GaAs Family: Photocathode Design

Godparent Review 2/26/2010

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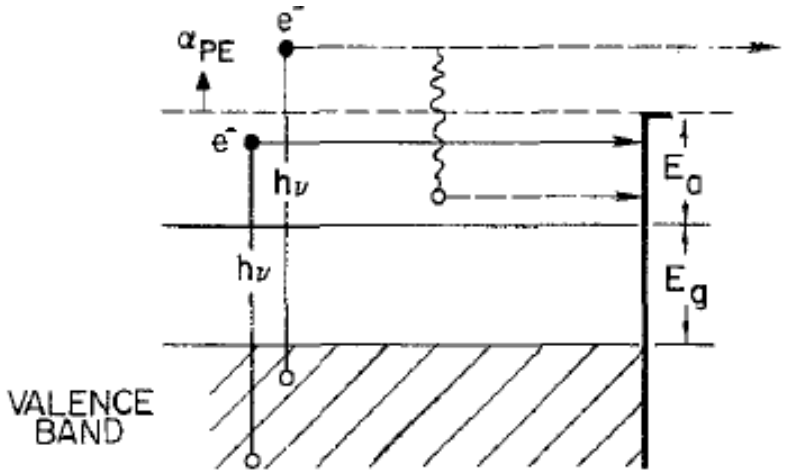
Overview

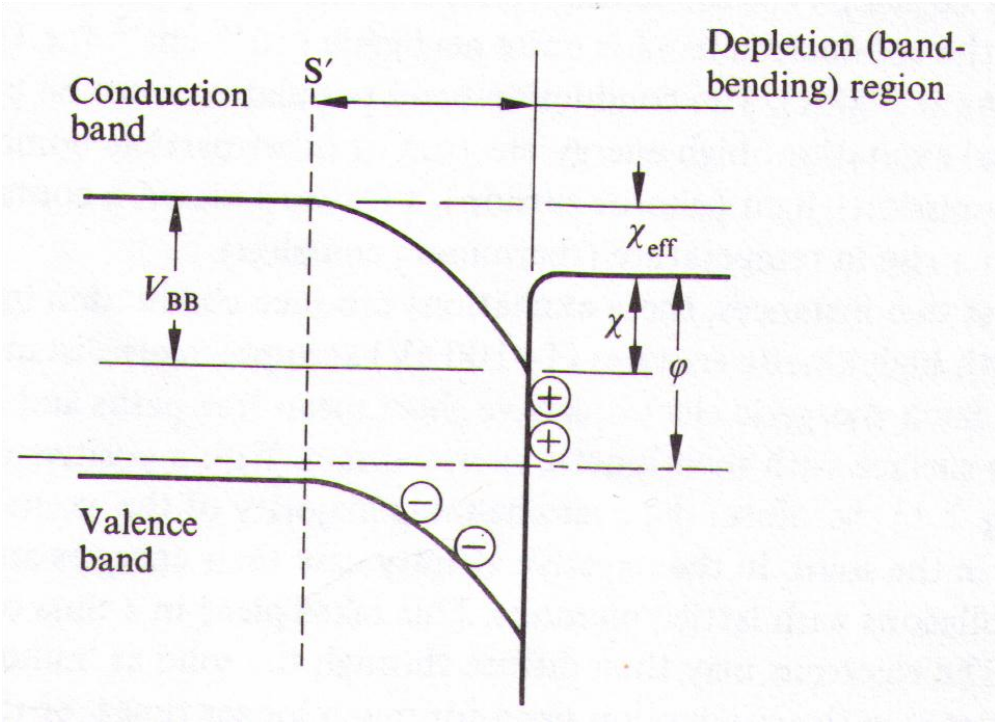
- Goals
- What is a photocathode?
- Wavelength Optimization
- Doping Profile
- Emission Properties
- Transfer Process
- Bonding
- Conclusion

Goals

- Wavelength optimization
- Quantum efficiency larger 20% in average with small batch-to-batch variation
- Reduction of dark-current: novel concepts of doping
- Development of cost-efficient large area transfer & bonding method
- All growth & bonding processes fully industrial compatible (foundry)

What is a photocathode?





