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Integration of GaAs nanowires on Si for photovoltaic applications

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GaAs vs Si

Si | **GaAs**


Si — Advantages:
- Low cost
- Bigger wafers (8 inch)

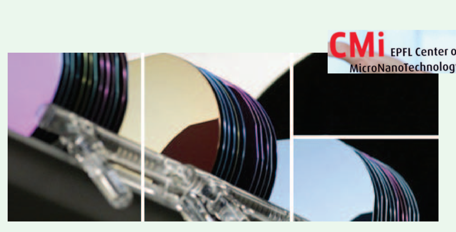
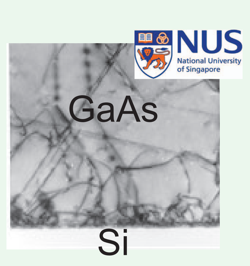
Disadvantages:
- Low Mobility
- Indirect band gap

Fang et al J. Appl. Phys. (1990)

GaAs — Advantages:
- Direct band gap
- High mobility

Disadvantages:
- Expensive
- Poor mechanical and thermal properties

GaAs on Si

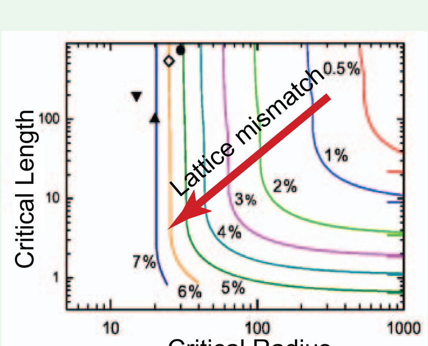
Advantages:

- Superior optical and electrical properties (GaAs).
- Good mechanical and thermal properties (Si).
- Well established technology (Si).

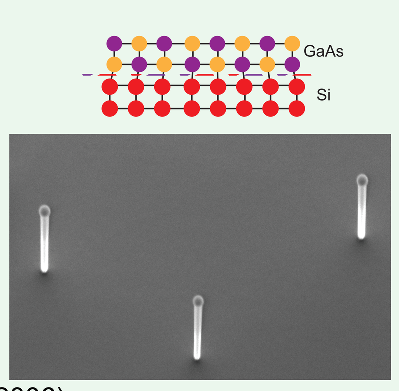
Challenges:

- Different thermal expansion coefficient.
- Polar semiconductor with non polar.
- Different lattice constants (4%).

Method:



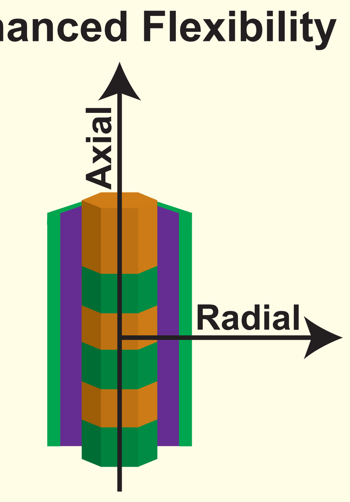
Glas and Harmand, Phys. Rev. B, (2006)



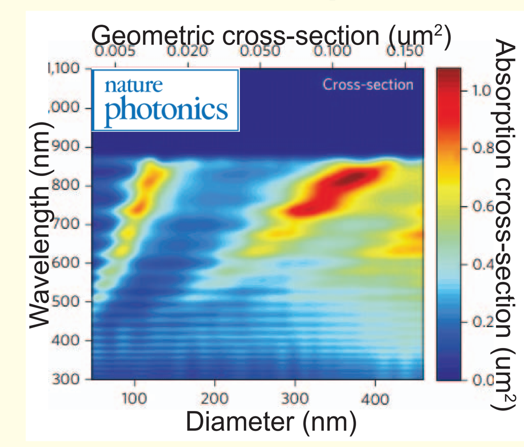
By combining GaAs and Si in a planar fashion the 4% lattice mismatch leads to cracking and defect-formation. The nanowire geometry allows elastic release of the stress thanks to its radial confinement.

