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Periodic Semiconductor Nanowire Array for High Efficiency Solar Cells

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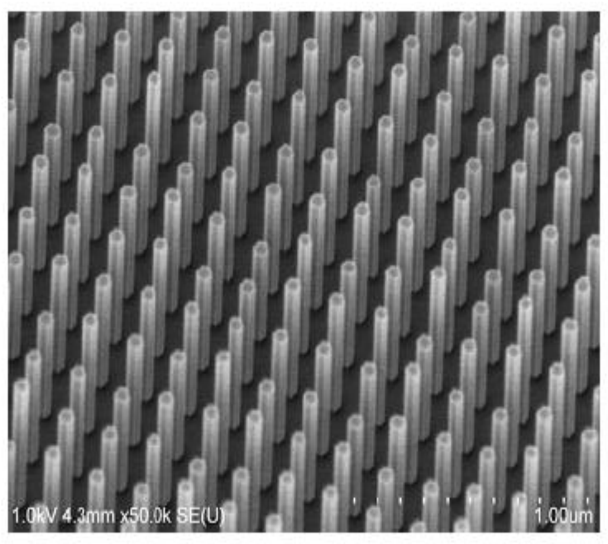
Introduction

- Semiconductor nanowire structures have attractive anti-reflection and light-trapping properties.
- Absorption properties depend on the nanowire array's structural parameters.[1,2]
- Nanowire heights can have important implications for cost

GaAs nanowires grown by Zhou/Dapkus groups (USC)

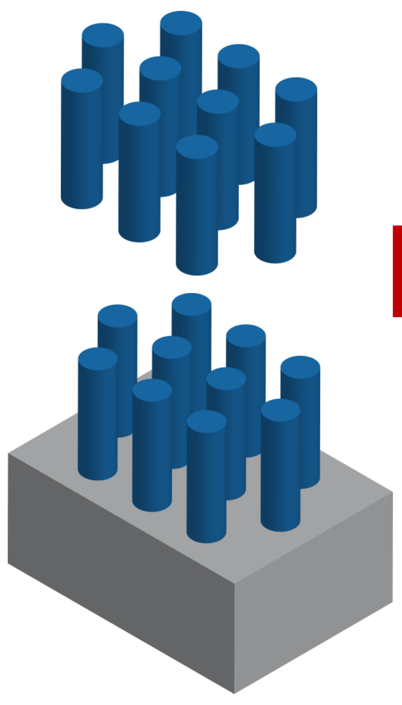


Methods

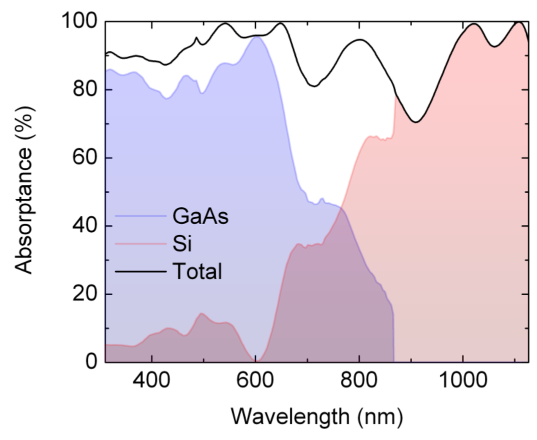
Optical modeling

Free standing nanowire

Nanowire on substrate



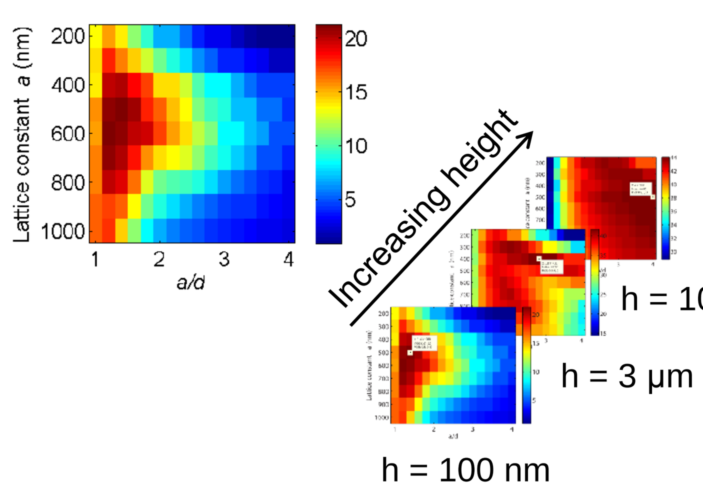
Full-vector simulation to get absorption



