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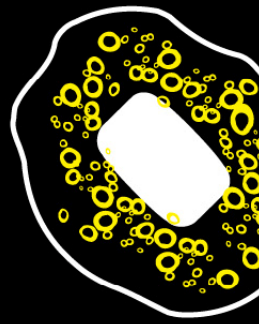
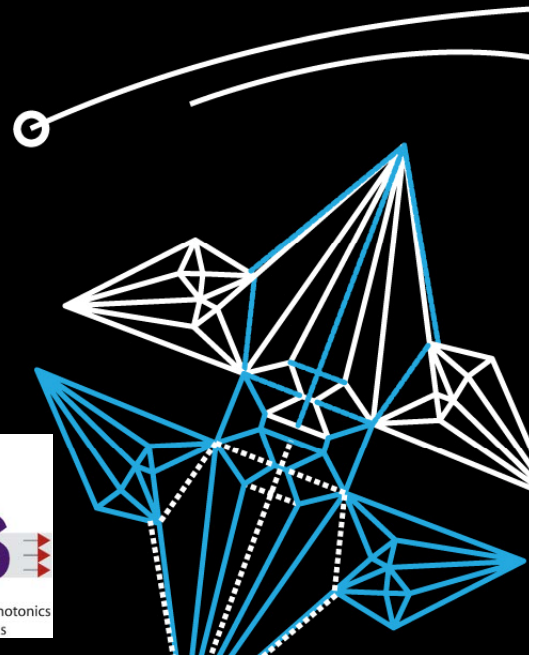


Role of junction depth in light emission from silicon p-i-n LEDs

G. Piccolo, A. Sammak, R.J.E. Hueting, J. Schmitz and L.K. Nanver.



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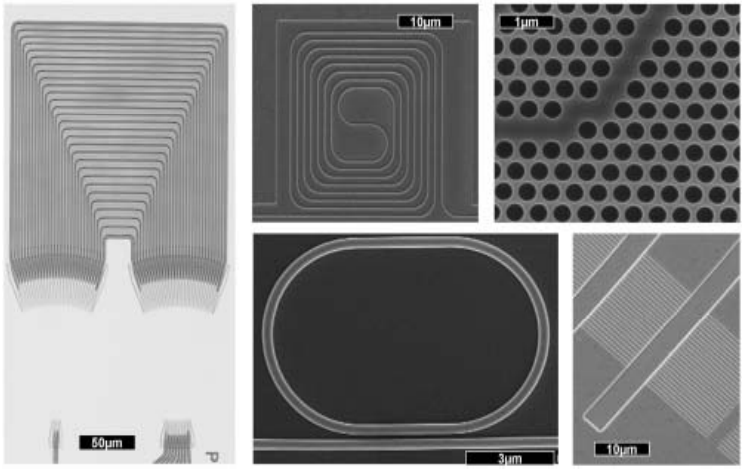
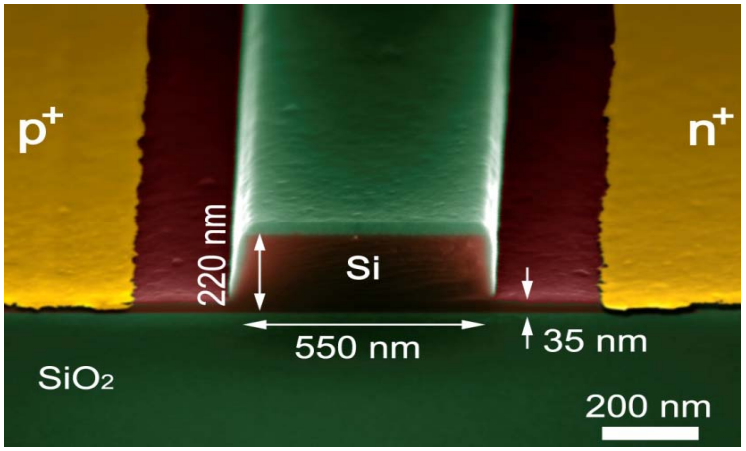
Merging Electronics and Micro & Nano-Photonics in Integrated Systems

INTEGRATION OF PHOTONICS ON CMOS PLATFORM

CMOS = SILICON

- ✓ Waveguides
- ✓ Amplifiers
- ✓ Multi- and demultiplexers
- ✓ Resonators
- ✗ Light emitting device



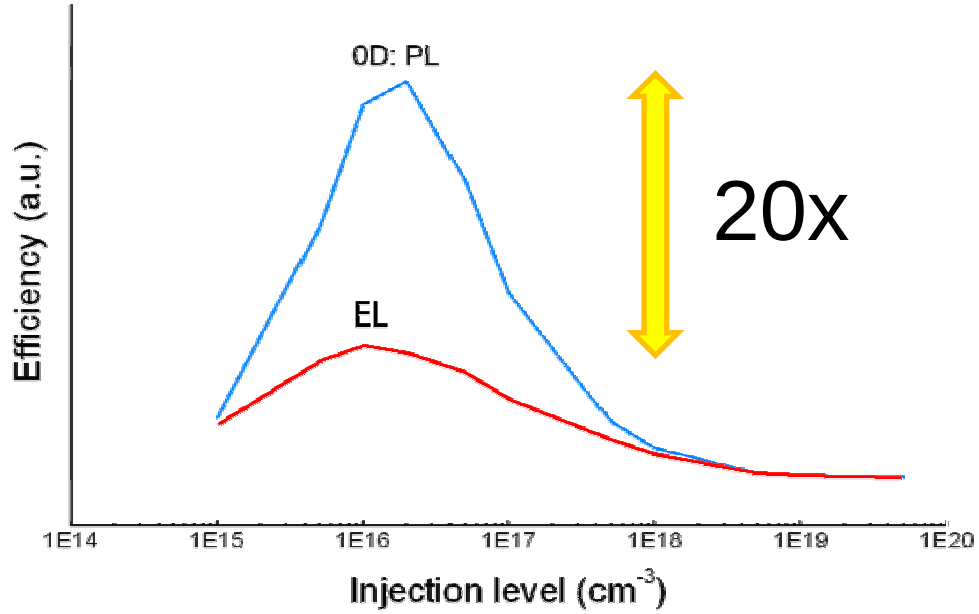


Images: Ghent University - IMEC and IBM

HOW TO IMPROVE LIGHT EMISSION FROM SILICON?

