Controlling Solution Surface Tension for the Cleaning of Small Size Textured Si Surface to Obtain Extremely Low Surface Recombination Velocity of 0.6 cm/s

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1. Introduction

Reducing thickness of crystalline silicon (c-Si) wafers to <100 µm is one of the keys to low-cost solar cells. On such thin c-Si wafers, a reduction in the size of textures is necessary to minimize c-Si losses by texturing process and to keep the robust property in cell fabrication processes. To obtain small textures with a size <2 µm through alkaline anisotropic etching, we have already established "Microparticle-Assisted Texturing" (MPAT) process [1]. However, cleaning of such small texture surface is always challenging. We have revealed the importance of surface cleaning to obtain high quality passivation [2]. Therefore, in this work, we aimed to develop a suitable cleaning procedure for the small texture surface. We discovered a novel effect of mixing methanol (CH_3OH) with hydrochloric acid (HF) on surface passivation quality of the c-Si surface. Surface recombination velocity (SRV) decreases from 3.5 down to 0.6 cm/s when methanol is mixed with HF. It is found that methanol reduces the surface tension of HF solution on the c-Si surface, leading to uniform chemical reaction or effective chemical cleaning. We named this finding "Methanol-Assisted Cleaning (MAC)" process.

2. Experiments and Results

Preparation of the small size textured c-Si surface

Mirror polished n-type floating-zone (100) c-Si substrates with a resistivity of 1–5 Ωcm and a bulk minority carrier lifetime of ~12 ms were used for all experiments. Figure 1(a) shows procedure for preparation of the small textures on c-Si with (b) a SEM image. The size of the textures is <2 µm.

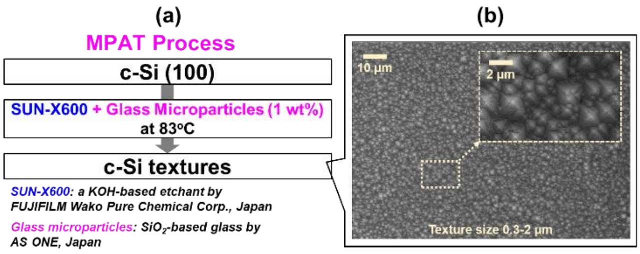

Fig. 1. (a) Procedure for formation of randomly textured c-Si using the MPAT process. (b) A scanning electron microscope (SEM) image of c-Si textures prepared by MPAT process.

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Without any cleaning other than using HF solution to remove native oxide layer (procedure A), we obtained very poor effective minority carrier lifetime (τ_{eff}) < 10 µs (SRV > 1400 cm/s) after passivation by coating of a well-known Cat-CVD amorphous-Si (a-Si)/silicon nitride (SiN_x) staked layers [1–3], as shown in Fig. 2(a). Therefore, we attempted many cleaning procedures to achieve a better τ_{eff}, and finally found an acceptable cleaning (procedure B) to obtain τ_{eff} =3.0 ms (SRV = 3.5 cm/s), as shown in Fig. 2(b). In this cleaning method, we noticed an important role of solution surface tension; hence methanol (CH_3OH) was mixed with the hydrochloric acid (HF) to control the surface tension, as shown in Fig. 2(c). As a result, τ_{eff} drastically increases up to 7.8 ms (SRV=0.6 cm/s). We named this finding "Methanol-Assisted Cleaning (MAC)" process. We also verified that mixing methanol reduces contact angles or surface tensions of the solutions on flat c-Si (100), flat c-Si (111), and textured c-Si surfaces. The contact angles decrease from ~90° down to ~0° when mixing ratio of methanol increase up to ~70 vol%. Owing to the low surface tension, the solution can reach even the bottom of the complicated small texture surface, leading to uniform chemical cleaning and better passivation quality. Features of the MAC process is also investigated in this work, which are expected to be useful for cleaning of any kinds of Si wafers other than solar cell ones. We summarized cleaning dependence of τ_{eff} and SRV in Fig. 3.

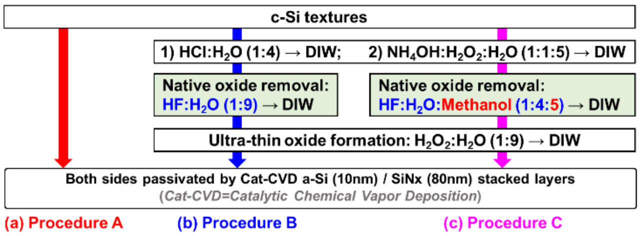

Fig. 2. Cleaning procedures for c-Si textures (a) without cleaning, (b) cleaning without methanol, (c) cleaning with methanol.

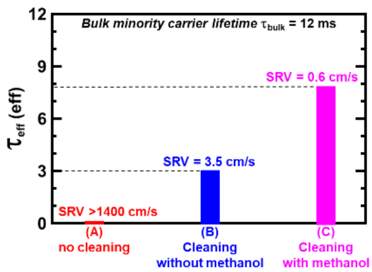

Fig. 3. Cleaning dependence of τ_{eff} and SRV

3. Conclusions

We revealed the importance of controlling solution surface tension by mixing methanol with HF to obtain extremely high passivation quality with surface recombination velocity of 0.6 cm/s. We named this finding "Methanol-Assisted Cleaning (MAC)" process.

Acknowledgements

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References

[1] C.T. Nguyen, *et al.*, Jpn. J. Appl. Phys. **56**, 056502 (2017).
[2] C.T. Nguyen, *et al.*, J. Mater. Res. **33**, 1515 (2018).
[3] K. Koyama, *et al.*, Appl. Phys. Lett. **97**, 082108 (2010).