Electronic Supplementary Material (ESI) for Energy & Environmental Science.


# Supplementary Information

# Flexible crystalline silicon radial junction photovoltaics with vertically aligned tapered microwires

*Inchan Hwang,[1,‡] Han-Don Um,[1,‡] Byeong-Su Kim,[1,2] Munib Wober,[3] and Kwanyong Seo [1,*]*

[1]Department of Energy Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Republic of Korea

[2]Department of Chemistry, Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Republic of Korea

[3]John A Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts 02138, U.S.A.

AUTHOR INFORMATION

‡ These authors contributed equally to this work.

* Corresponding author: kseo@unist.ac.kr

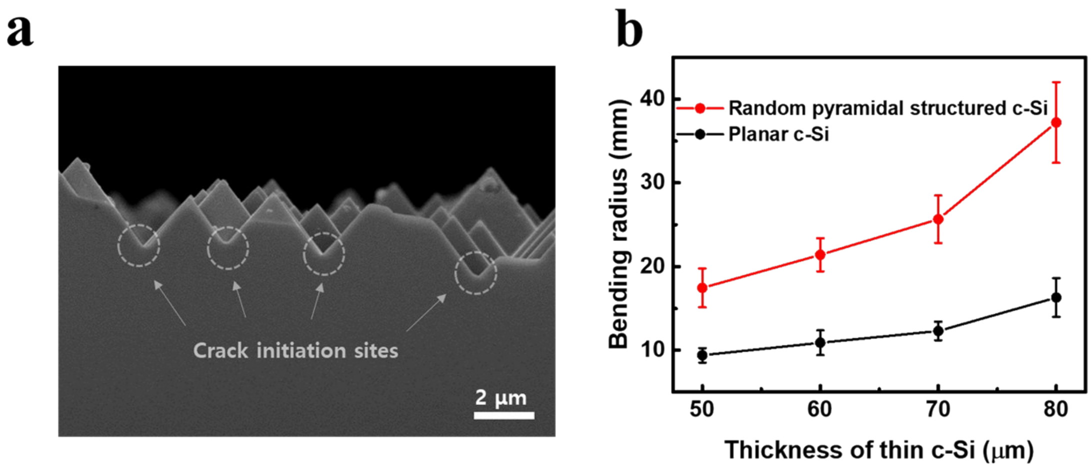


**Fig. S1** (a) Cross-sectional SEM image of the random pyramidal structures (b) Experimental bending properties of various thicknesses of the random pyramidal structured thin c-Si from 50 to 80 μm (red solid line with circles), as well as planar thin c-Si from 50 to 80 μm (black solid line with circles).

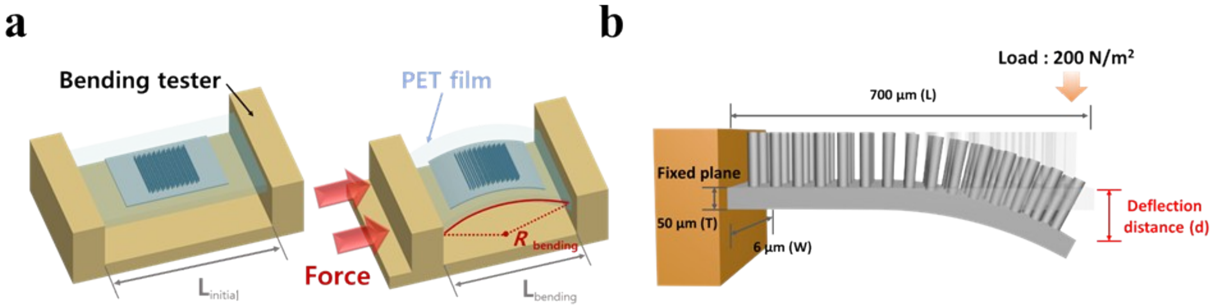


**Fig. S2** (a) Schematics of the apparatus to evaluate the bending property of thin c-Si and with various length of MWs. (b) Schematic of the designed the thin c-Si with MWs for the mechanical simulation.

