CMOS Image Sensor Simulation

2D and 3D Simulation

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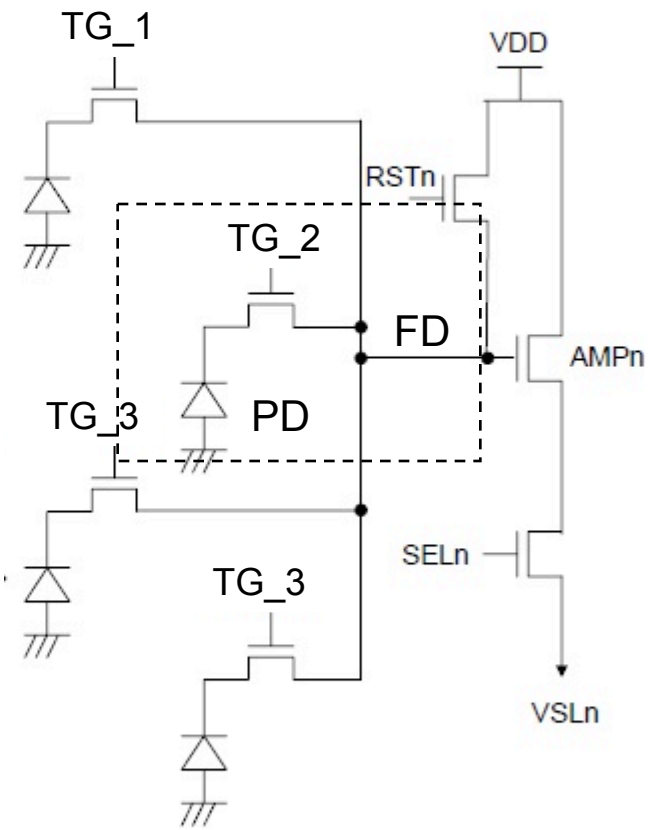
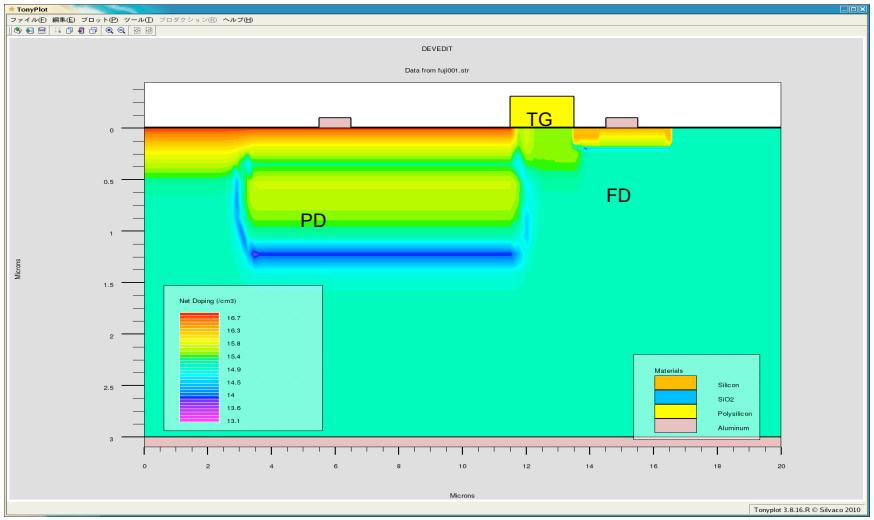
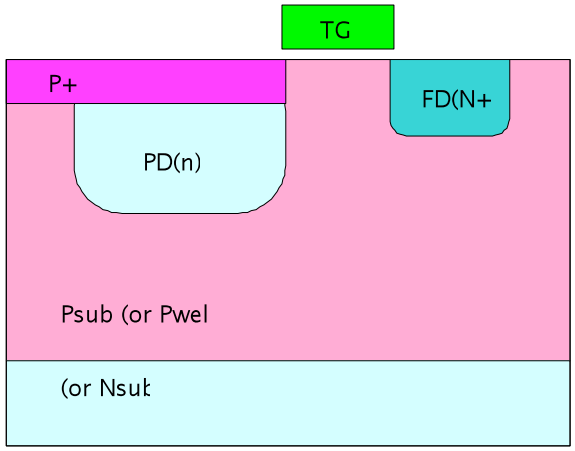
Basic Structure and operation of CMOS Image Sensor

