H_2 Annealing for Improving of Si Nanowire-based Solar Cells

°ジェバスワン ウィパコーン，中島清美，杉本喜正，深田 直樹
NIMS, °Wipakorn Jevasuwan, Kiyomi Nakajima, Yoshimasa Sugimoto and Naoki Fukata,
E-mail: JEVASUWAN.Wipakorn@nims.go.jp

Nanowires (NWs) are promising as building blocks for next generation solar cells due to many advantages of their structure compared to planar structure [1]. Several NW synthesis methods such as MCEE, CVD, and Bosch process have been proposed, and their application for high efficient three-dimensional structure solar cells has been intensively investigated. Appropriate NW-based solar cell materials and junction properties are important issues to realize this target [2]. In this work, we would like to propose H_2 annealing technique and its effects on efficiency of single junction SiNW solar cells.

SiNWs in this study were synthesized by two methods, MCEE and nanoimprint with Borch process, using n-Si(111) substrates with resistivity of 1-50 Ω·cm. For MCEE method, 1.45-µm-length NW samples were prepared by etching with 0.02M $AgNO_3$ in 4.6M HF solution [3]. In case of nanoimprint samples, the same length NWs were prepared by 30-nm-thick Cr patterning with SF_6 and C_4F_8 plasma etching. Prior to p-Si deposition, all n-SiNW samples were etched by 1.1M HF in 2.6M isopropanol and immediately set into CVD chamber. p-Si matrix formation was carried out at 750 °C with B doping concentration of ~4×10^{19} cm^{-3}. Then, 200-nm-thick Al front electrode with finger-grid pattern and 150-nm Ag back contact were sputtered. In this work, we investigated the effects of H_2 annealing after n-SiNW syntheses and p-Si CVD process. The annealing temperatures of 900 °C and 1000 °C were used with annealing time of 10 min.

Figure 1 shows scanning electron microscopy (SEM) images of SiNWs synthesized by (a) MCEE and (b) nanoimprint, and (c) p-Si layer formed by CVD without H_2 annealing and with 10-min H_2 annealing at 900 °C and 1000 °C. The SiNW structures of both synthesis methods were not significantly changed by H_2 annealing up to 1000 °C. In case of p-Si layer, the coalescence of Si islands and defects were obviously shown after H_2 annealing at 900 °C and 1000 °C, respectively. The effect of H_2 annealing was clearly revealed by electron spin resonance (ESR) measurements at 4.2 K and microwave power of 0.5 mW that defects at n-SiNW surface and in p-Si layer (g-value of 2.005) could be reduced by H_2 annealing. The defect intensities are similarly low at both annealing temperatures. Current-voltage characteristics of MCEE-SiNW solar cells, shown in Fig. 2, were improved by H_2 annealing. H_2 annealing at 900 °C for 10 min after MCEE and CVD processes gave the highest solar cell efficiency indicating the improvement of solar cell materials and junction. Short circuit current (I_{sc}), open circuit voltage (V_{oc}), fill factor (FF), and efficiency (E_{ff}) were 22.24 mA/cm^2, 0.49 V, 50 % and 5.41 %, respectively. Study of nanoimprint-SiNW solar cells is now in progress.

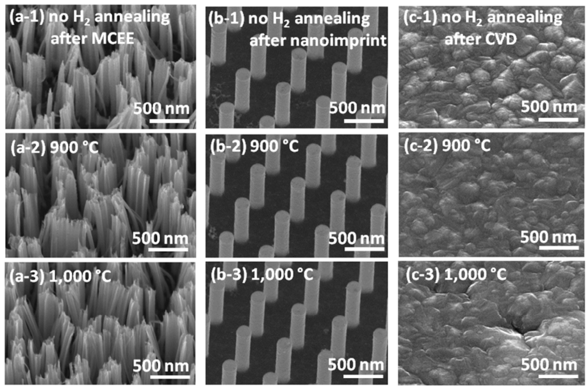

Fig. 1 SEM images of SiNWs synthesized by (a) MCEE and (b) nanoimprint, and (c) p-Si matrix layer after CVD without H_2 annealing and with 10-min H_2 annealing at 900 °C and 1,000 °C.

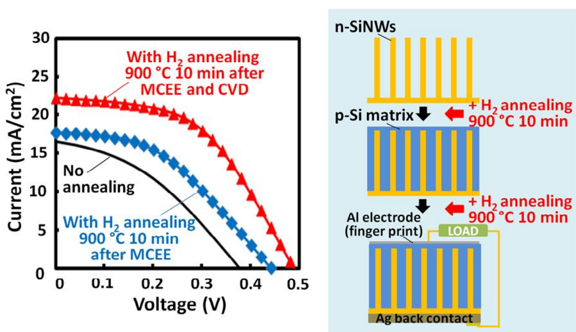

Fig. 2 I-V characteristics of MCEE-SiNW solar cells were improved by H_2 annealing.

[1] K. Yu and J. Chen, Nanoscale. Res. Lett., 4 (2009) 1.
[2] J. W. Li, *et al.*, Int. J. Quantum Chem., 109 (2009) 3705.
[3] M. Dutta and N. Fukata, Nano Energy 11 (2015) 219.

© 2015年 応用物理学会