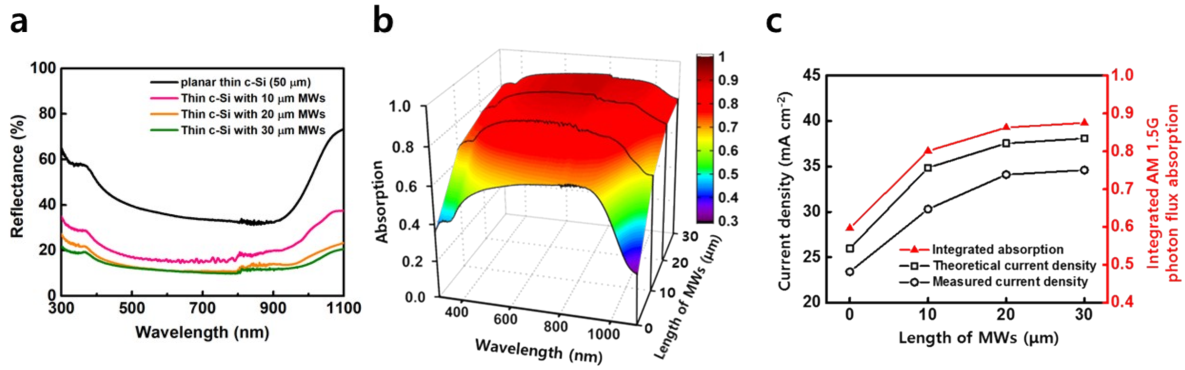


**Fig. S3** (a) Reflection spectra of 50-μm-thick Si substrate with and without the various length of MWs**.** (b) Enhanced light absorption properties of the thin c-Si with MWs by increasing length of MWs. (c) Integrated photon flux absorption of the thin c-Si with various length of MWs and the theoretical current density which is calculated by the obtained absorption spectra.

**Calculation of the integrated photon flux absorption and the theoretical current density**

The integrated photon flux absorption is calculated by Equation S1

$$A(\lambda)_{\text{Integrated photon flux}} = \frac{\int_{300nm}^{1100nm} b(\lambda)A(\lambda)d\lambda}{\int_{300nm}^{1100nm} b(\lambda)d\lambda} \quad \text{(S1)}$$

Where $b(\lambda)$ is the photon flux density of the AM 1.5G solar spectrum, $A(\lambda)$ is the absorption spectra depending on wavelength.

The theoretical current density, assuming no recombination, is calculated from

$$J_{sc} = q\int_{300nm}^{1100nm} b(\lambda)d\lambda * A(\lambda)_{Integrated\,photon\,flux} \quad \text{(S2)}$$

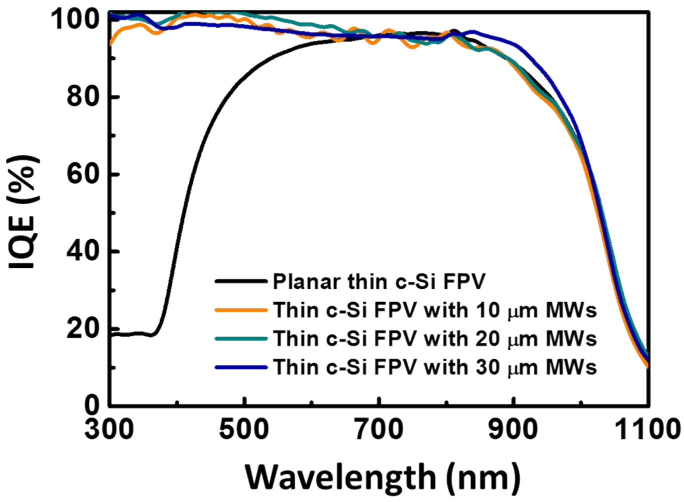


**Fig. S4** Internal quantum efficiencies of MW based FPVs showed significantly improved value compared to that of planar thin c-Si FPV at the short-wavelength region.

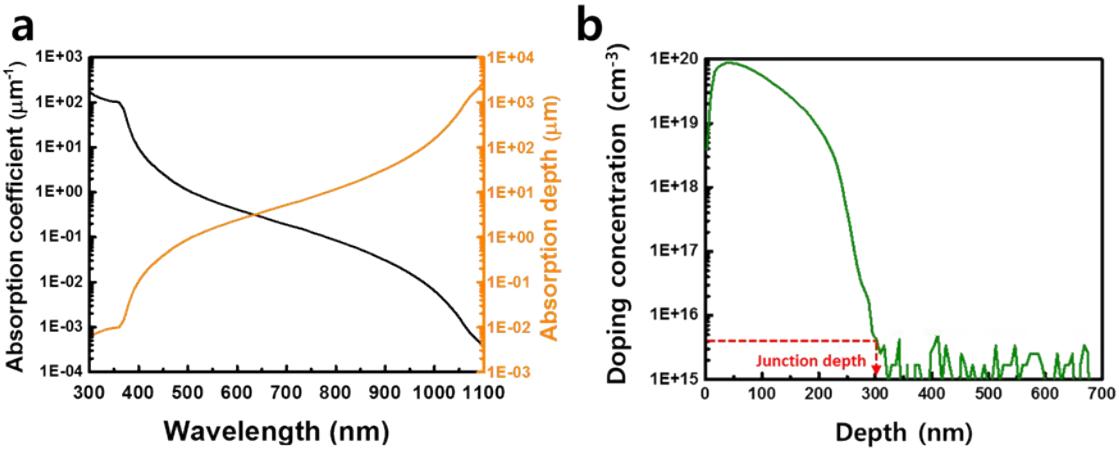


**Fig. S5** (a) Crystalline silicon has the low absorption coefficient at the near infrared region.[1] (b) Junction depth of the radial junction is around 300 nm.