CMOS Image Sensor equivalent circuit



CMOS Image Sensor cross section of (PD/TG_2/FD):





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Basic Structure and operation of CMOS Image Sensor

Light ⇨ Charge (electron/hole) conversion

⇩ ATLAS: Device Simulator with Luminous module

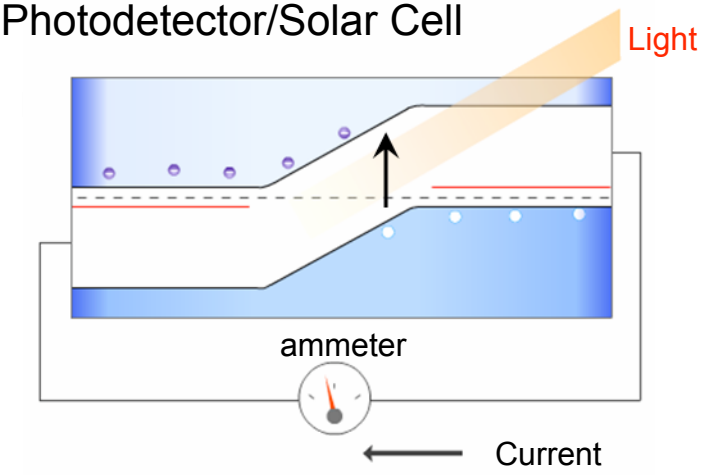
Accumulation of generated charges (electrons)

(Holes may also be used)

⇩ Transfer from PD to FD (See the next page)

Charge ⇨ Voltage conversion

Same as Photodetector/Solar Cell

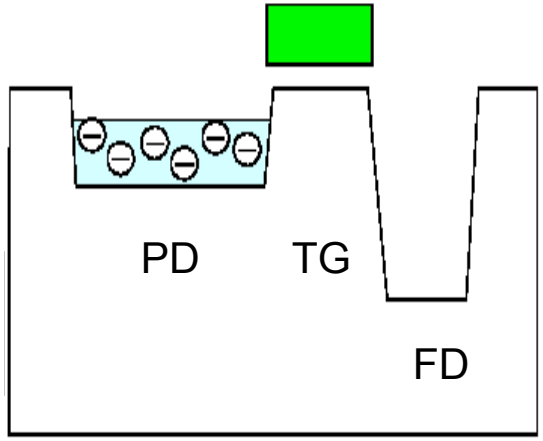


A potential well is formed, into which electrons are accumulated. Holes will flow to P-type layer.

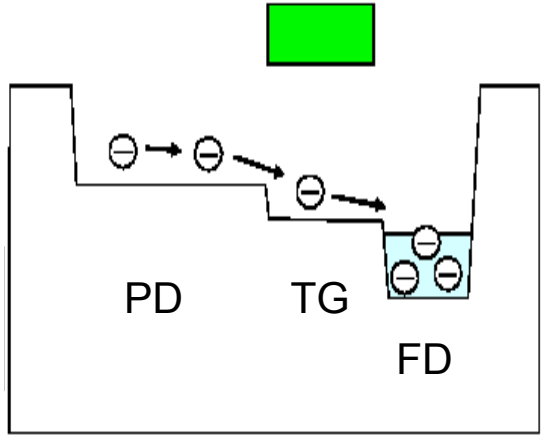
Electrons will be converted to voltage (q=CV) and they will be output through the source follower (AMPn)

Basic Structure and operation of CMOS Image Sensor

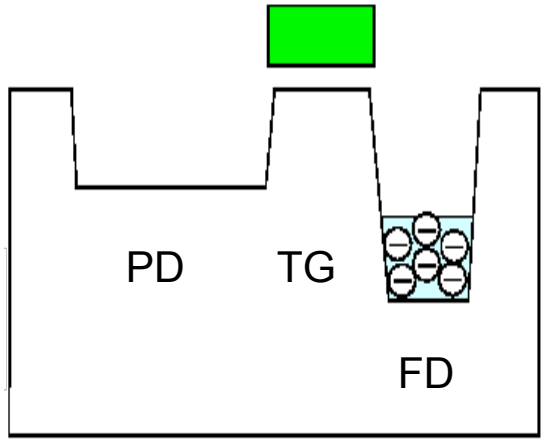
Potential during accumulation (@off)