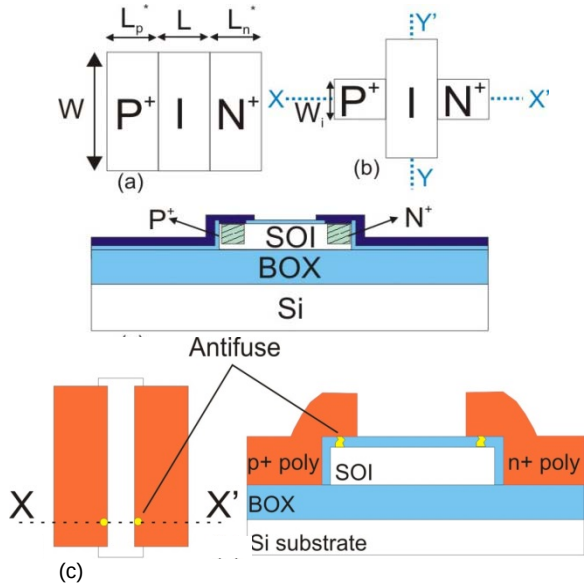
Electrical stimulation results in higher non-radiative recombination

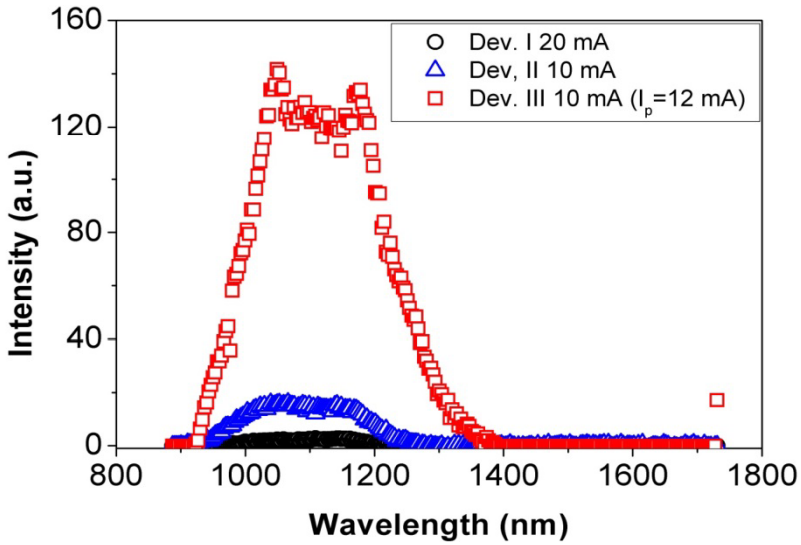
Carrier injection causes loss in efficiency

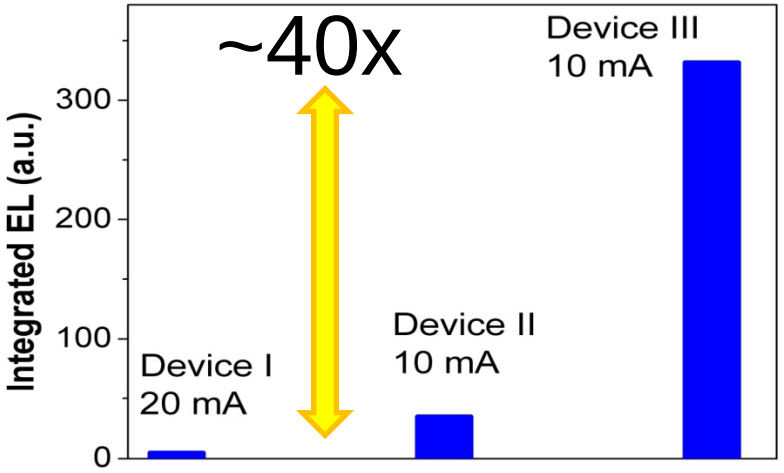


Exploit carrier injection properties to fill the gap

PREVIOUS WORK ON INJECTORS PROPERTIES



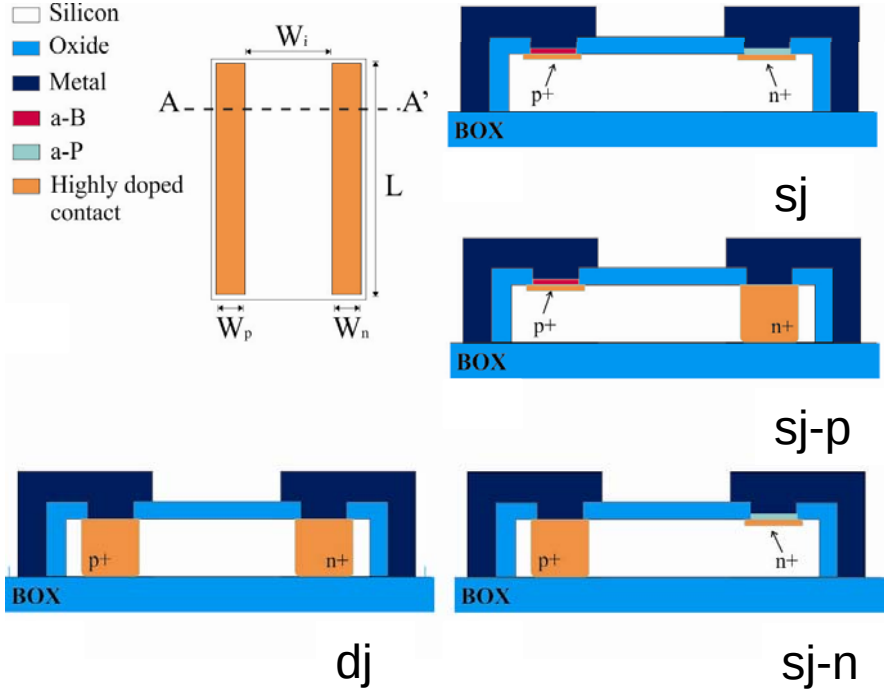




- DEV. I: reference (a)
  W_i = 100 µm
- DEV. II: reduced injector (b)
  W_i = 10 µm
- DEV. III: nano-size injector (c)