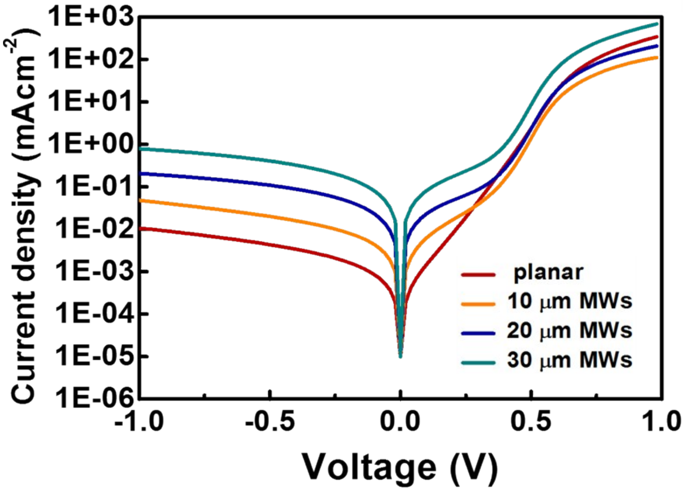


**Fig. S6** Dark current density-voltage curves of thin c-Si FPVs with various length of MWs. By increasing length of the MWs, reverse saturation current is slightly increased.

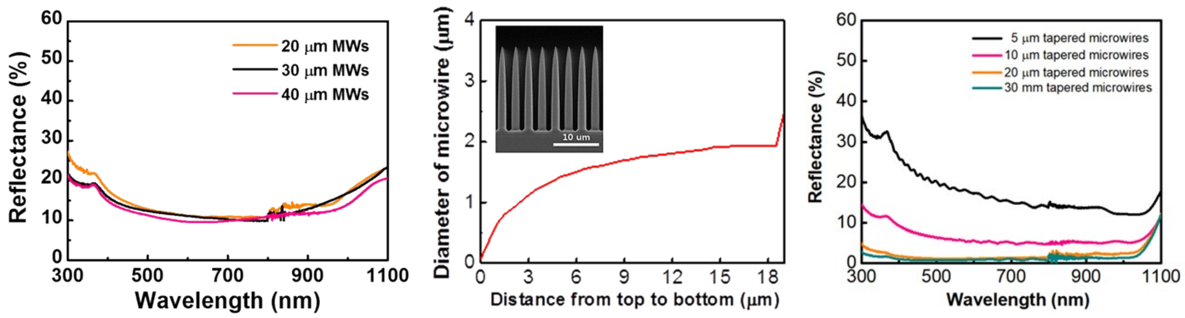


**Fig. S7** (a) Surface reflection of the various length of MWs. Although the length of MWs is increased from 20 μm to 40 μm, the surface reflection spectra is nearly constant value at the entire wavelength region. (b) Tapered MWs showed sharp tip and gradually increased diameter from top to bottom. (c) Surface reflection spectra of the tapered MWs with the various lengths.