Potential during transfer (@on)



Potential during output (@off)



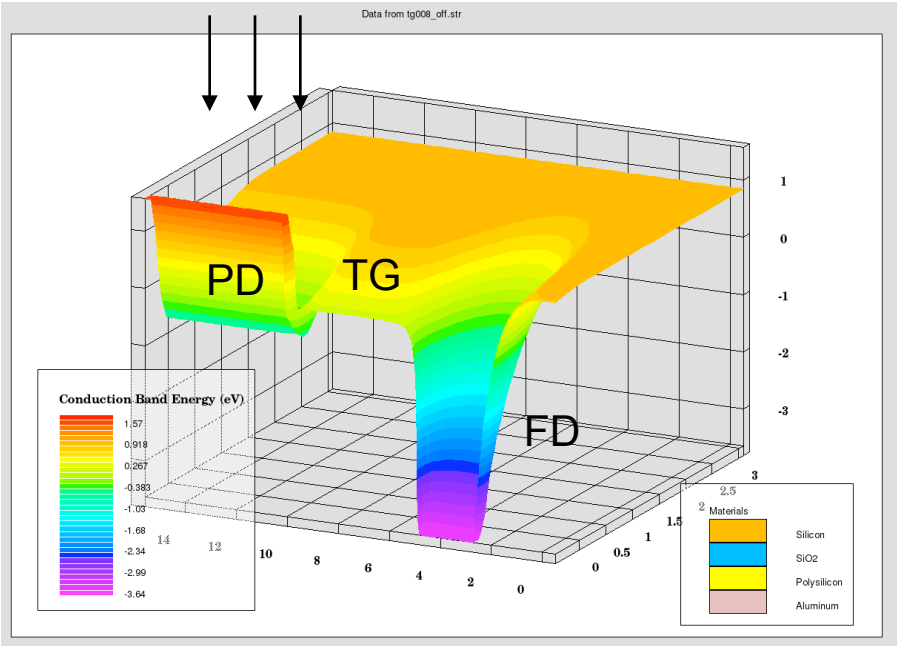
Design of the potential resulting in charge transfer is critical. If the accumulation capacity in PD and FD is out of balance, untransferred charges will occur.

Basic Structure and operation of CMOS Image Sensor

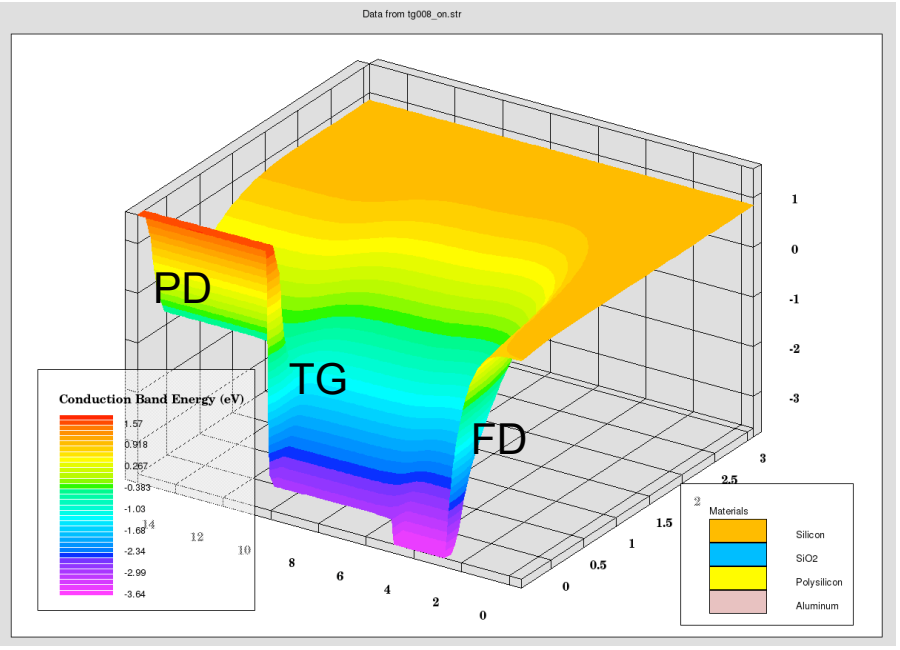
Potential profile simulated using ATHENA + ATLAS