Nanowire's Properties

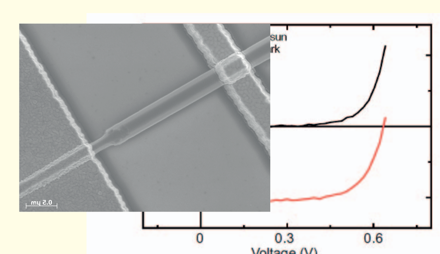
- Enhanced Flexibility



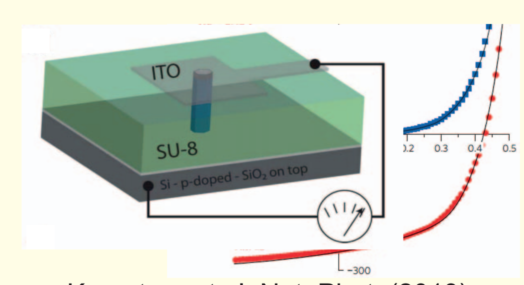
- Novel Properties



PiN Junction:



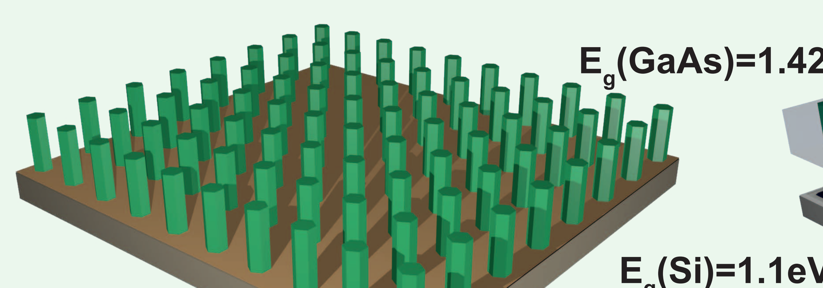
Colombo et al, Appl. Phys. Lett. (2009)



Krogstrup et al, Nat. Phot. (2013)

GaAs/Si Dual Junction

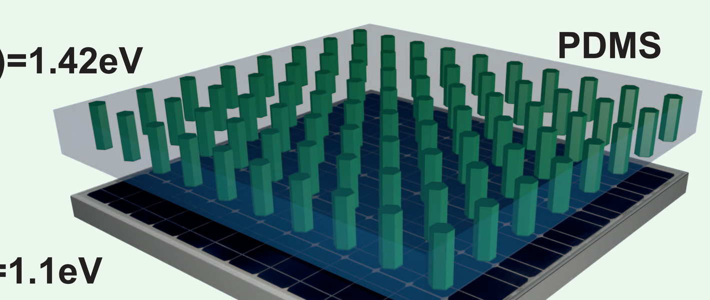
Tandem



Advantages:
The GaAs nanowire PiN junction is directly grown on the Si junction providing monolitic integration as grown.

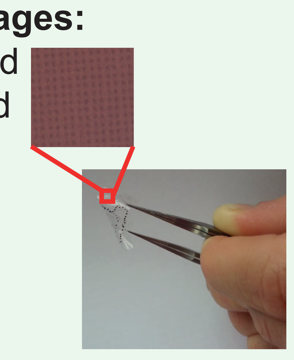
Disadvantages:
Since the two junctions are in series the current generated from the GaAs junction goes through the Si junction, that act as bottleneck.

Mechanically Stacked



Advantages:
The GaAs junction and Si junction are in parallel, avoiding the current limitation problem.

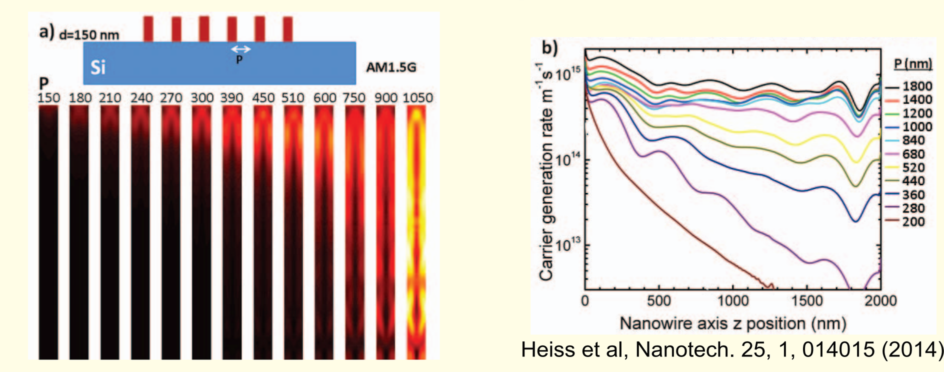
Disadvantages:
The GaAs junction need additional stripping and contacting step to put them in parallel.