$$Y = \frac{\alpha_{PE}}{\alpha} \times \frac{1}{1+\ell a/L} \times P$$

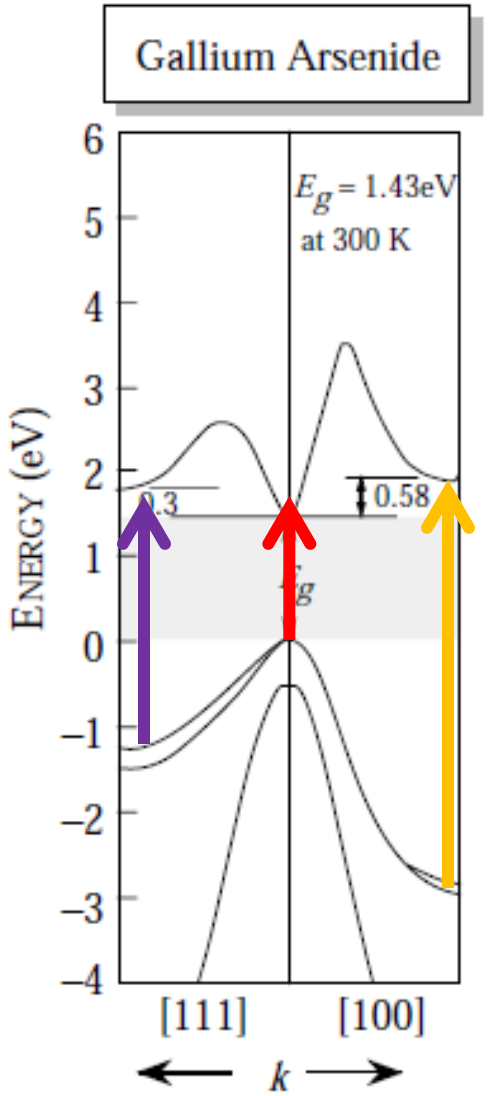
PROBABLITY OF BEING EXCITED WITH SUFFICIENT ENERGY TO ESCAPE

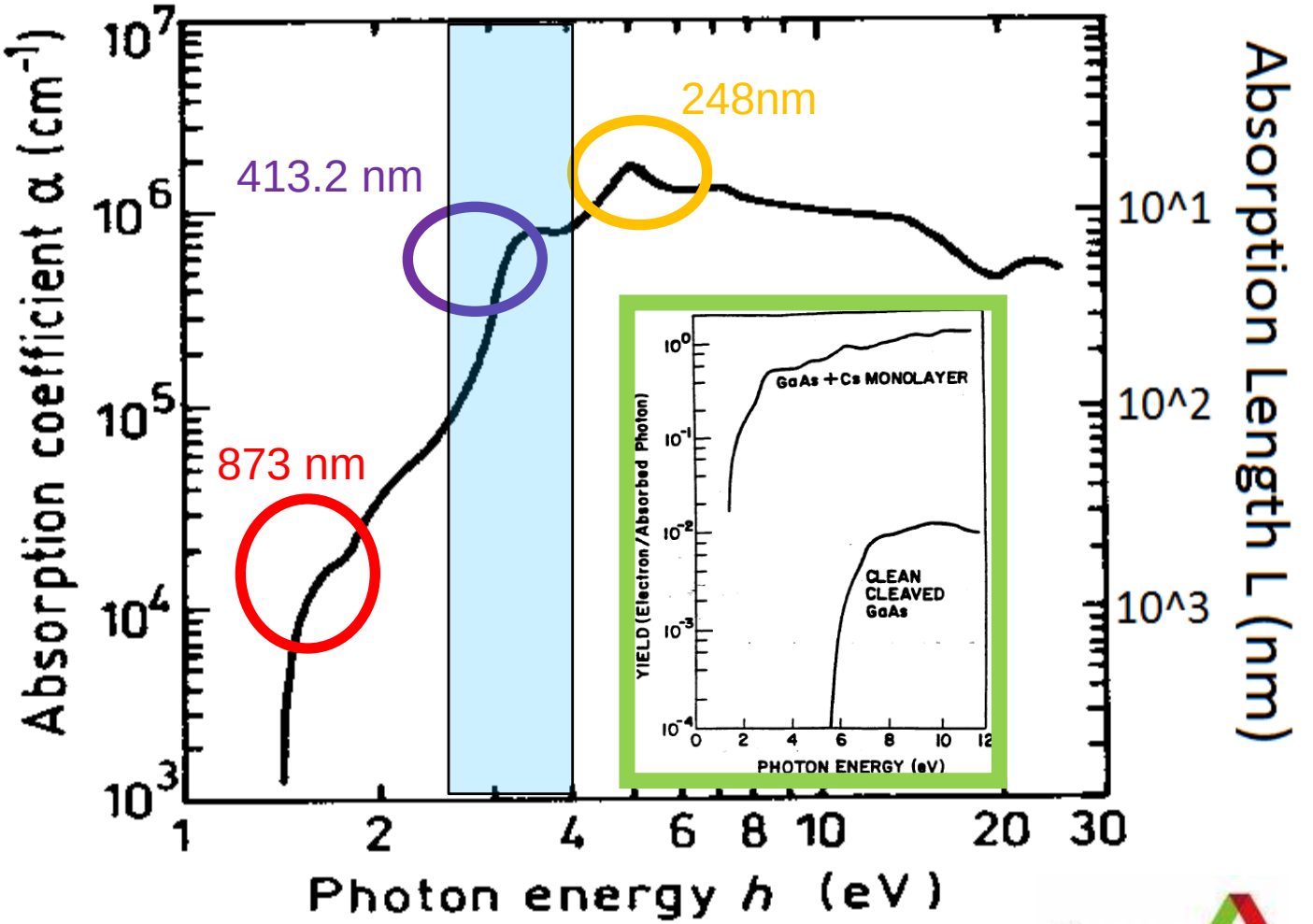
