Reflectivity Study of Acid Textured Multicrystalline Silicon Wafers in Different Solutions for Solar Cells Application

Firoz Khan, Minwu Song, Sadia Ameen, Young-Soon Kim, Hyung-Shik Shin*

Energy Materials & Surface Science Laboratory, Solar Energy Research Center, School
of Chemical Engineering, Chonbuk National University, Jeonju, 561-756,
Republic of Korea
*Email: hsshin@jbnu.ac.kr

Abstract

In this paper, an attempt was made to reduce the optical loss of multicrystalline silicon (mc-Si) wafer. The texturization of wafer was carried out in acidic solution by controlling the chemical compositions and temperatures. The two different acidic solutions of $HF:HNO_3:H_3PO_4$ and $HF:HNO_3:H_2O$ used and examined with respect to the etching time.The minimum (~ 17%) and maximum reflectivity in $HF:HNO_3:H_3PO_4$ solution obtained by 10 s and 16 s respectively, indicating the smoothness of surface increased with the increase of etching time. The reflectivities in $HF:HNO_3:H_2O$ solution minimized to ~5%. The reflectivity was reduced by the replacement of H_3PO_4 to H_2O and thus obtained the minimum reflectivity.

Introduction

When light rays will be reflected from one angled surface may strike to other surface and hence improved the probability of absorption, and therefore reduce the reflection [1]. Secondly, light refracted will propagate at an angle causing photon absorption near the junction and also increased the path length and hence enhanced the absorption of light. Texturization is done for reducing the reflection losses and enhances the short circuit current density of solar cells. Texturization of monocrystalline silicon (c-Si) is done in alkaline solution i.e. NaOH or KOH to form random pyramids but texturization of multicrystalline silicon (mc-Si) can not be done very effectively using anisotropic etching in alkaline solution as grains have different orientation. Texturization of multicrystalline silicon has been done in acidic and also in alkaline solutions [1-6]. Macdonals et al. [1] studied mc-Si texturing for application in industrial solar cells by wet acid, masked and maskless RIE methods and found masked RIE method to be the best. Significantly contribution regarding acidic texturization of mc-Si was made by Nishimoto et al. [2] in which they used mainly $HF:HNO_3:H_3PO_4$::12:1:3, $HF:HNO_3:H_3PO_4$ ::12:1:9 and $HF:HNO_3:H_3PO_4$ ::12:1:12 solutions for short durations. They have studied scanning electron microscopic (SEM) micrographs and observed texturization to be a part of a hemisphere and theoretically calculated that reflection starts declining when H/2R exceeds 0.2 and keeps on declining further as H/2R increases where 2R is the diameter of the hemisphere and H is the depth of texture. They used H_3PO_4 as a catalytic agent. Xi et al. [3] also observed part of hemispherical structure in acid texturization and according to their calculations the reflectivity at 500 nm starts declining when H/2R exceeds 0.3. While Khan et al. [7] done acid texturization in different composition of $HF:HNO_3:H_2O$ for constant duration. In this work acid texturization has been done in two different solutions i.e. $HF:HNO_3:H_3PO_4$ ::10:1:4 for 10-16s and $HF:HNO_3:H_2O$::10:1:5 for 8-20 min respectively.

Experimental

The starting material was multicrystalline silicon wafers laped on both sides of 50 mm in diameter having resistivity 0.5-1.2 Ωcm p-type (B-doped) and minority carrier lifetime (τ) ≤ 10μs. The wafers were ultrasonically cleaned using DI water and acetone. The cleaned wafers were textured in ice cold solution $HF:HNO_3:H_3PO_4$ ::10:1:4 for 10-16s and in $HF:HNO_3:H_2O$::10:1:5 for 8-20 min.

SEM micrographs under 5000X magnification were taken for each textured wafers using SEM model LEO 440. Subsequently, the reflectivity of the textured wafers were measured by Shimaadzu Spectrophotometer Model UV-3101-PC as a function of λ in the range 400-1100 nm.