Kandala et al, phys. stat. sol. (a), 1-6 (2008)

Nanowires' Ensemble

Novel Properties

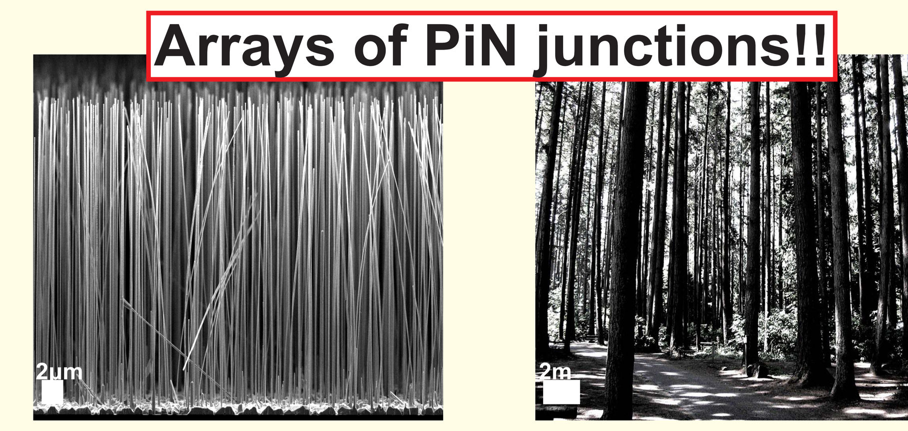


Heiss et al, Nanotech. 25, 1, 014015 (2014)

The nanowires' density controls the concentration of the electric field into the nanowires and the carrier generation rate along the nanowire axis.
Achieving control over density is a key step for efficient light harvesting.

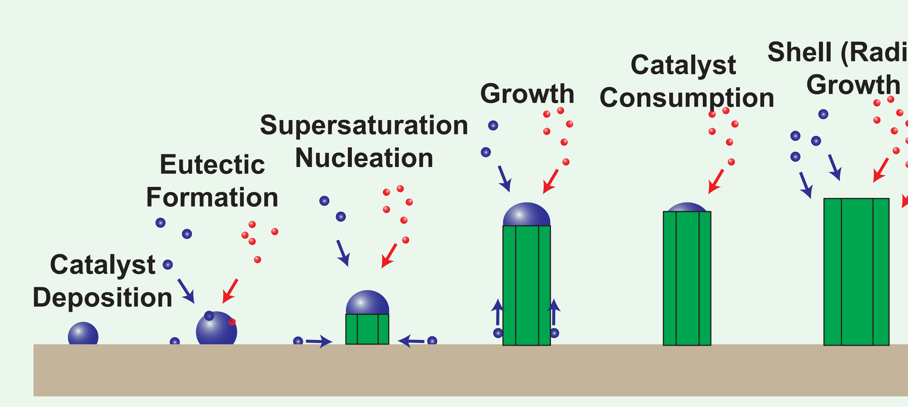
Goal:

Arrays of PiN junctions!!



