Recent HVPE Grown Solar Cells at NREL

Preprint

John Simon, Dennice M. Roberts, Jacob Boyer, Kevin L. Schulte, Anna Braun, Allison N. Perna, and Aaron J. Ptak

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Recent HVPE grown solar cells at NREL

John Simon, Dennice M. Roberts, Jacob Boyer, Kevin L. Schulte, Anna Braun, Allison N. Perna, and Aaron J. Ptak

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***Abstract*—In this work we present solar cells grown via hydride vapor phase epitaxy (HVPE) in NREL's dynamic HVPE reactor. We show single junction GaAs and GaInP solar cells with efficiencies as high as 25.5% and 15.2% respectively, and dual junction solar cells with an efficiency of 24.9%.**

Keywords*—*III-V solar cells, GaAs, GaInP, HVPE

I. Introduction

III-V materials have achieved the highest solar cell efficiencies in both single and multi-junction configurations[1]. Their strong absorption coefficients permit the formation of thin structures that are flexible and light, but still optically thick, enabling improved energy harvesting. Despite all of their advantages, III-Vs are limited to high-value applications such as space power primarily due to their high manufacturing costs [2]. Hydride vapor phase epitaxy (HVPE) has emerged as a potential lower cost alternative to current manufacturing processes of III-V solar cells [3, 4]. In this work, we highlight recent advances at NREL in the use of dynamic-HVPE (D-HVPE) to obtain high efficiency single and dual junction solar cells. D-HVPE uses multiple adjacent HVPE chambers to generate high quality interfaces needed for optoelectronic devices[5]. This has made it possible for us to demonstrate single junction GaAs[3] and GaInP[6] solar cells, tunnel junctions[7], and tandem devices[8]. We will show progress in improving the performance of these devices, enabling us to reach efficiencies >25% for single-junction GaAs devices.

II. Experimental Methods

Solar cells were grown in our dual growth chamber D-HVPE reactor[5] using pure Ga and In metal, HCl, AsH_3, and PH_3, with a H_2 carrier gas. Dilute H_2Se was the n-type dopant, while diethylzinc was the p-type dopant. Heterointerfaces were formed by rapid mechanical transfer of the substrate between the two growth chambers, with each chamber stabilized at a new growth condition (either a change in material, doping, or both). Substrates were (100) n+ GaAs doped with Si and offcut 6° towards the (111)A plane. The growth rates of the thick $Ga_{0.5}In_{0.5}P$ and GaAs absorber layers were 0.9 and 1.0 μm/min, respectively. The structures, shown in Fig. 1, were grown in an inverted fashion and processed using the method detailed in ref. [9]. Ni/Au front contact grids and Au metal were used for the front and back contacts respectively. External quantum efficiency (EQE) was measured on a custom instrument using LED illumination (470 and 850 nm) to limit each individual subcell in the tandem devices, allowing measurement of individual subcell EQE. The spectral reflectance was measured and used to calculate the internal quantum efficiency (IQE) of each cell. The solar cell one-sun AM1.5G current density-voltage (*J-V*) curves were measured under a calibrated spectrum using separate reference cells for each cell. All simulator measurements were certified by the PV performance characterization team at NREL.