PROBABLITY OF REACHING SURFACE WITH SUFFICIENT ENERGY TO ESCAPE

PROBABLITY OF ESCAPE AFTER REACHING SURFACE

[1],[2]

Wavelength Optimization





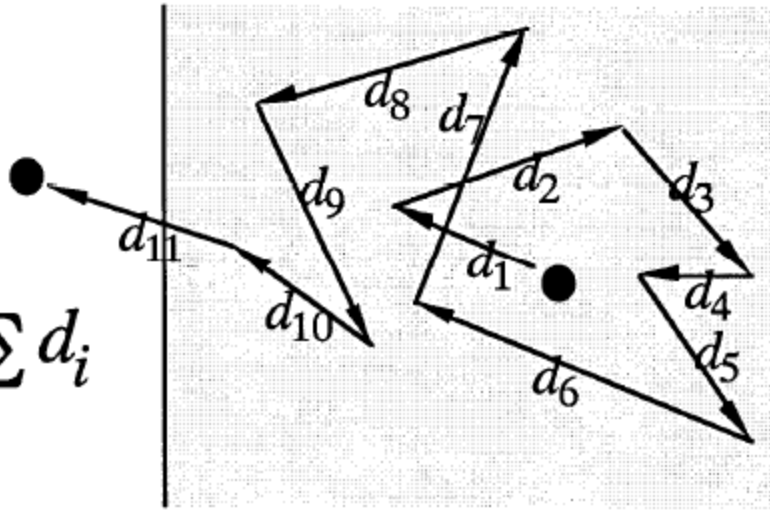
[1],[3]