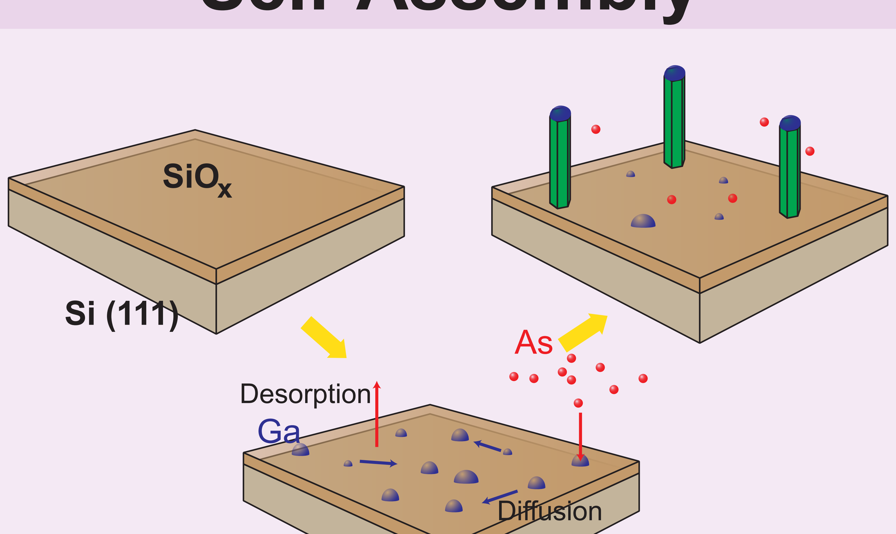
Mechanism

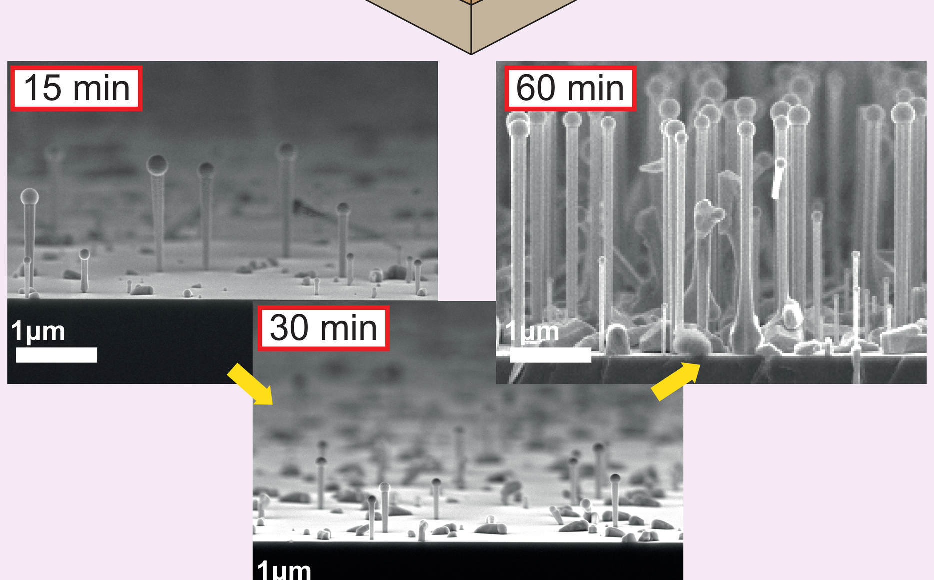
Vapor Liquid Solid (VLS)



The catalyst is liquified by eutectic formation. The liquid droplet acts as reservoir until supersaturation is reached, triggering nucleation and growth.