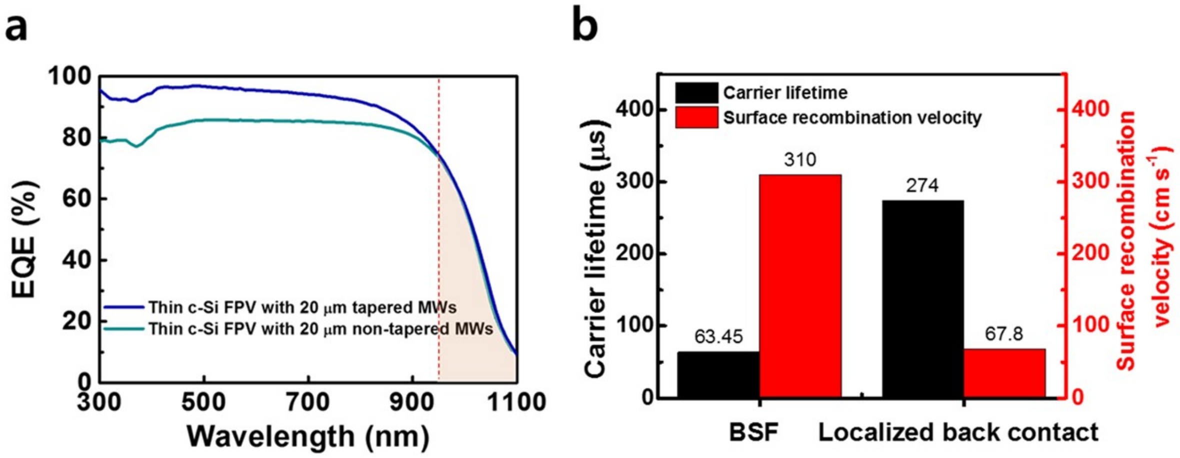


**Fig. S8** (a) The EQE of the thin c-Si FPV with the non-tapered and tapered MWs. (b) Comparison of the surface recombination velocity of the BSF and localized back contact.

**Calculation of the surface recombination velocity**

The surface recombination velocity ($S_{eff}$) is calculated by using effective carrier lifetime ($\tau_{eff}$) which is evaluated by quasi-steady-state photoconductance (QSSPC).

The $S_{eff}$ is calculated at a condition of 1 x $10^{15}$ $cm^{-3}$ fixed excess carrier density by following equation,

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_{bulk}} + \frac{2S_{eff}}{W} \tag{S4}$$

Here, intrinsic lifetime limit ($\tau_{bulk}$) is assumed as 4700 μs considering doping concentration of the thin c-Si substrate (4.4 x $10^{15}$$cm^{-3}$). W refers to the thickness of the Si substrate.

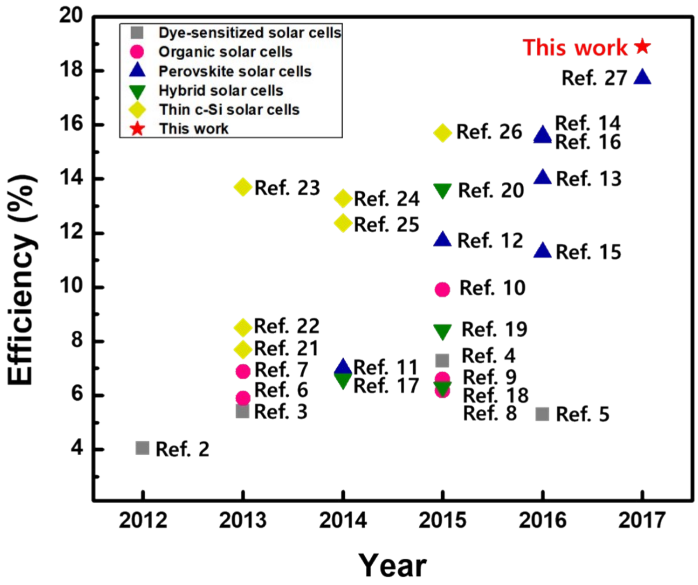


**Fig. S9** Comparison of power conversion efficiency achieved in this study with those of previously reported flexible photovoltaics.[2-27]

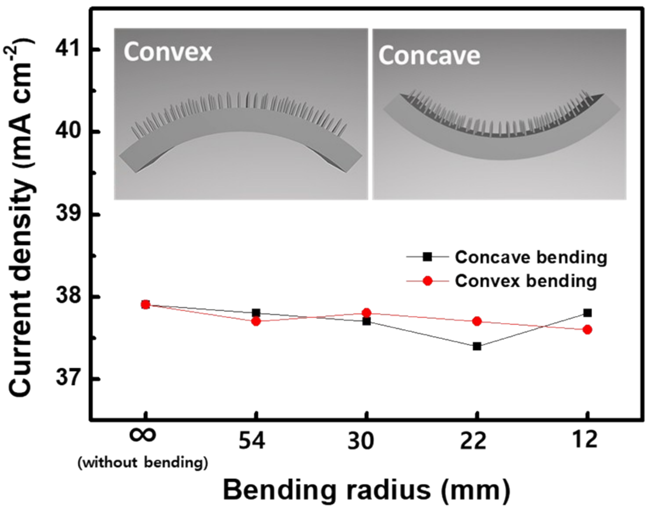


**Fig. 10** Change in the current density ($J_{sc}$) of the thin c-Si FPV with the tapered MWs according to the bending radius. The $J_{sc}$ of the thin c-Si FPV with the tapered MWs is nearly constant regardless of bending property.

## Supplementary References


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