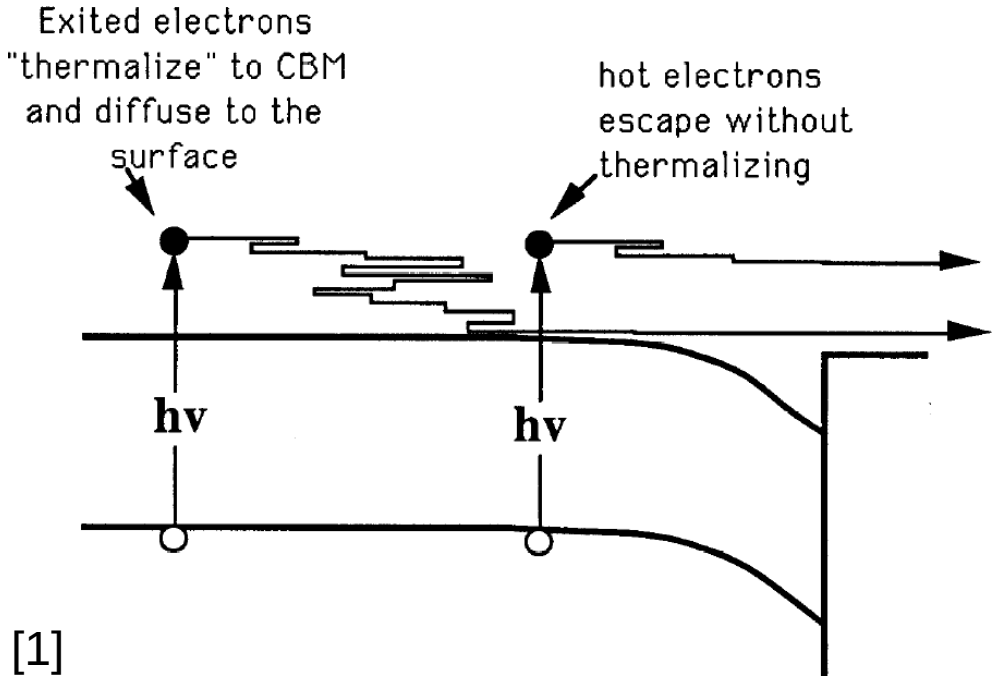
Wavelength Optimization

•Without the presence of an electric field, electrons randomly diffuse

•Only motion normal to the surface aids in electron escape

