Assessing Silicon Nanowires as a Bottom Cell Material for III-V Multijunction Solar Cells using Thin InGaP/GaAs Filter

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One of the main challenges of III-V based multijunction solar cells (MJSCs) is the high cost due to the rarity of III-V materials. To investigate low-cost, low-bandgap materials that can be in tandem with III-V solar cells without fabricating the whole device, one may use a III-V filter on top of a solar cell containing the candidate material. Silicon-based nanostructures, such as silicon nanowires (SiNWs), are attractive candidates because they have better light trapping and require shorter charge separation distance in the junction than their planar counterpart. In this work, we evaluated SiNW solar cell if it is a suitable bottom cell candidate for III-V MJSCs. This was done by placing it under InGaP/GaAs 2J filter during various characterization methods [Fig. 1]. Particularly, current-voltage (*J-V*) characteristics curves and external quantum efficiency (EQE) were obtained. The *J-V* characteristics curves and their corresponding electrical parameters are shown in Fig. 2(a) and Table 1, respectively. The J_{SC} produced in SiNW reduces to 3.46 mA/cm^2 under 2J filter because most of the current were absorbed by the filter. Consequently, the SiNW solar cell efficiency dropped by about 4.98%. These results agree with the J_{SC} derived from EQE [Table 2, Fig. 2(b)], in which the slight difference with the J_{SC} from the *J-V* curve can be attributed to the difference in lamp sources used during measurements. If SiNW is used as a bottom cell in InGaP/GaAs//SiNW triple junction solar cell (3JSC), in which a typical tandem III-V solar cell produces 10 to 14 mA/cm^2 at 1 sun, SiNW is expected to limit the 3J current, and therefore, the conversion efficiency. To make SiNW a more desirable bottom cell material, strategies such as passivation, two-step H_2 annealing, or amplifying the luminescent coupling effect towards it are then suggested to reduce the anticipated current mismatch with the InGaP/GaAs tandem.

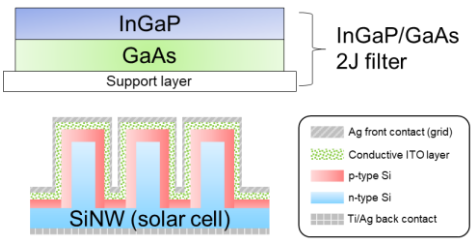

Fig. 1. Cross-section schematic of InGaP/GaAs 2J filter and SiNW solar cell.

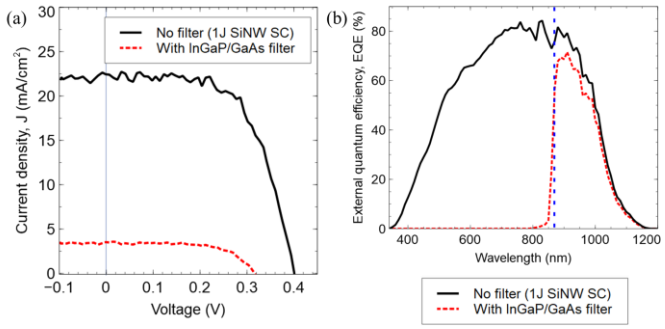

Fig. 2. (a) AM 1.5G, 1-sun *J-V* characteristics and (b) EQE of SiNW solar cell without and with 2J filter

Table 1. Electrical parameters of SiNW solar cell without and with InGaP/GaAs 2J filter

Parameter	No 2J filter	With 2J filter
Short-circuit current, J_{SC} (mA/cm^2)	22.32	3.46
Open-circuit voltage, V_{OC} (V)	0.40	0.32
Fill factor, *FF*	0.63	0.64
Conversion efficiency, η (%)	5.68	0.70

Table 2. J_{SC} derived from EQE measurements without and with InGaP/GaAs 2J filter

Wavelength range (nm)	J_{SC} derived from EQE (mA/cm^2)	
	No 2J filter (λ_1 = 350 nm)	With 2J filter (λ_1 = 780 nm)
λ_1 to 1170	25.78	5.45
870 to 1170	5.78	5.04