ROLE OF JUNCTION DEPTH – EXPERIMENTAL MATERIAL

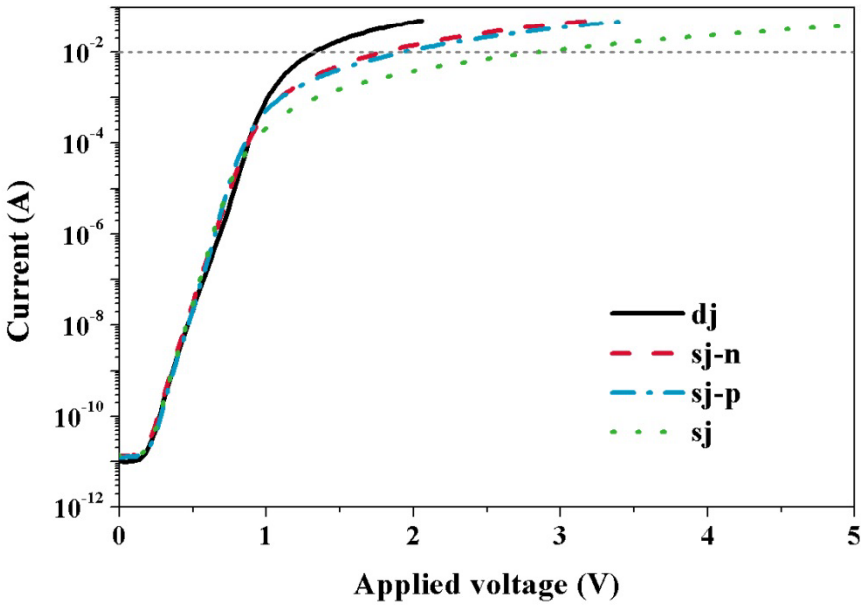
- Simple structure: lateral p-i-n diode
  Full CMOS compatibility
- High purity SOI substrates (~300 nm)
  Low SRH recombination
- All-around passivated surface
  Low surface recombination
- Ultra-shallow junctions
  (RP)CVD B or P