$$L_T = \sum d_i$$



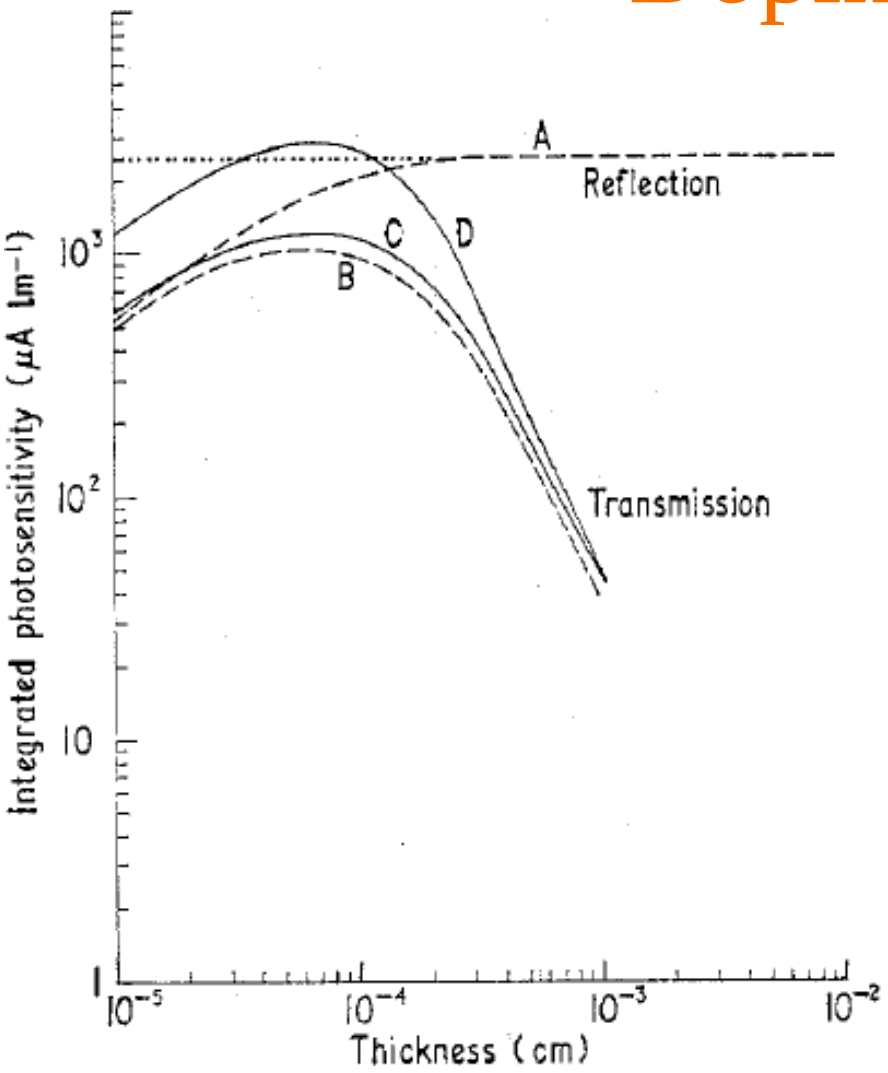


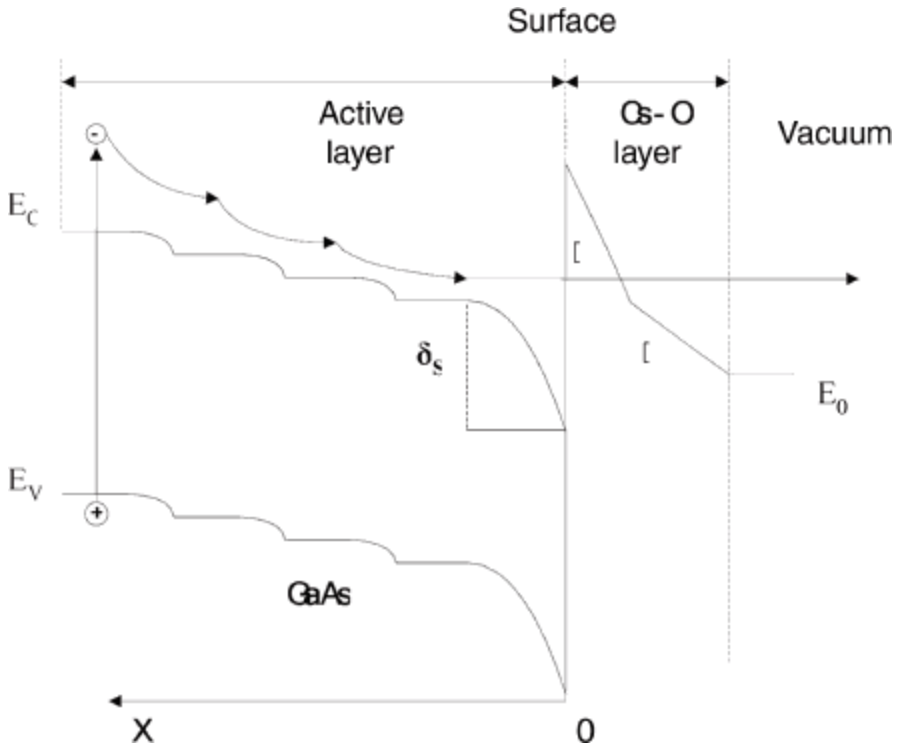
•Generated electrons may either thermalize towards the band edge or remain “hot”