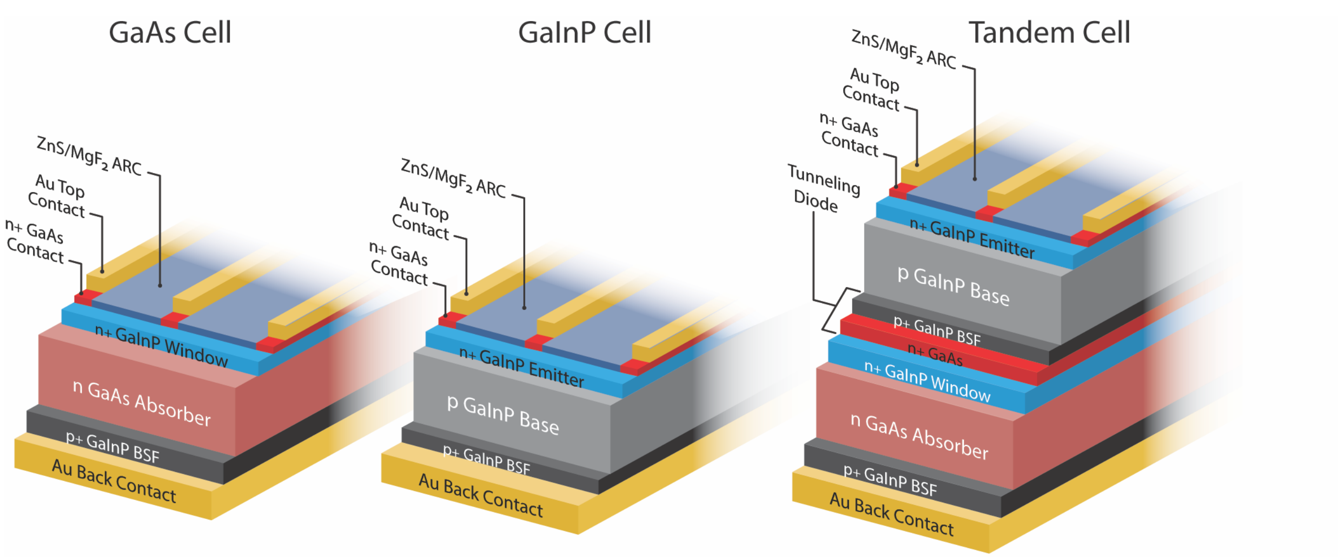

Fig 1. Structure of GaAs (left), GaInP (middle) and tandem (right) cells used in this work.

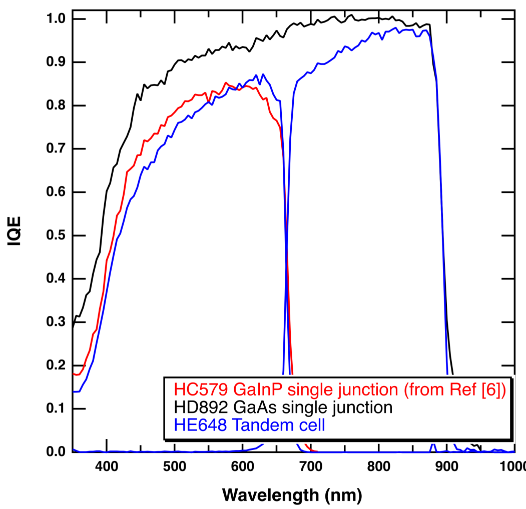

Fig 2. IQE of GaInP (red), GaAs (black), and a GaInP/GaAs tandem cell (blue) grown by D-HVPE.

III. Results

Fig. 2 shows the IQE of each type of cell. The near unity IQE of the single junction GaAs cell near the bandedge showcases the high collection efficiency of the D-HVPE devices. Both the GaInP cell and the tandem device collection is limited by the unpassivated GaInP emitter (see Fig. 1).

Table I shows a summary of the certified solar cell measurements. The highest GaAs and GaInP single junction cell efficiencies achieved are 25.5% and 15.2%[6], respectively. Fig. 3 shows the certified *J-V* characteristics. The dual junction tandem devices, limited by the top cell current[10], achieved an efficiency as high as 24.9%.

TABLE I. Certified One-Sun Solar Cell Data

Cell	*Type*	*Voc (V)*	*Jsc (mA/cm²)*	*FF (%)*	*η (%)*
HD892	GaAs	1.08	27.8	85.1	25.5
HC579[a]	GaInP	1.35	13.0	86.7	15.2
HE648	Tandem	2.34	12.6	84.3	24.9

a. From [6]

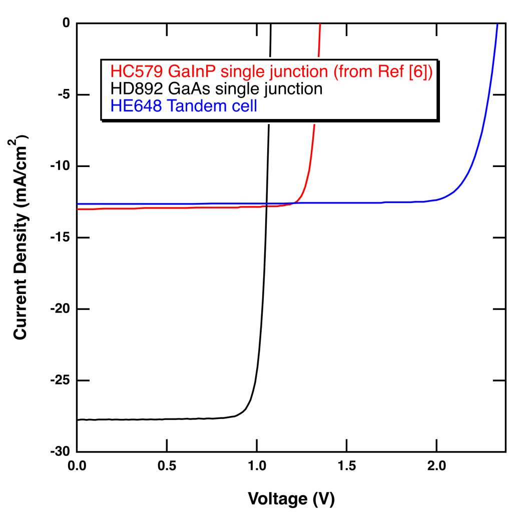

Fig 3. Certified current density-voltage measurements under AM1.5G conditions for GaInP (red), GaAs (black), and a GaInP/GaAs tandem cell (blue) grown by D-HVPE.

IV. Conclusion

We produced high efficiency solar cells via D-HVPE. We obtained certified efficiencies as high as 15.2% and 25.5% for single junction GaInP and GaAs solar cells, respectively. Dual junction GaInP/GaAs solar cells show efficiencies as high as 24.9% despite the lack of front-surface passivation. In the future, we will use higher bandgap materials[11, 12] to improve the top GaInP solar cell passivation to enhance the efficiency of both the single junction top cell and tandem devices.

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