Potential during accumulation (@off)

Light :532nm



Potential during transfer (@on)



Basic Structure and operation of CMOS Image Sensor

CMOS Sensor Performance

- Light (Input)

  Determined by the structure (material and geometry)

  ← ATLAS Luminous

- Photoelectric conversion

  Determined by the structure (doping)

  ← ATLAS ATHENA

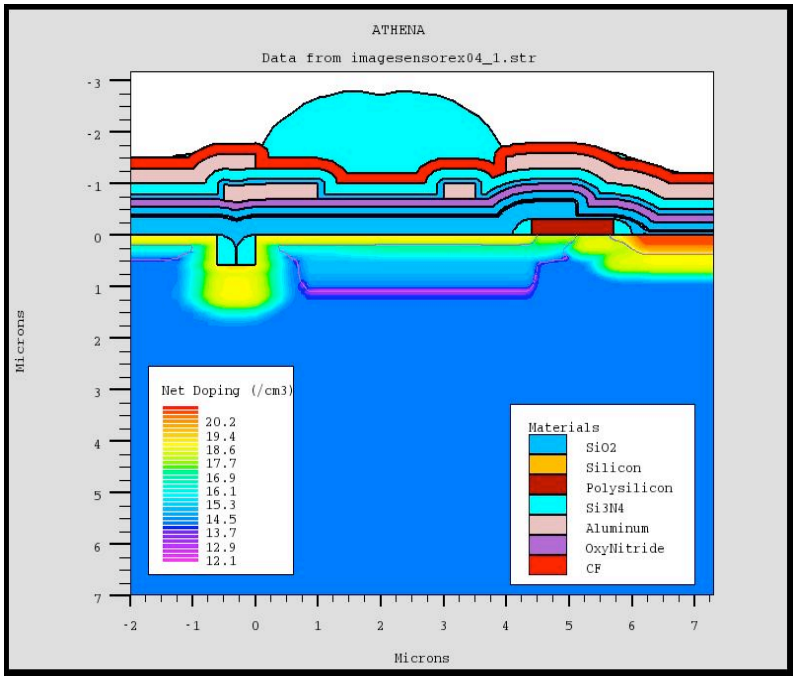
- Charge/Voltage conversion (output)

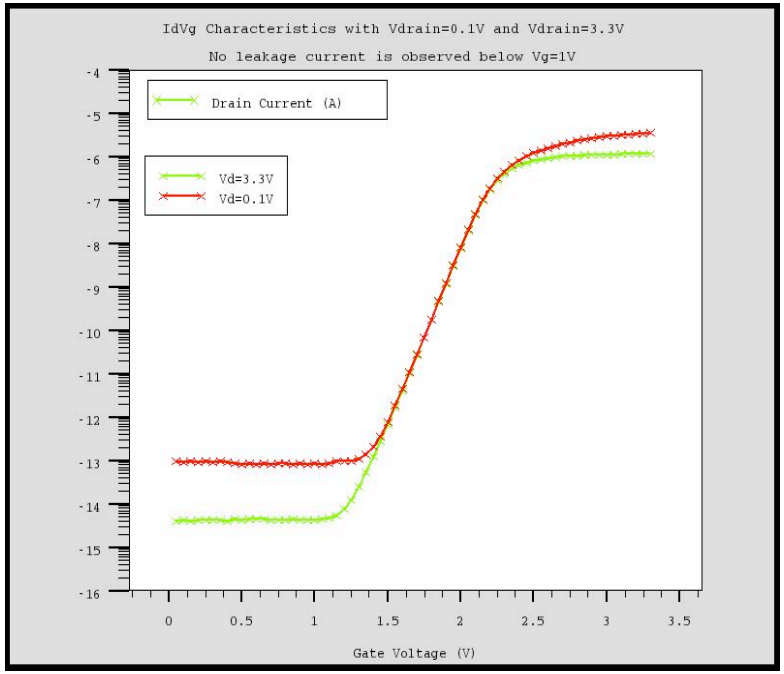
  Determined by total capacity of FD (junction + wiring)