Result and Discussions

The reflectance spectra of textured multicrystalline silicon (mc-Si) wafers in ice cold solution $HF:HNO_3:H_3PO_4$ ::10:1:4 for 10-16s are shown in Fig.1. The minimum reflectivity is found between 17.5-20.4%. The reflectivity is minimum for 10s and maximum for 16s which shows that smoothness of surface is increased with etching time.

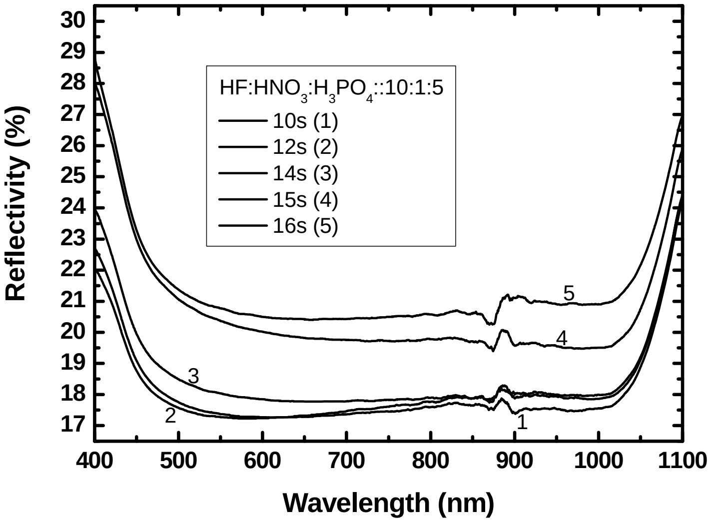

Fig. 1. Reflectivity of mc-Si in solution A.

The reflectance spectra of textured multicrystalline wafers in ice cold solution $HF:HNO_3:H_2O$:: 10:1:5 for 8-20 min are shown in Fig. 2. The minimum reflectivity is obtained between 5.5-10.5%. The reflectivity is minimum for 18 min and maximum for 14 min.

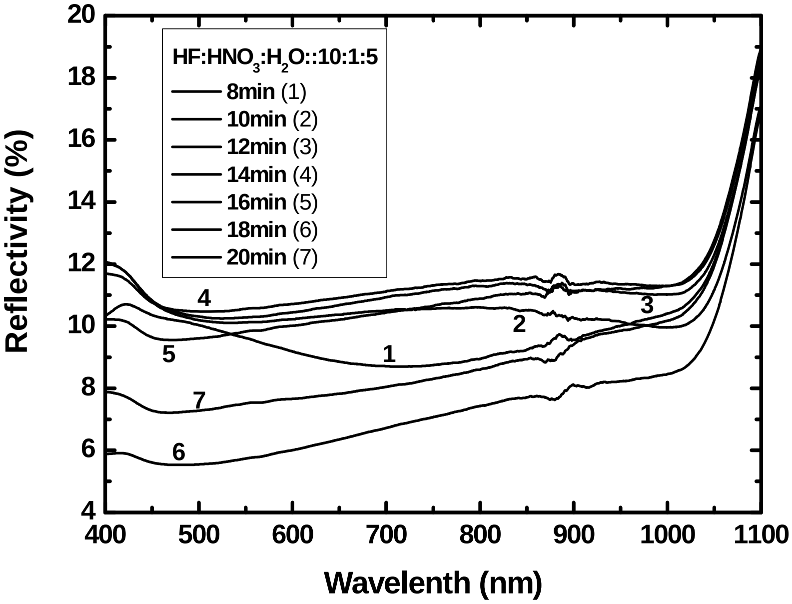

Fig. 2. Reflectivity of mc-Si in solution B.

Fig. 3 and 4 show the SEM micrographs of textured mc-Si in solutions of HF:HNO$_3$:H$_3$PO$_4$ ::10:1:4 for 16s and HF:HNO$_3$:H$_2$O ::10:1:5 for 20 min. The smaller pits are observed when mc-Si textured by HF:HNO$_3$:H$_3$PO$_4$ ::10:1:4 whereas, the sizes of pits are increased when mc-Si textured by HF:HNO$_3$:H$_2$O ::10:1:5.

