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Towards III-V / Si tandem solar cells

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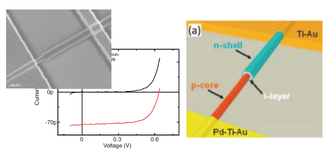
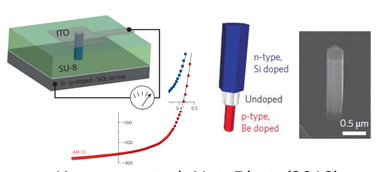
NW-based solar cells

Single nanowire device

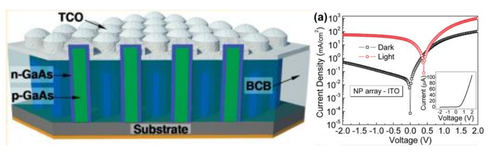


Colombo et al, Appl. Phys. Lett. (2009)



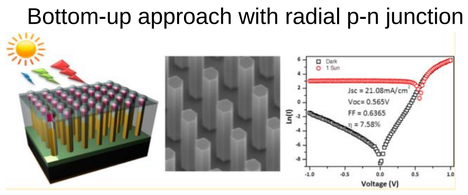
Krogstrup et al, Nat. Phot. (2013)

Nanowire arrays device



Jsc = 17.6 mA/cm²
Voc = 0.39V
FF = 37%
η = 2.54%
G. Mariani et al, Nano Lett. (2011)

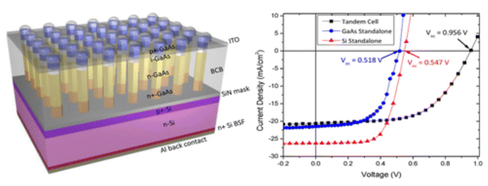
Bottom-up approach with radial p-n junction



M. Yao et al, Nano Lett. (2014)

Bottom-up approach with axial p-i-n junction

Tandem solar cells with nanowire arrays

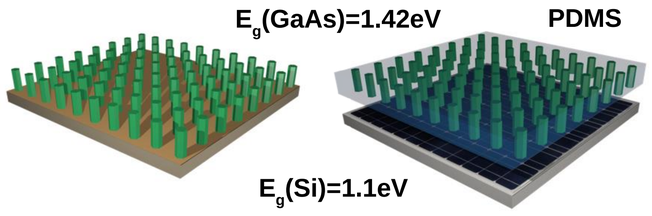


M. Yao et al, Nano Lett. (2015)

GaAs axial NW / Si tandem solar cell realization

Objectives

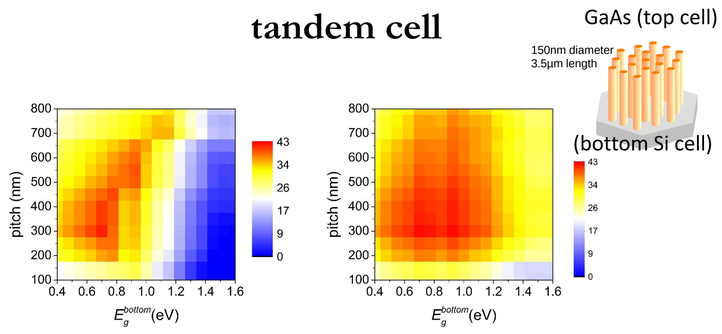
- Tandem **- Mechanically Stacked**



Advantages:
Monolitic integration.
Disadvantages:
Series connection.

Advantages:
Parallel connection.
Disadvantages:
Additional processing.

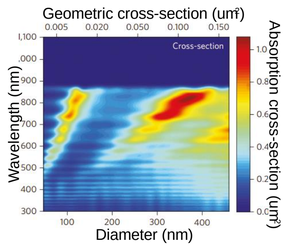
Evaluation of c-Si / GaAs nanowire tandem cell



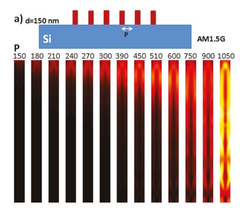
Mechanically stacked design offers more design freedom, higher theoretical efficiencies and advantage in using silicon as bottom cell

Nanowire properties

- Enhanced Absorption **- Reduced Material Consumption**

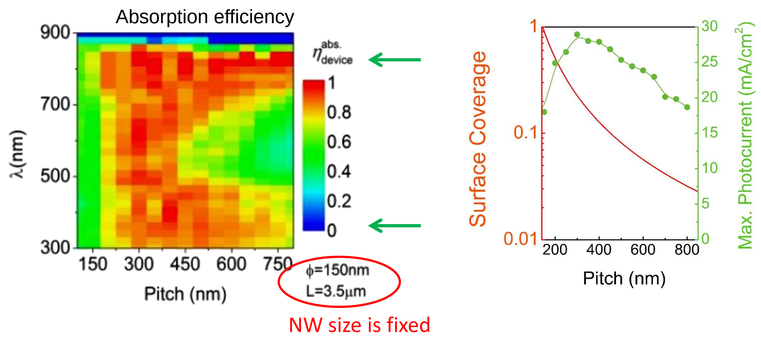


The absorption crossection can exceed up to 10x the geometrical crossection. Nanowire acts as natural light concentrator.