  ← ATLAS CLEVER

2D Process and Device Simulation Example

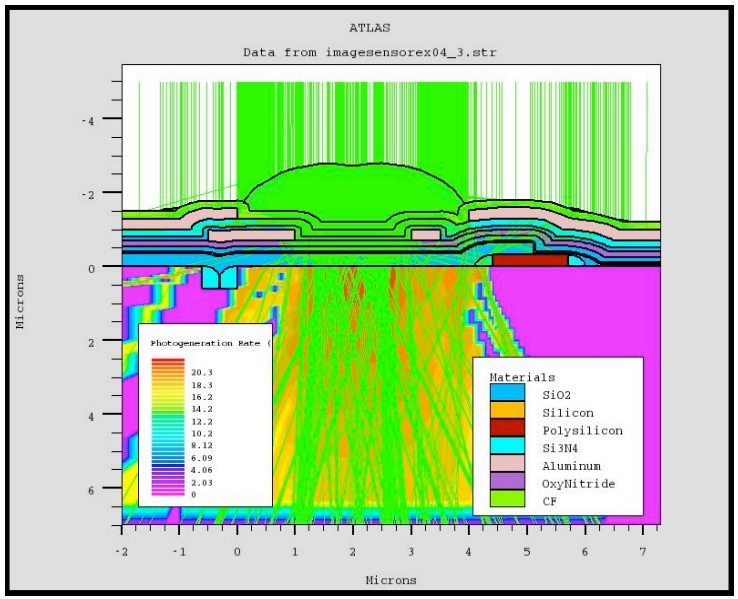
- CIS Process simulation including Back End and lens to focus light
- Un-saturated and saturated DC IV characteristics show low leakage current all the way up to Vg=1V