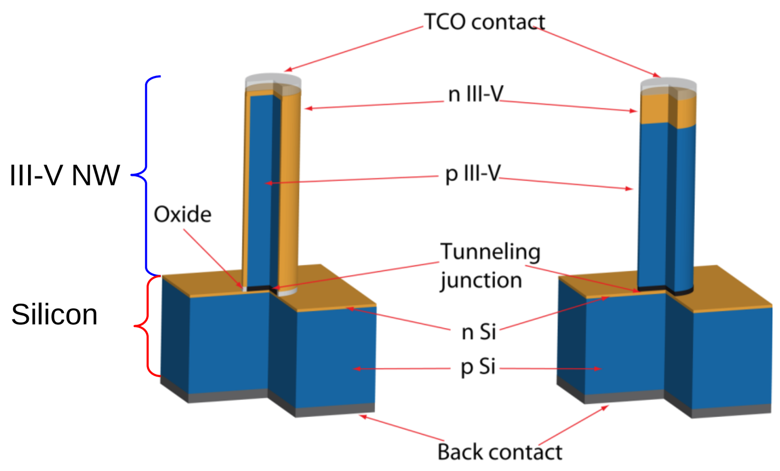
$$\nabla \cdot \varepsilon(\mathbf{r})\mathbf{E} = 0 \qquad \nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad \nabla \times \mathbf{B} = \mu_0 \varepsilon(\mathbf{r}) \frac{\partial \mathbf{E}}{\partial t}$$

Optimized for highest efficiency by changing parameters (*a*,*d* and *h*)