•Depending on the band-bending at the surface, it may be harder for thermalized electrons to escape

[1]

Doping Profile

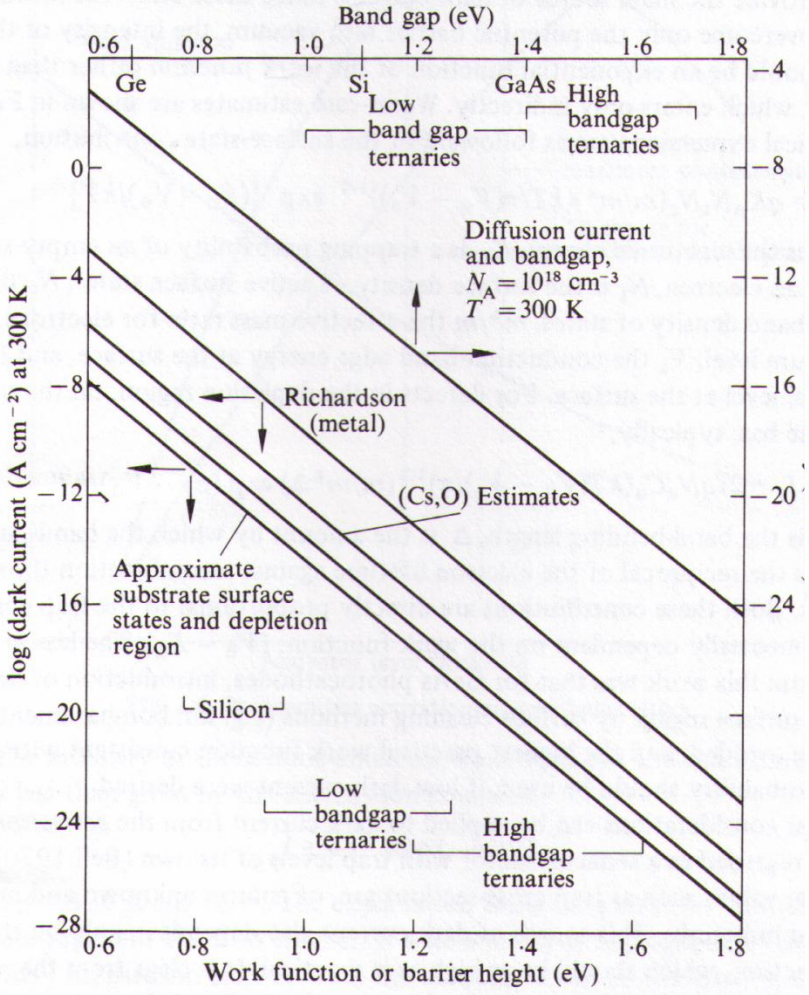


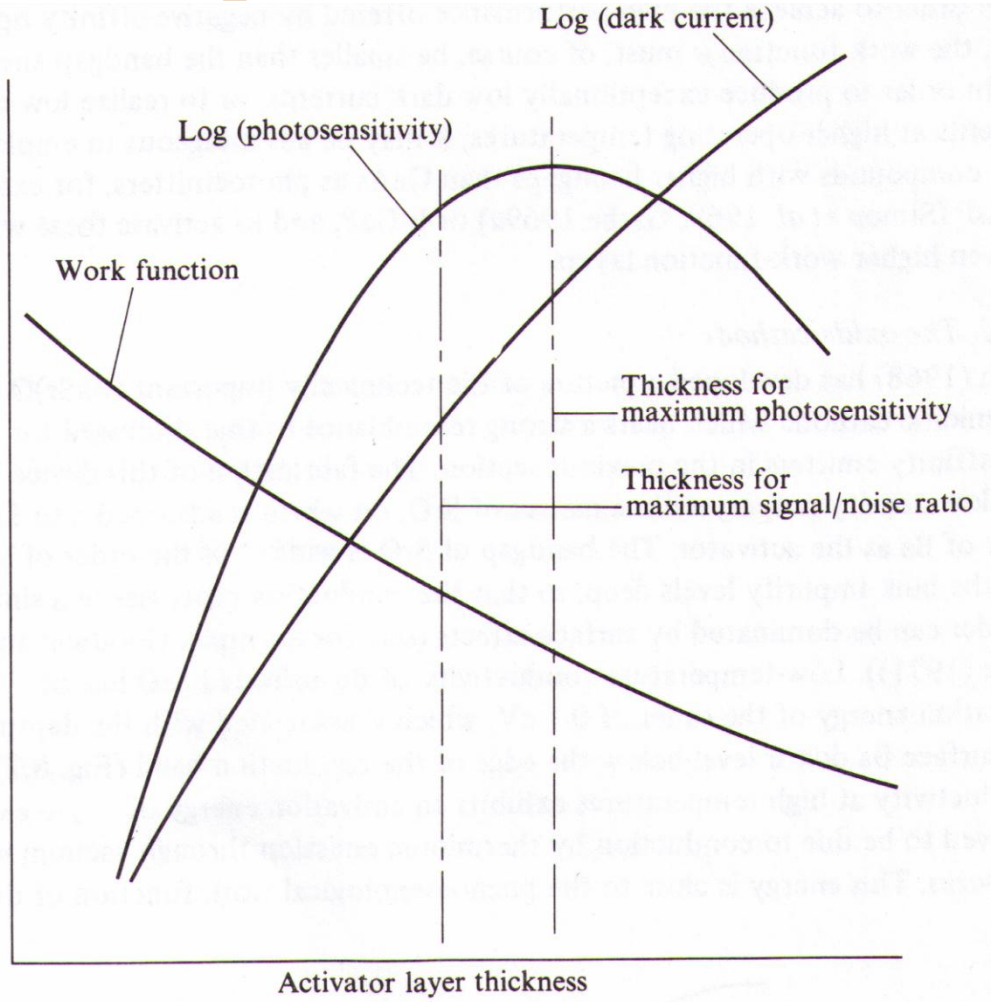


0.25μm 1×10^{18} cm^{-3}	← section 4
0.25μm 4×10^{18} cm^{-3}	← section 3
0.25μm 7×10^{18} cm^{-3}	← section 2
1.85μm 1×10^{19} cm^{-3}	← section 1
p-GaAs(100) substrate	

[4],[5]