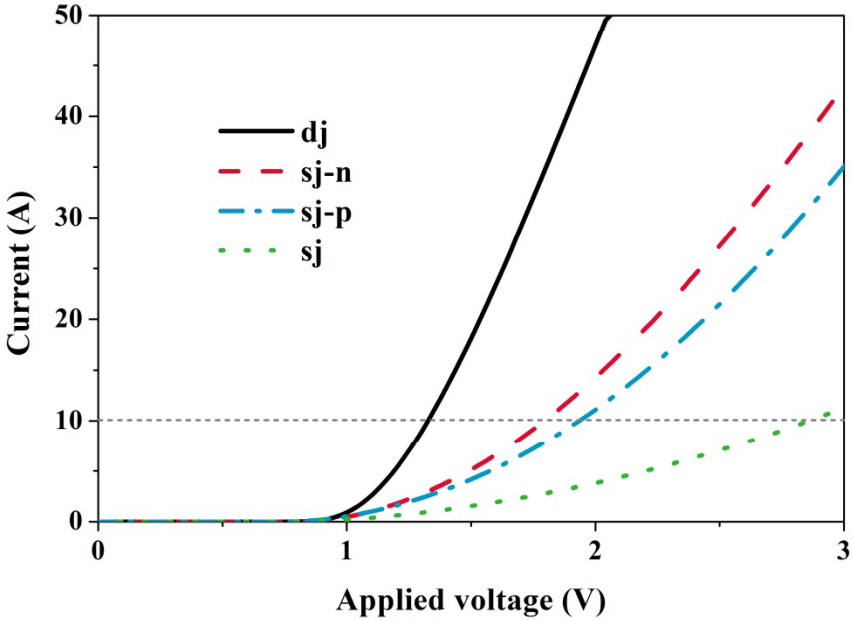
W_i= 20 µm
$W_p = W_n$= 5 µm
L = 100 µm

EXPERIMENTAL DATA: ELECTRICAL BEHAVIOR

Semi-logarithmic scale



Linear scale

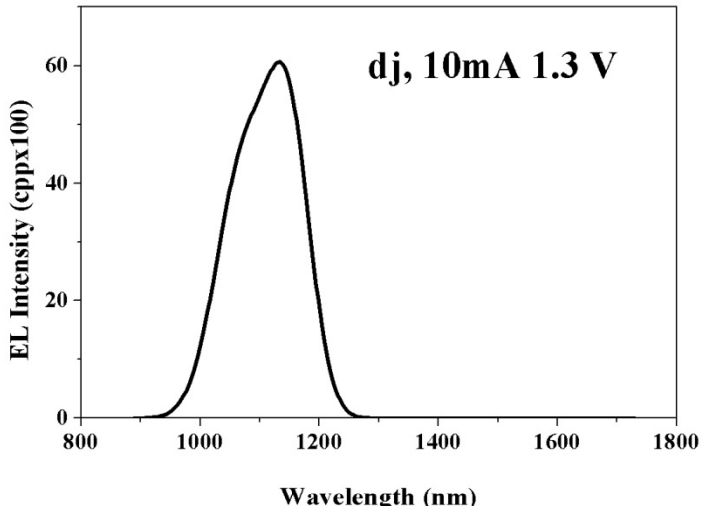


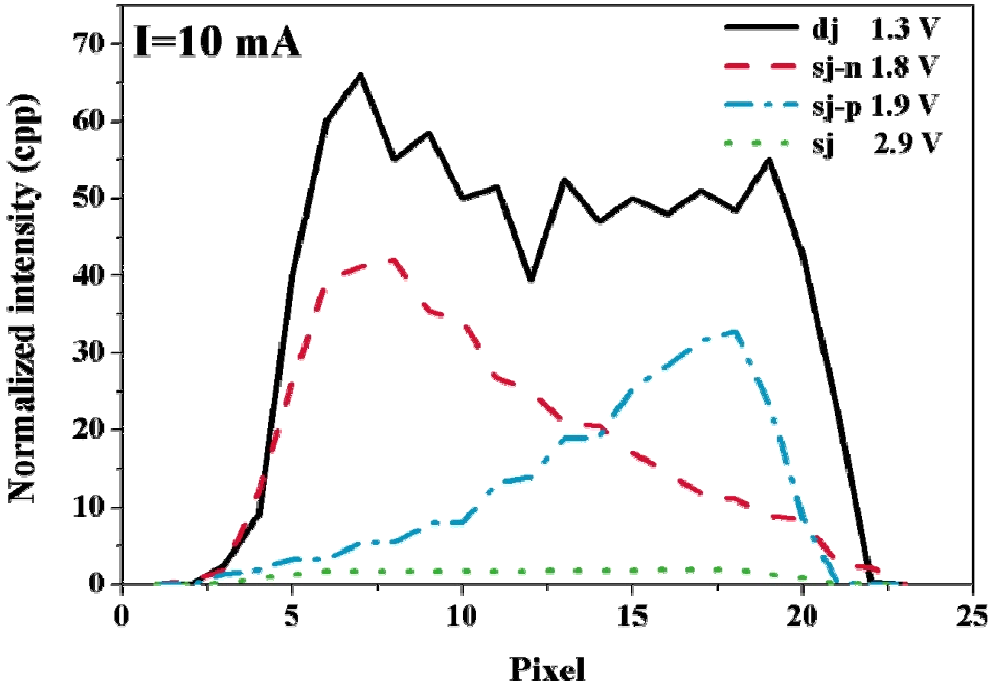
Ultra-shallow junctions result in higher series resistance (lower current)
Effect more pronounced on p^+-i junction

MEASURED LIGHT EMISSION

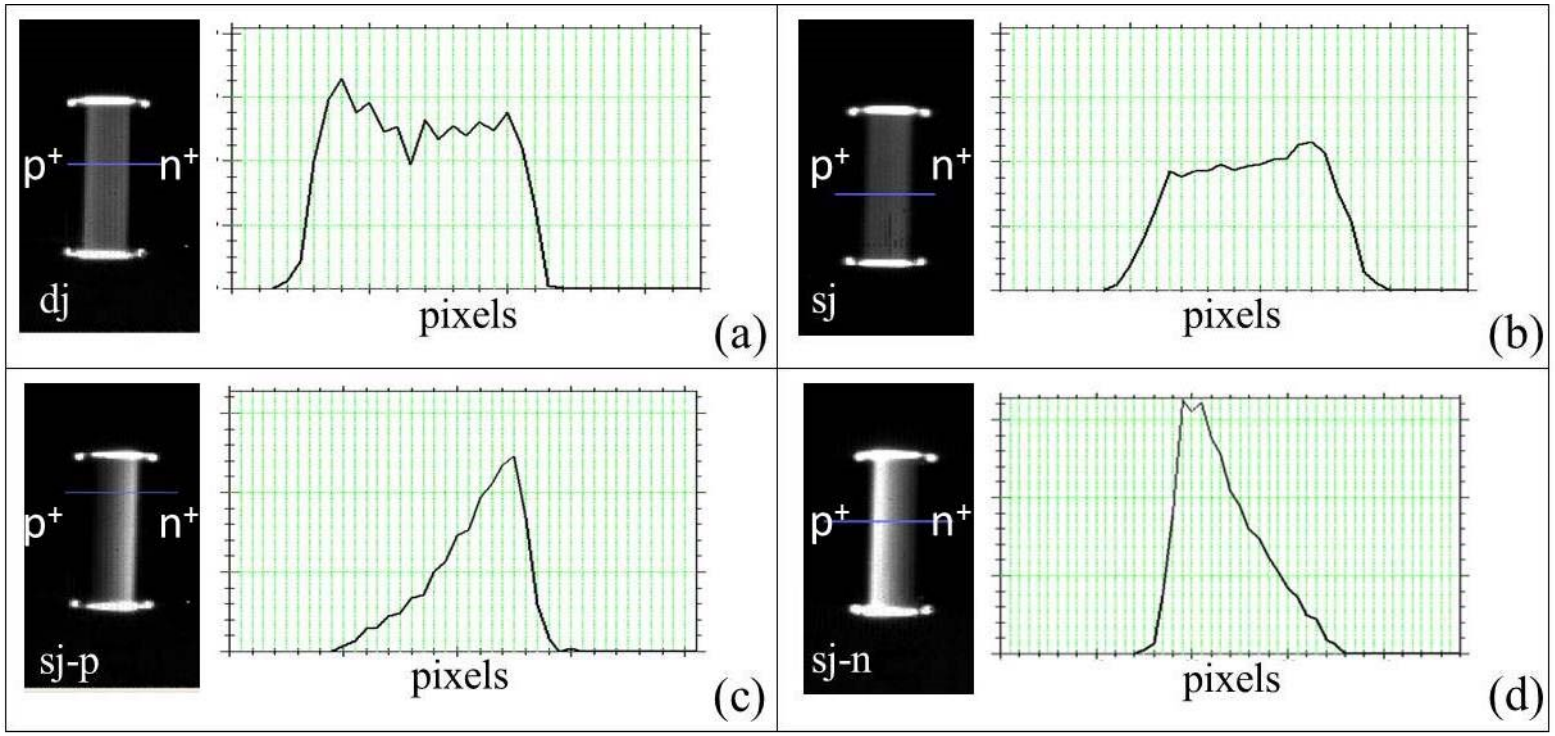
Silicon band-to-band emission:
spectral peak @ ~1150 nm

Light intensity follows current intensity.