Device simulation

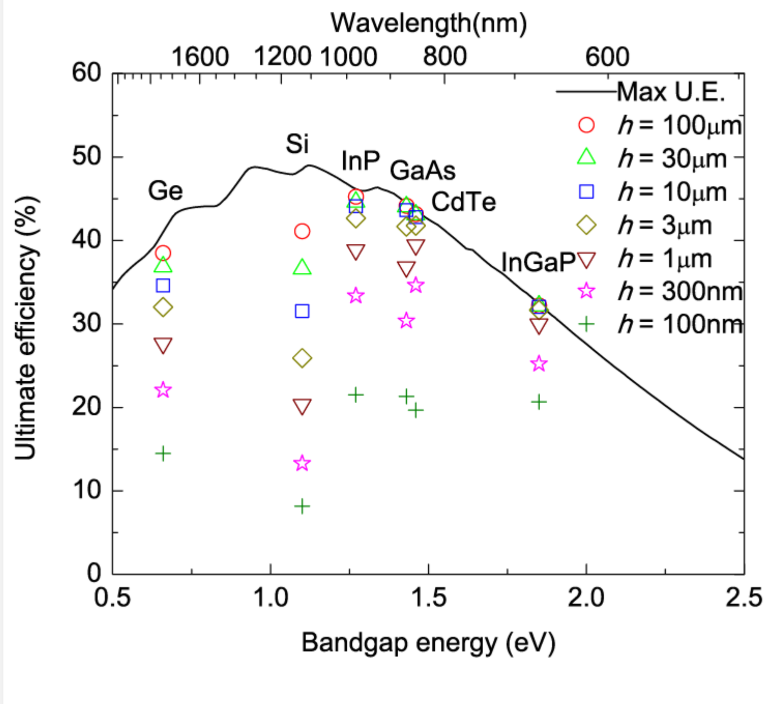


$$\nabla \cdot (\varepsilon \nabla \phi) = -q(p - n + N_D - N_A) - \rho_{trap}$$

$$\nabla \cdot \mathbf{J}_n = -\nabla \cdot \mathbf{J}_p = -qG + qR$$

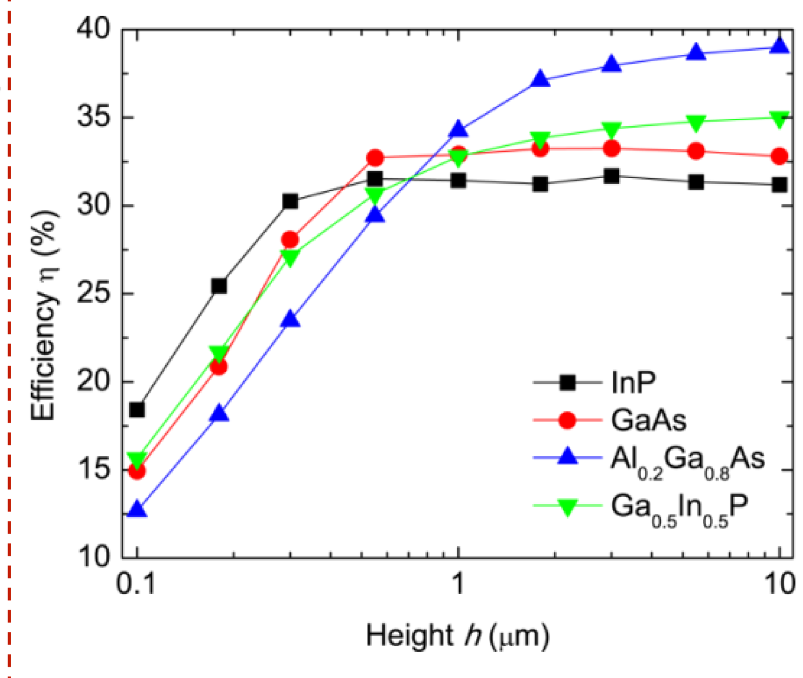
Results

Free standing nanowire



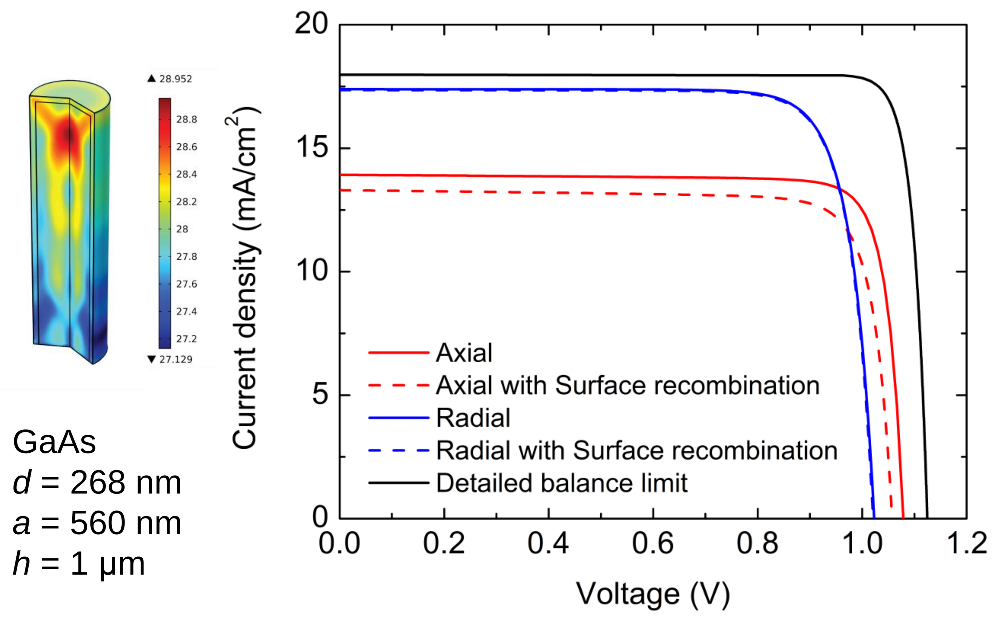
For direct band gap material, nanowire structure with 3 µm height provides close to limiting efficiency.[2]

Nanowire on silicon tandem cell



Non-optimal bandgap material can still achieve detailed-balanced efficiency as high as 30% with 1 µm wire height.[3]

Carrier generation rate and JV curve



Junction in nanowire can collect carrier efficiently.[3]

Conclusion

- Direct band gap free-standing nanowire arrays with 3-5 µm can have Near-unity absorption
- Nanowire on silicon tandem cell has larger than 30% theoretical efficiency
- Junction need to be optimized to have larger carrier collecting efficiency

References

1. Chenxi Lin and Michelle L. Povinelli, Opt. Express **17** (22), 19371 (2009).
2. Ningfeng Huang, Chenxi Lin, and Michelle L. Povinelli, Journal of Optics **14** (2), 024004 (2012).
3. Ningfeng Huang, Chenxi Lin, and Michelle L. Povinelli, in preparation

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