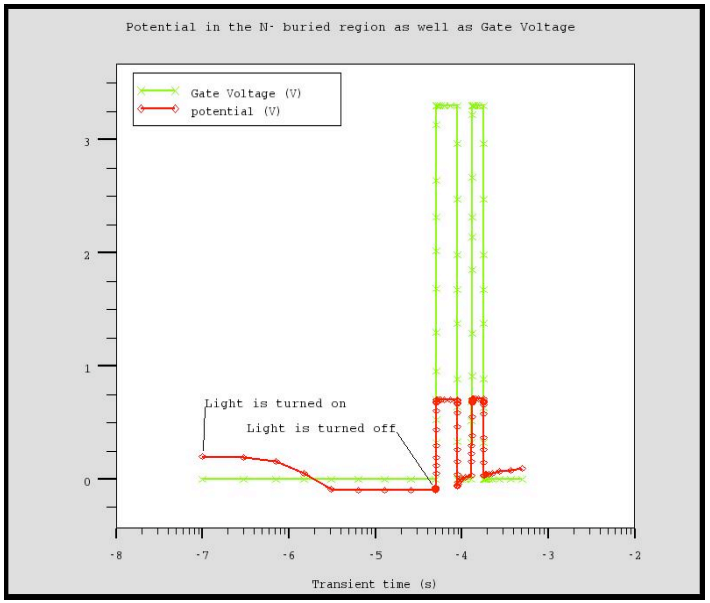




2D Process and Device Simulation Example

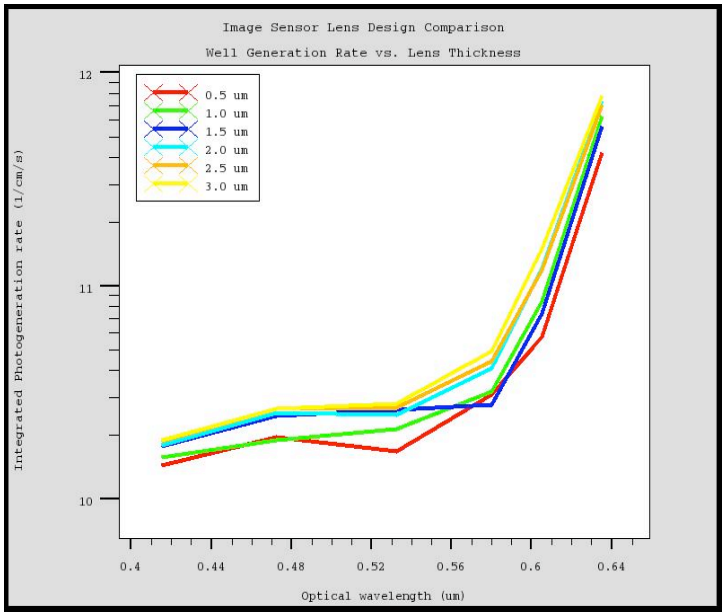
- The light is shone on the structure during 50us. Potential of the N- region gradually decreases as the light generated carriers are integrated
- At around 3us the image sensor is saturated
- At 50us the gate is ramped in transient to 3.3V to transfer the charge previously generated in the N- region to the floating drain

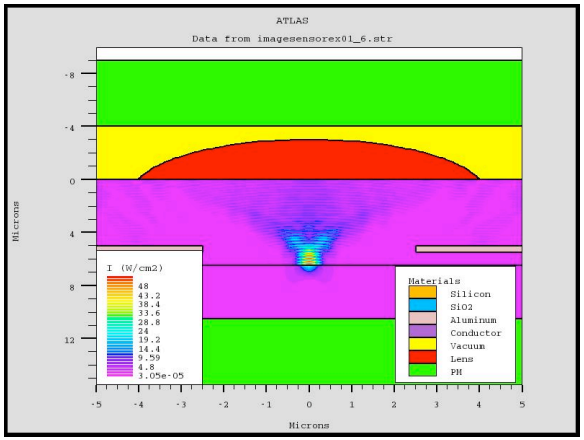


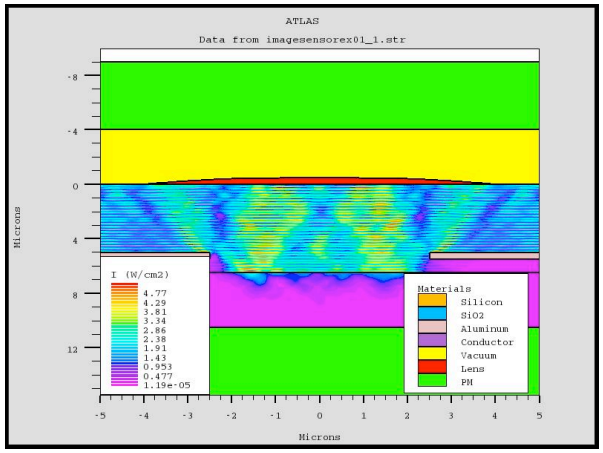


Comparison of Several Lenses Design

- All lenses are spherical but have different radiuses
- Built-in analytical lenses are used during FDTD simulation
- The advantage is to prevent the introduction of lot of mesh points during the device simulation and to reduce simulation time.