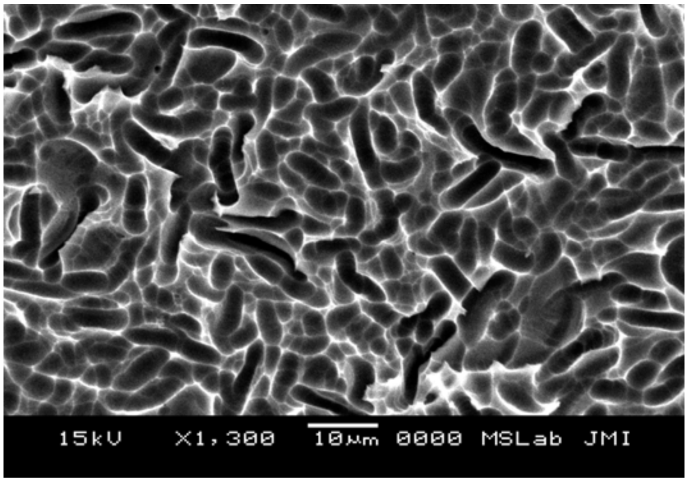

Fig. 3 SEM micrograph of acid textured mc-Si in Solution A for 16s.

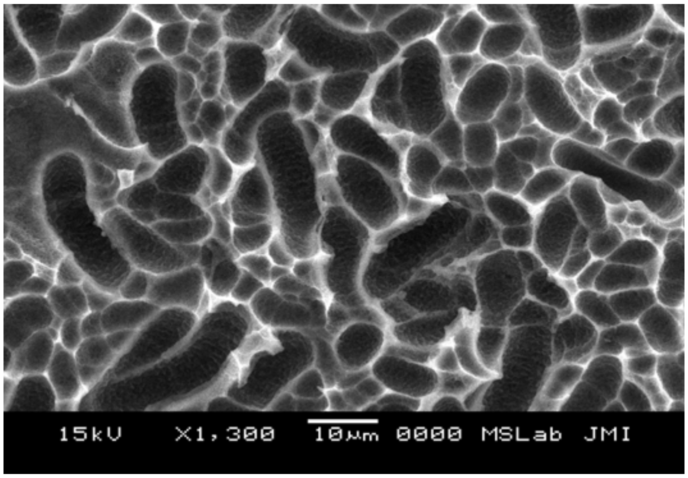

Fig. 4 SEM micrograph of acid textured mc-Si in Solution B for 20min.

Conclusions

The reflectivity of textured mc-Si wafers in $HF:HNO_3:H_3PO_4$ ::10:1:4 are increased with time due to width of pits are increased, while in $HF:HNO_3:H_2O$ ::10:1:5 initial increased with etching time then decreased and finally increased due to depth (h) and width (d) ratio changed with etching time.

References

1. D. H. Macdonald, A. Cuevas, M.J. Kerr, C. Samundsett, D. Ruby, S. Winderbaum, A. Leo, *Solar Energy,* 76 (2004) 277.
2. N. Nishimoto, T. Ishihara, K. Namba, *J. Electrochem. Soc.,* 146 (1999) 457.
3. Zhengiang Xi, Deren Yang, Wu Dang, Chen Jun, Xianhang Li, Duanlin Que, *Semicond. Sci. and Technol.,* 19 (2004) 485.
4. J. M. Kim, Young K.Kim, *Sol. Energy Mater. Sol. Cells,* 81(2004)239.
5. V. Gangopadhyay, S. K. Dhungel, K. Kim, U. Manna, P. K. Basu, H. J. Kim, B. Karunagaran, K. S. Lee, J. S.Yoo, J.Yi, *Semicond. Sci. and Technol.,* 20 (2005) 938.
6. K. Tsujino, M. Matsumura, Y.Nishimoto, *Sol. Energy Mater. and Sol., Cells,* 90 (2006)100.
7. F. Khan, D. Kumar, B. C. Chakravarty, M. Kar, R. Kumar, V. Agrawal, S.N. Singh, M. Husain, *International Conference on Solar Cells,* (2008), Cochin, India, pp 249.