Emission Properties

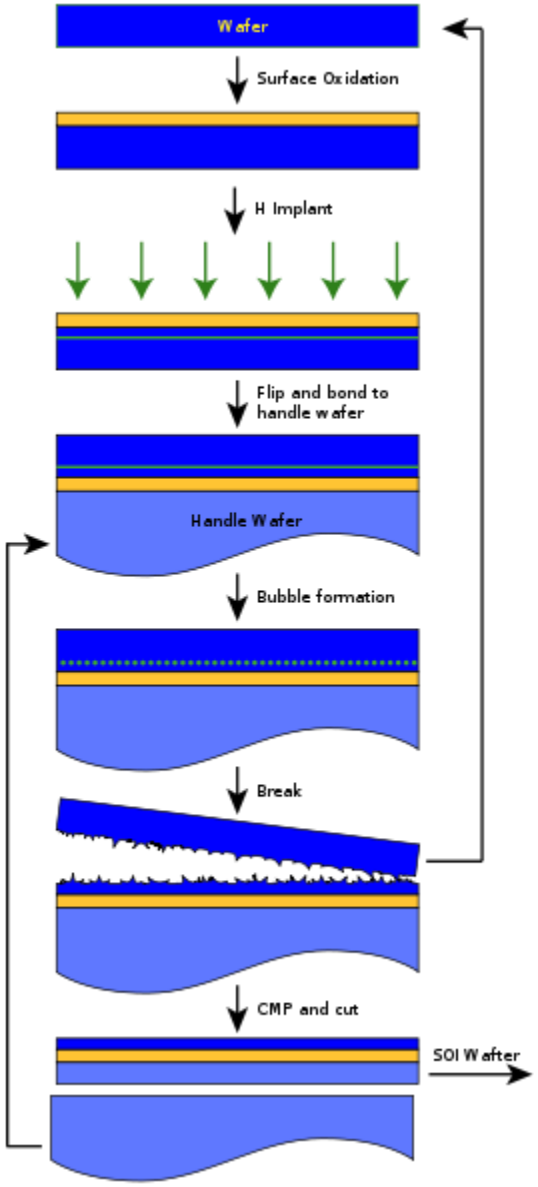




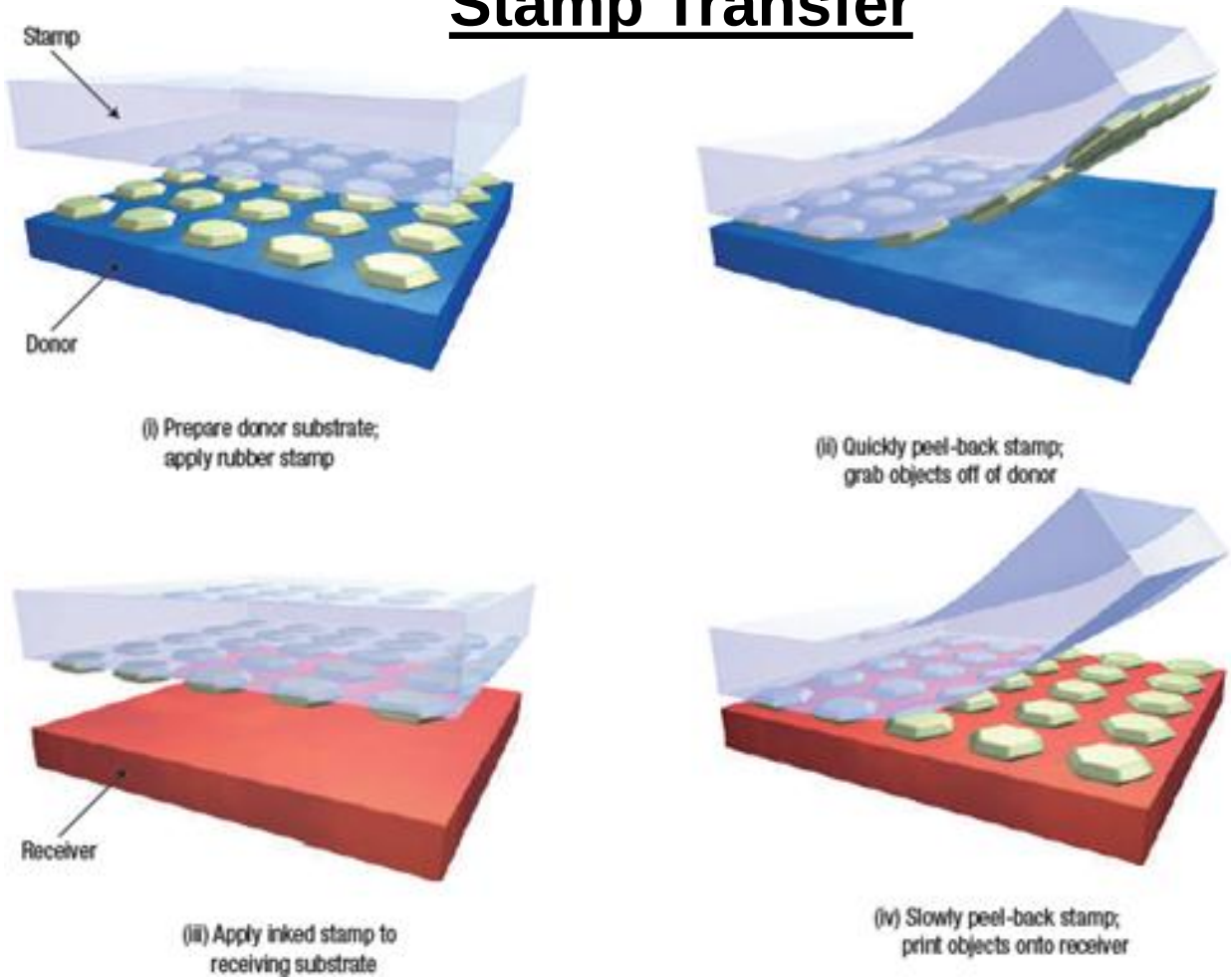
[2]

Transfer Process

Smart Cut



Stamp Transfer



[6],[7]