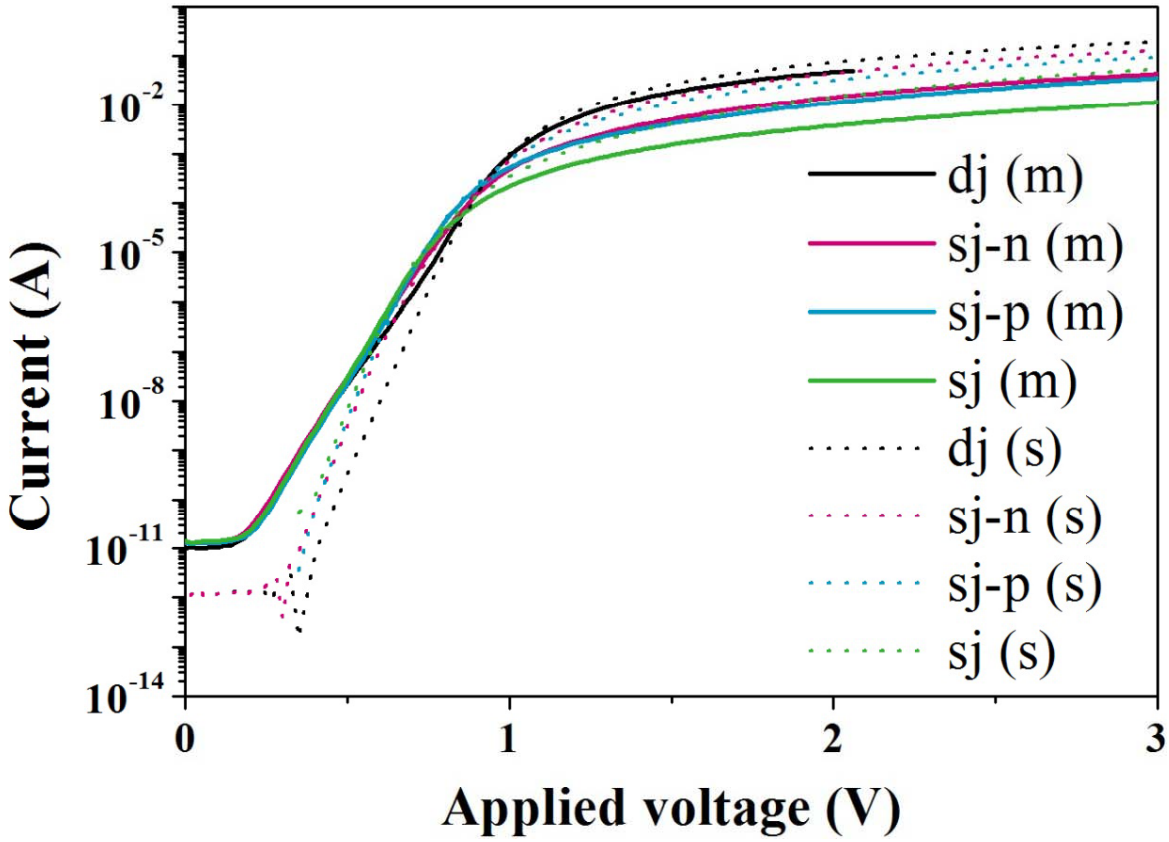


SPATIAL RESOLUTION OF LIGHT EMISSION



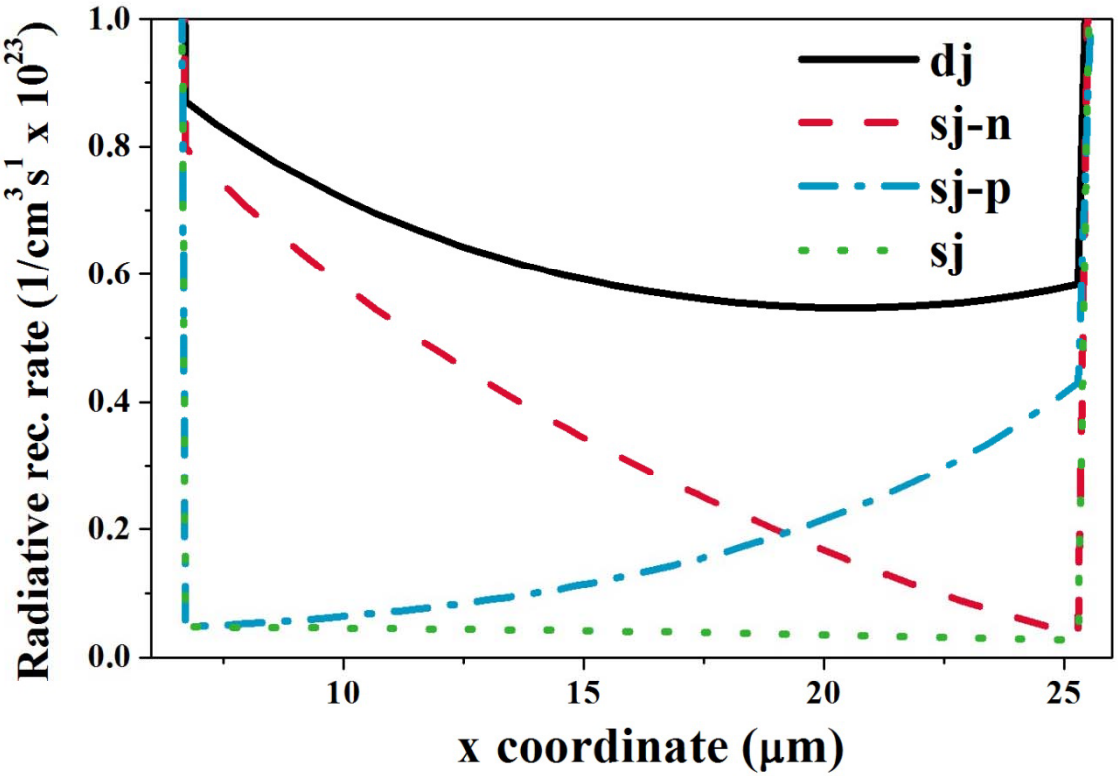
Light emission gradually decreases toward shallow junction side