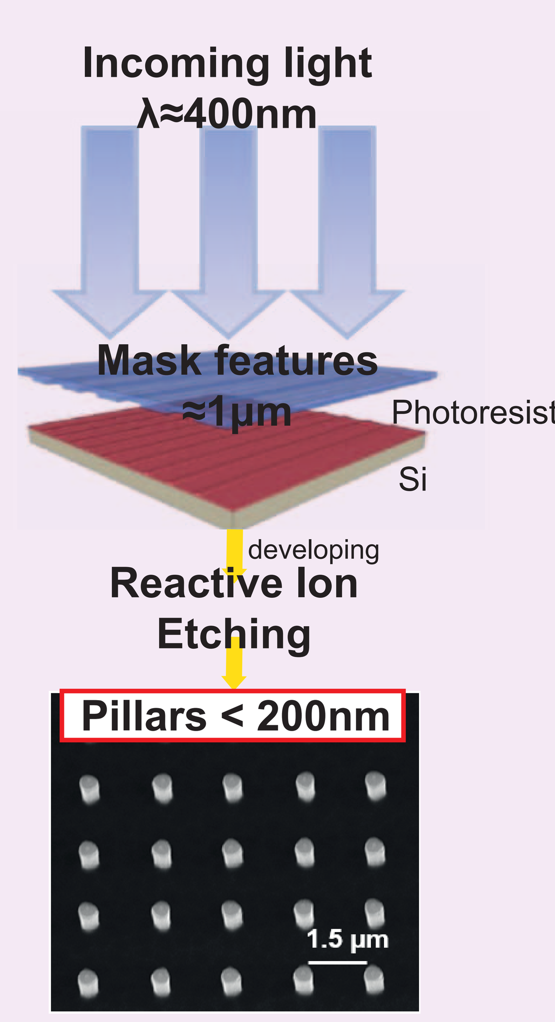
Self-Assembly



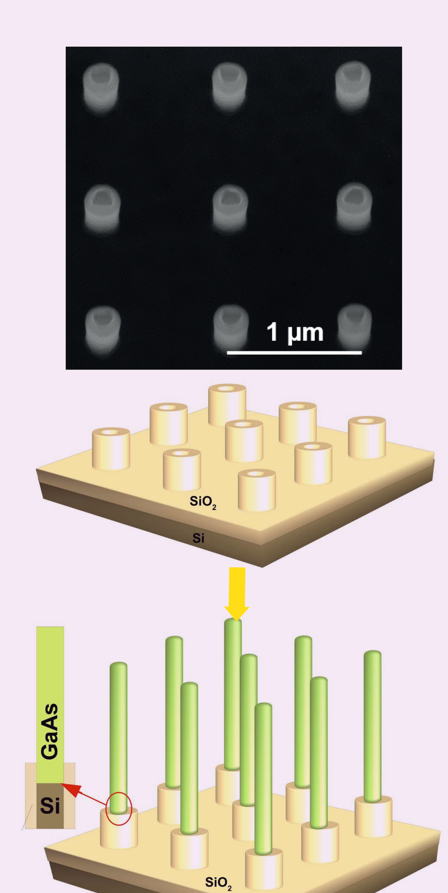


In this approach the process is self-catalyzed by Ga. No catayst-predeposition is needed since Ga naturally form the liquid droplets, due to its lower vapor pressure compared to As.

Phase-Shift Photolithography

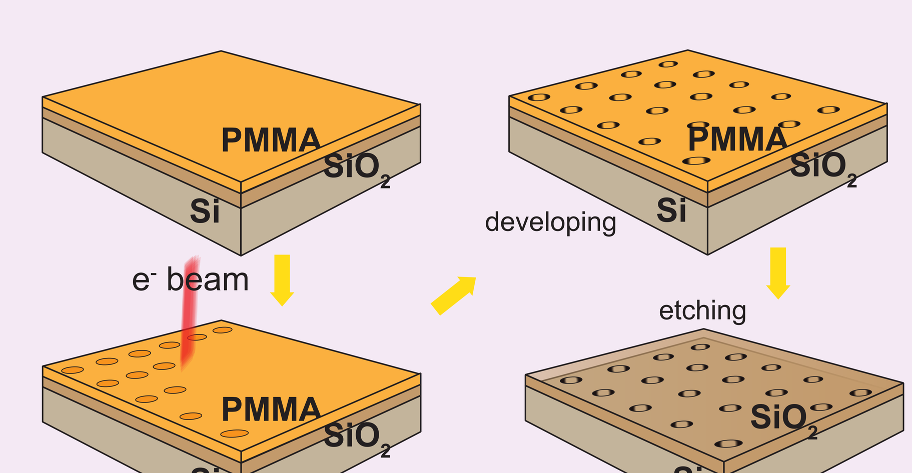


Phase shift photolitography allows sub-wavelength precision.

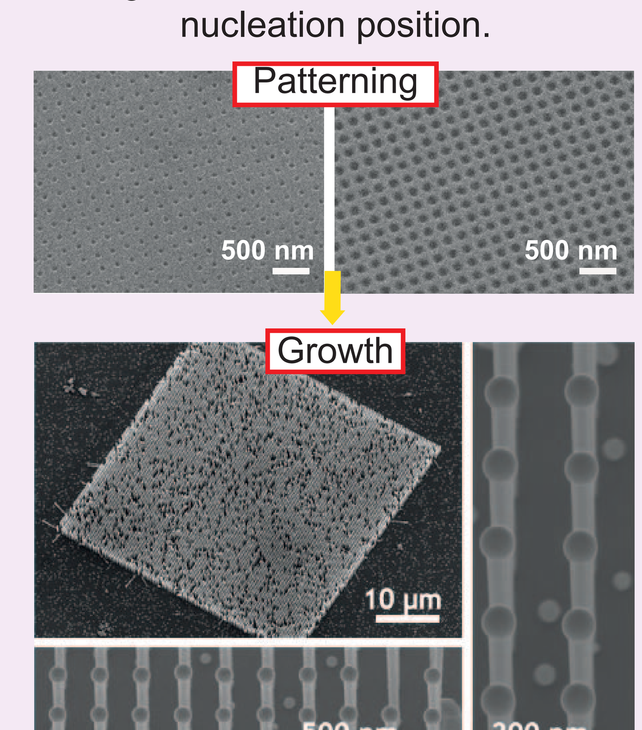


The Si pillars are then used to make SiO_2 tubes, templates for nanowire growth.

e⁻- Beam Lithography



Patterning the substrate allows to control the nucleation position.



Acknowledgments

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