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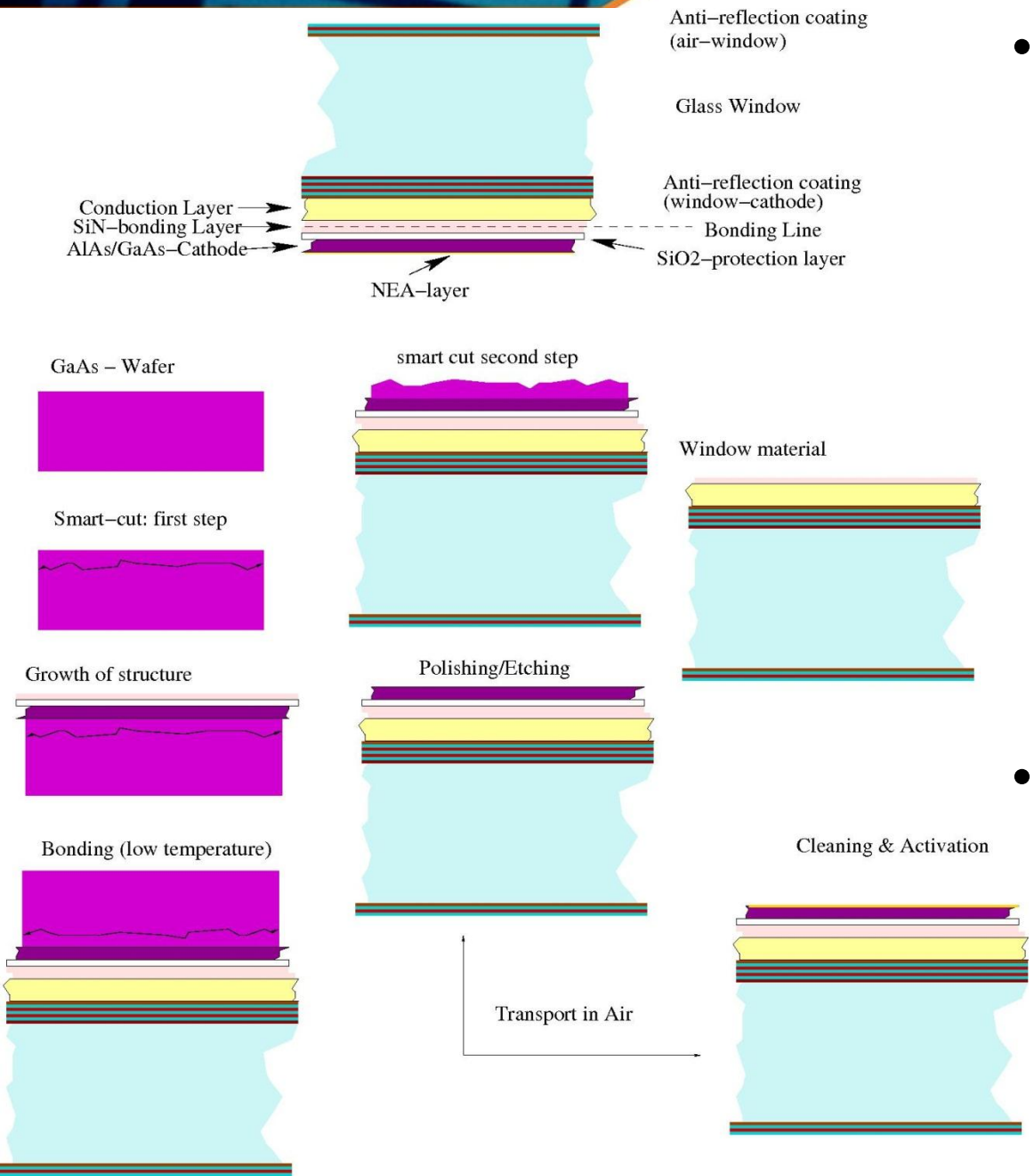

- SiN-bonding
  - Developed for 3d integration
  - Low temperature process (maximal temp~400C)
  - About 30nm-60nm thickness
  - Industrially available
- Protection of cathode structure
  - Low temperature
  - Inter-diffusion barrier

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Conclusion

- GaAs is a suitable material for the proper wavelength
  - III-V system can be alloyed for adjustment
- Doping profile has to maintain a balance between electric field, dark current, recombination rate and quantum efficiency
- Transferring and bonding have to be efficient and repeatable but maintain electrical and structural integrity of the photocathode

References

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[3] http://www.eecs.umich.edu/~singh/bk7ch03.pdf

[4] G.A. Allen, “The performance of negative electron affinity photocathodes,” Journal of Physics D: Applied Physics, vol. 4, 1971, pp. 308-317.

[5] Z. Yi-Jun, C. Ben-Kang, Y. Zhi, N. Jun, and Z. Ji-Jun, “Distribution of carriers in gradient-doping transmission-mode GaAs photocathodes grown by molecular beam epitaxy,” Chinese Physics B, vol. 18, 2009, pp. 4541-4546.

[6] “Smart Cut - Wikipedia, the free encyclopedia.”

[7] M.A. Meitl, Z.T. Zhu, V. Kumar, K.J. Lee, X. Feng, Y.Y. Huang, I. Adesida, R.G. Nuzzo, and J.A. Rogers, “Transfer printing by kinetic control of adhesion to an elastomeric stamp,” Nature Materials, vol. 5, 2006, pp. 33–38.