluated the presence or absence of crystallization of the Si film by Raman spectroscopy.

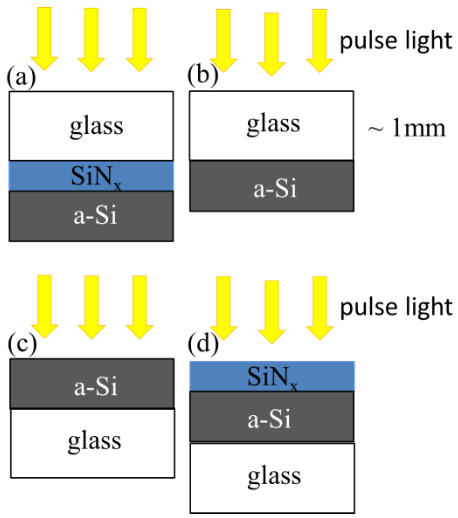

Fig. 1 Schematics of EB-evaporated a-Si structures: (a) glass/SiN_x/a-Si, (b)glass/a-Si, (c) a-Si/glass, and (d) SiN_x/a-Si/glass. Pulse light was suppled from the glass side for glass/SiN_x/a-Si and glass/a-Si structures, and from the film side for the a-Si/glass and SiN_x/a-Si/glass structures.

3. Results and discussion

Figure 2 shows the Raman spectra of the Si film after FLA with a fluence of 12.42 J/cm^2 for glass/SiN_x/a-Si and glass/a-Si structures. The sample with SiN_x shows the peak of crystalline Si at around 520 cm^{-1}, while the sample without SiN_x shows only a broad peak at around 480 cm^{-1} originating from a-Si phase. This fact demonstrates that the anti-reflection effect of SiN_x contributes to reduction in the fluence of flash lamp pulse needed to crystallize a-Si films. The c-Si peak of the Raman spectrum for the glass/SiN_x/a-Si structure has a peak position of ~517 cm^{-1} and a full width at half maximum (FWHM) of ~4.9 cm^{-1}. These facts indicate that poly-Si films formed have a strong tensile stress, due to tensile stress which precursor EB-evaporated a-Si originally have, and consist of relatively large grains [3].

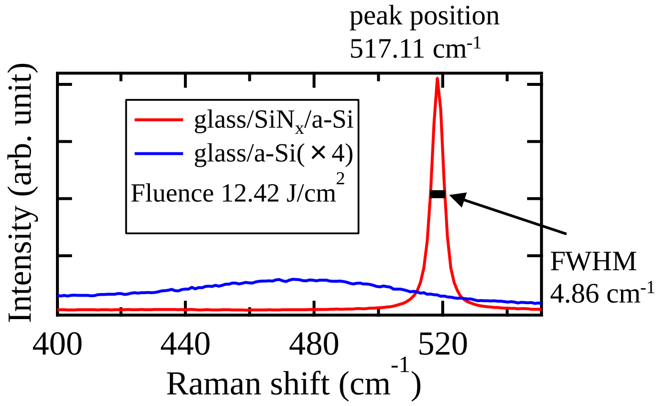

Fig. 2 Raman spectra of Si films after FLA at a fluence of 12.42 J/cm^2 for glass/SiN_x/a-Si and glass/a-Si structures.

Figure 3 shows the optical reflectance spectra of the a-Si structures before crystallization. The usage of SiN_x anti-reflection films leads to effective reduction in the optical reflectance. By using flash pulse fluence at each wavelength $I(\lambda)$, which we have reported previously [4], and optical reflectance $R(\lambda)$ obtained experimentally, total energy actually absorbed in a-Si is expressed to be $\int[1-R(\lambda)]I(\lambda)d\lambda$. Table 1 shows the total energy required for crystallization and calculated actual absorbed energy for the glass/SiN_x/a-Si, glass/a-Si, a-Si/glass, and SiN_x/a-Si/glass structures. Although fluence needed for crystallization varies widely depending on the sample structure, estimated energies actually absorbed in a-Si are almost the same. According to this result, we can conclude that the addition of anti-reflection film results in the crystallization of a-Si films by FLA at lower pulse fluence. The effective reduction in the fluence of flash lamp pulse needed for the crystallization of EB-evaporated a-Si films will contribute to energy saving in the production of poly-Si films.

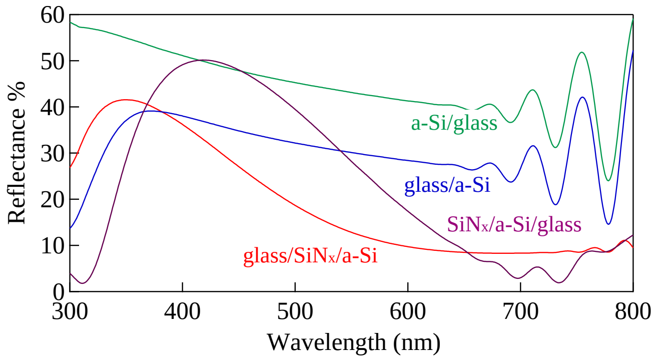

Fig. 3 Optical reflectance of the glass/SiN_x/a-Si, glass/a-Si, a-Si/glass, and SiN_x/a-Si/glass structures.

4. Conclusions

The fluence of flash lamp pulse for the crystallization of precursor a-Si films can be effectively reduced by using anti-reflection SiN_x films. We have also quantitatively demonstrated the reduction of flash pulse fluence needed for crystallization by calculating actual fluence absorbed in a-Si by using optical and flash lamp pulse spectra.

Acknowledgment

The authors would like to thank Dr. Sergey Varlamov of University of New South Wales for the preparation of EB-evaporated a-Si films.

References

[1] K. Ohdaira, J. Vac. Soc. Jpn. **55** (2012) 535.
[2] K. Ohdaira and H. Matsumura, J. Cryst. Growth **362** (2013) 149.
[3] K. Ohdaira, K. Sawada, N. Usami, S. Varlamov, and H. Matsumura, Jpn. J. Appl. Phys. **51** (2012) 10NB15.
[4] K. Ohdaira, Jpn. J. Appl. Phys. **52** (2013) 04CR11.

Table 1 Experimental fluence of flash lamp pulse and calculated incident energy for glass/SiN_x/a-Si, glass/a-Si, a-Si/glass and SiN_x/a-Si/glass structures.

	glass/SiN_x/a-Si	glass/a-Si	a-Si/glass	SiN_x/a-Si/glass
Fluence needed for crystallization	11.94 J/cm^2	14.46 J/cm^2	17.38 J/cm^2	12.29 J/cm^2
Calculated incident energy	9.55 J/cm^2	9.62 J/cm^2	9.47 J/cm^2	9.16 J/cm^2