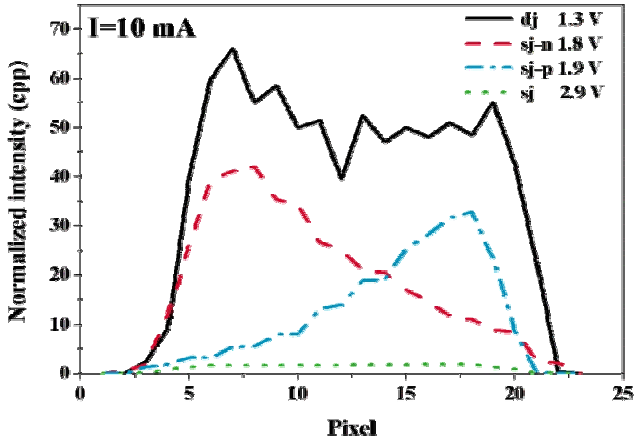
2D SIMULATIONS



Difference to ascribe to contact resistance

SIMULATED RADIATIVE RECOMBINATION



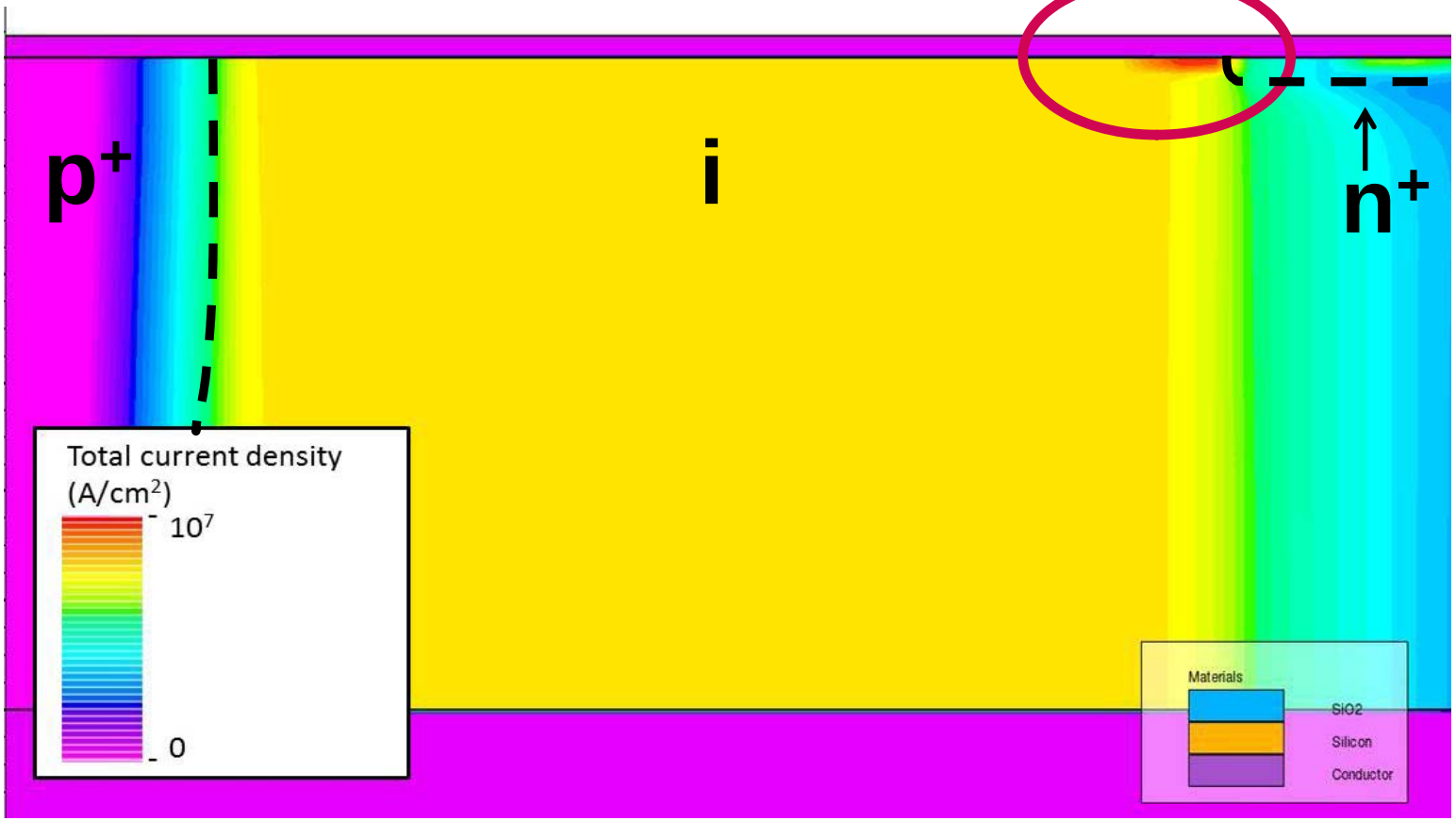


Actual measurement

Good agreement with experimental light emission

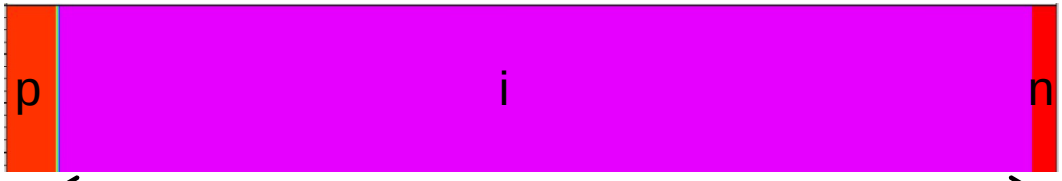
EVIDENCE OF CURRENT CROWDING

Consistent with observed increase in R_{series}



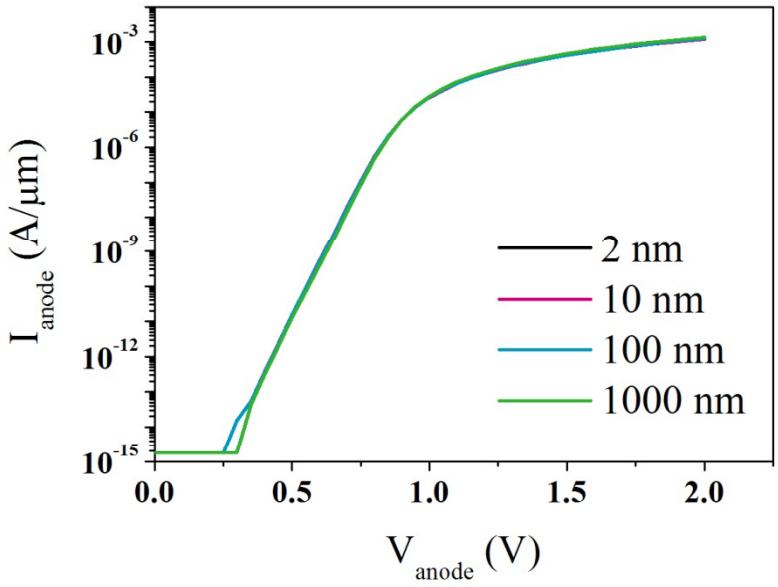
1D SANITY CHECK: NO VISIBLE EFFECT

p^+ side is a deep junction

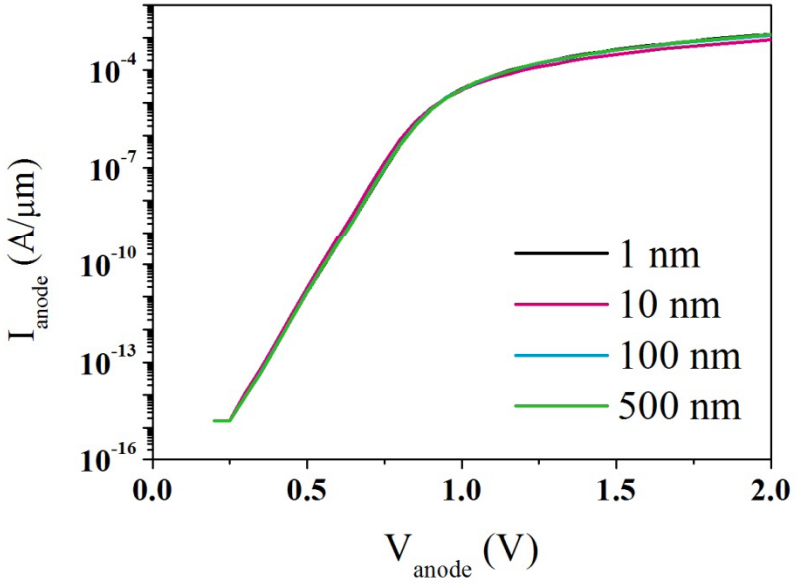


n^+ side is the variable

W_i is kept constant



Variable distance between junction and electrode



Variable doping profile

CONCLUSIONS