In radial PiN-junctions the full length of the nanowire is used for carrier generation and carrier extraction.

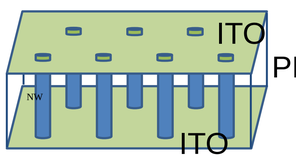
Light resonances and absorption in vertical NWs



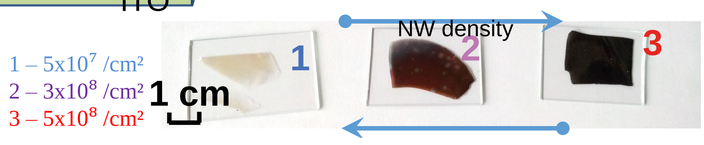
NW size is fixed

- At low pitch size, NW array performs as a thin film
- With increasing pitch size, NW array leads to boost of absorption efficiency, finally ending in resonance given by NW diameter

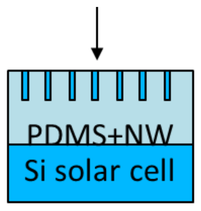
Optical properties of PDMS-NW

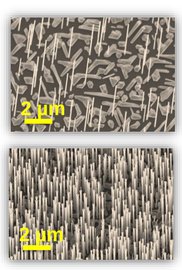


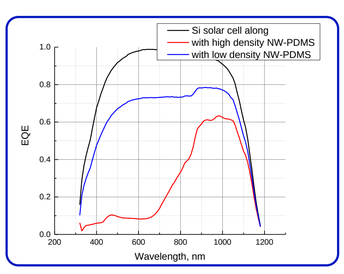
NW embedded in the PDMS and peeled from the substrate



Transmittance



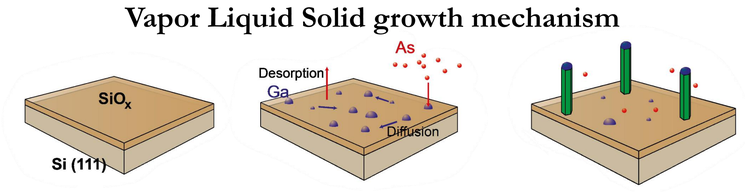




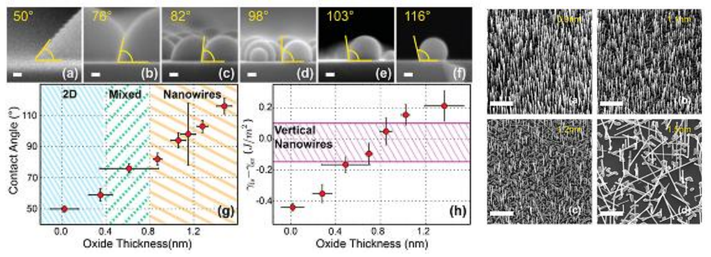
GaAs NW growth on Si substrates

Verticality issues due to the mismatches between materials (polarity, lattice)

Vapor Liquid Solid growth mechanism



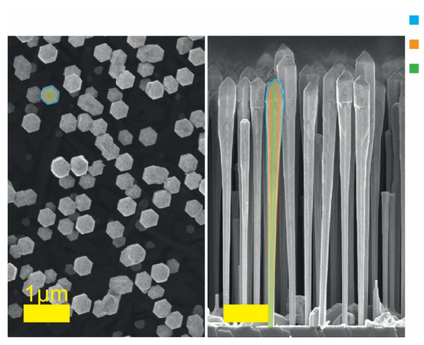
Controlling the verticality by controlling the SiOx thickness

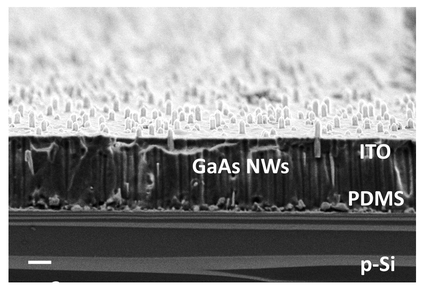


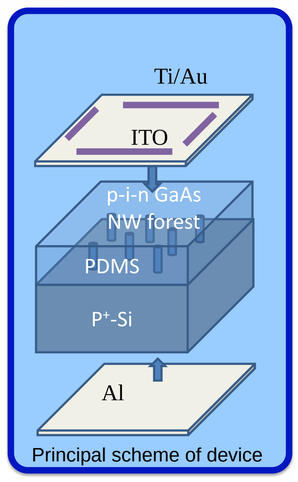
Matteini et al, Crystal Growth and Design (2015)