Demonstrated role of junction depth in light emission (lateral p-i-n devices):

- **Current crowding** is proved to be detrimental to light emission
- 2D simulation as support
- Other possible effects ruled out via 1D simulation

AKNOLEDGEMENT

The authors gratefully acknowledge the support of the Smart Mix Programme of the Netherlands Ministry of Economic Affairs and the Netherlands Ministry of Education, Culture and Science.

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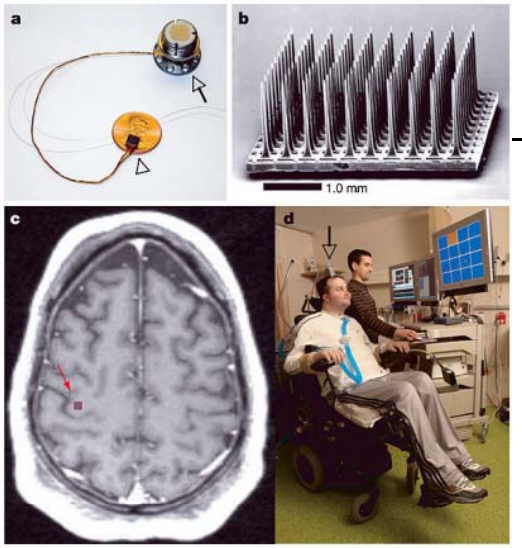
Any questions?

An example: the BrainGate® chip



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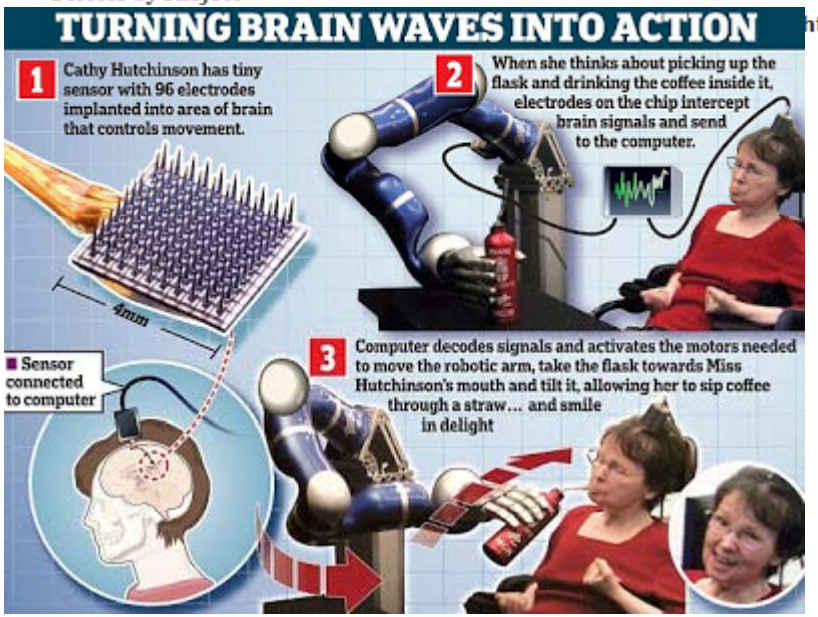