Uccelli et al, Nano Letters (2011)

Device design



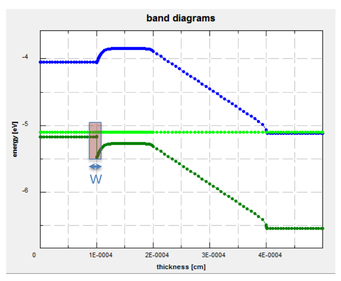




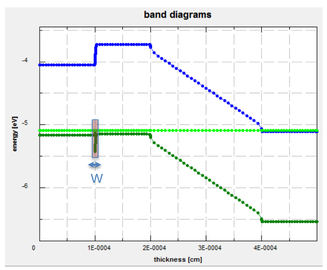
Principal scheme of device

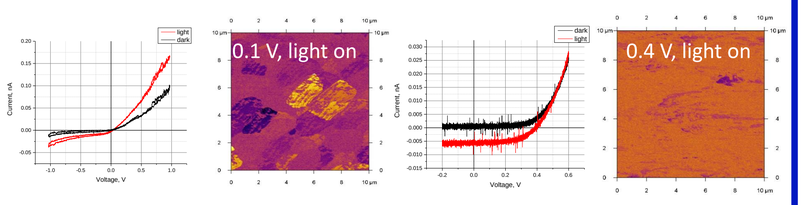
Doping level of the core

Low doping



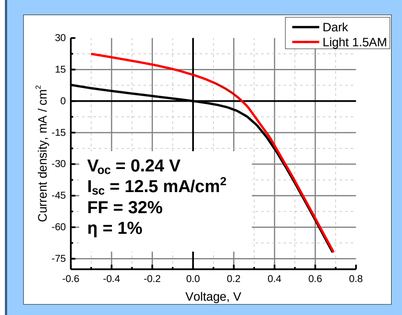
High doping





1. With higher doping of the base, the width (W) of hetero-barrier becomes smaller and tunneling is possible
2. Higher concentration increases internal electric field, leading to higher Voc

First device prototype on Si

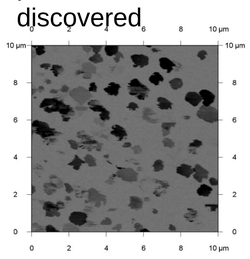


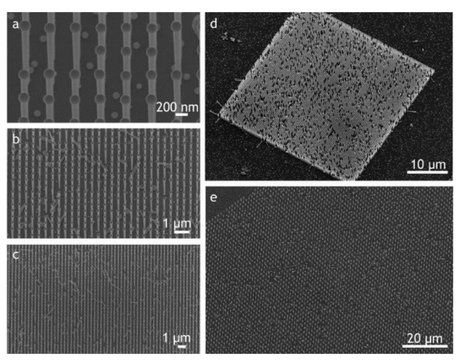
Causes of low efficiency and bad I–V characteristics:

- NW inhomogeneity
- Core doping level
- Surface recombination

Addressing NW Inhomogeneity

Conductive AFM current map – high inhomogeneity in NWs performances discovered

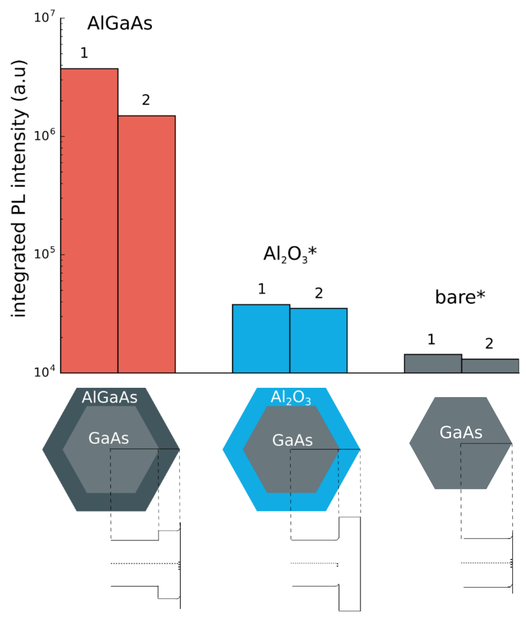




Surface passivation

Strong surface recombination affects on Voc due to high surface to volume ratio

PL measurement for different passivation layers



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