REQUIREMENTS

Non-toxic, reliable material and wireless connection between deep implant and the controller on the skull to avoid infections

Source: http://www.braingate.com/science.html

THINNED ACCESS SILICON LEDs

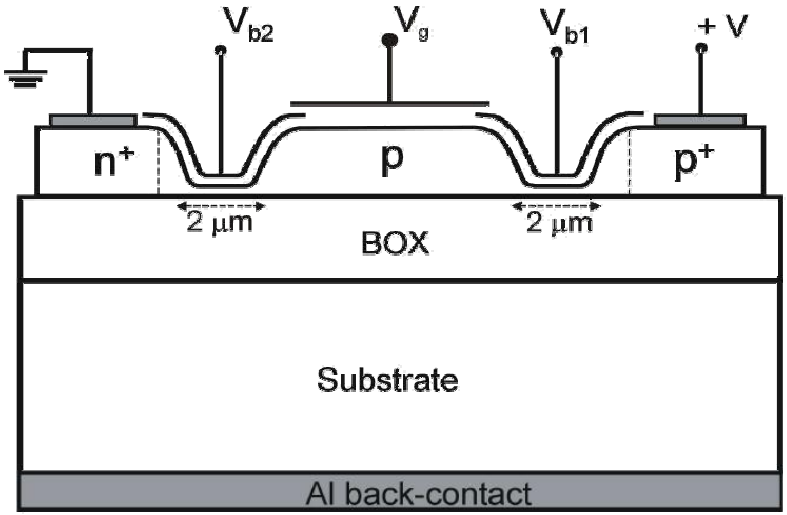
- Contacts: carrier confinement

  Field effect (gates)

  Physical narrowing of the access

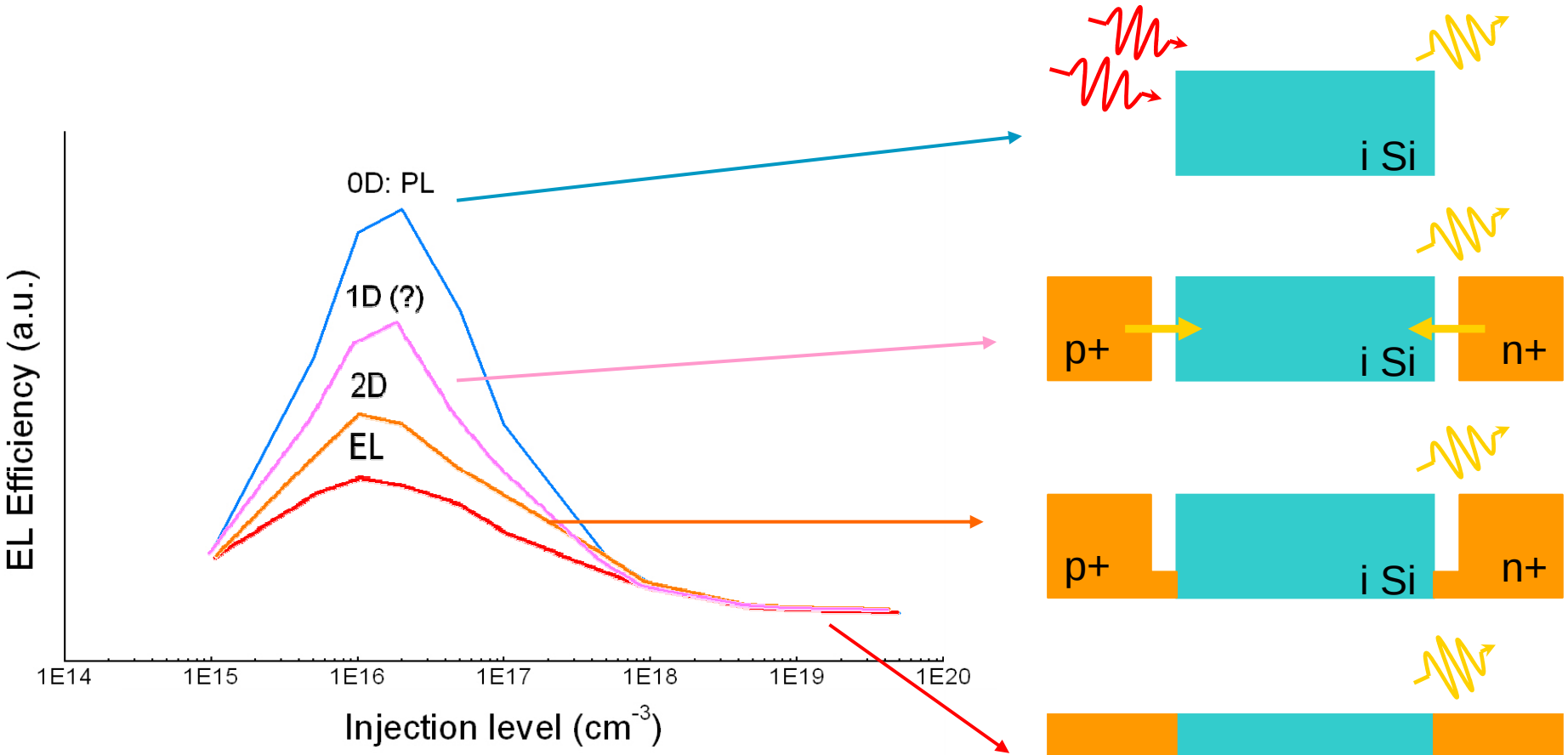
  Potential barrier: band gap widening effect[6]

- SRH: high quality substrates
- Surface: high quality and depletion via gate action
- Auger: low injection level regime



[5] T. Hoang *et al., IEEE El. Dev. Lett.,* vol. 28, May 2007
[6] J. –L. P. J. van der Steen *et al, IEEE El. Dev. Lett.,* vol. 28, 821-824, Sept. 2007

PUSHING TOWARDS THE PHYSICAL LIMIT



Basic p-i-n diode

EFFECT ON CARRIER VELOCITY: ELECTRONS