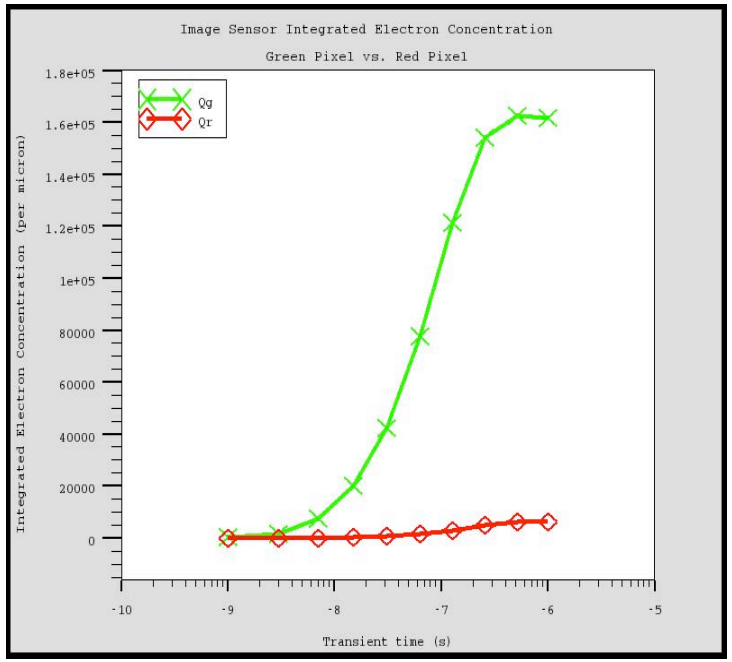


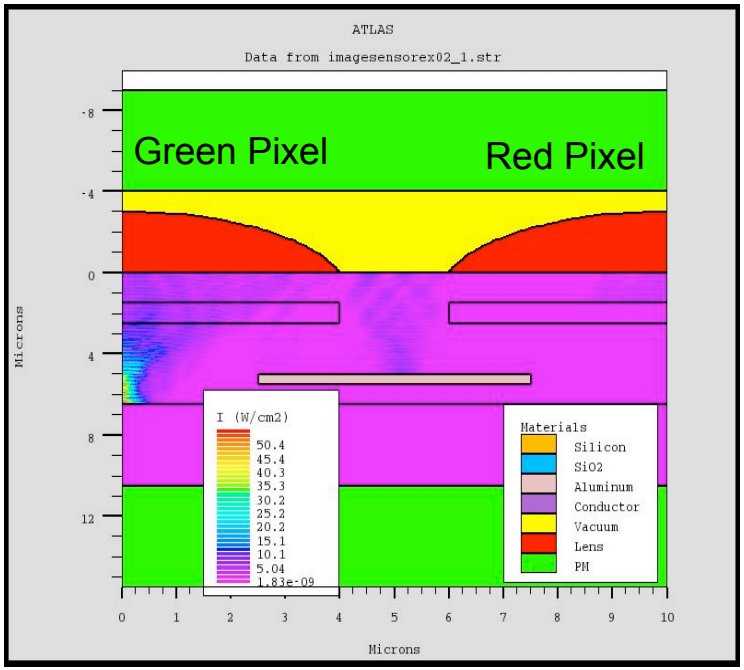




Charge Integration Analysis

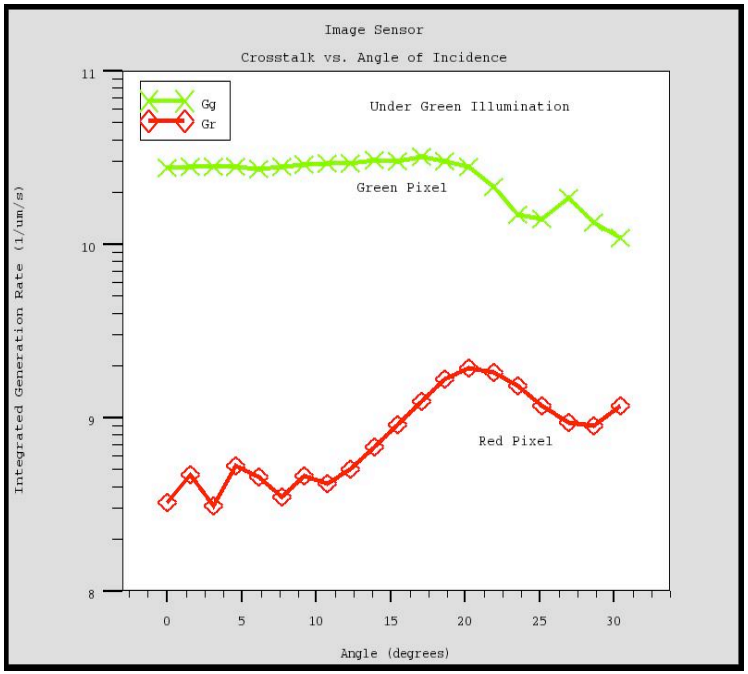
- We examine the time integration of charge in the N Well of the imaging device and look at crosstalk caused by charge blooming into an adjacent cell

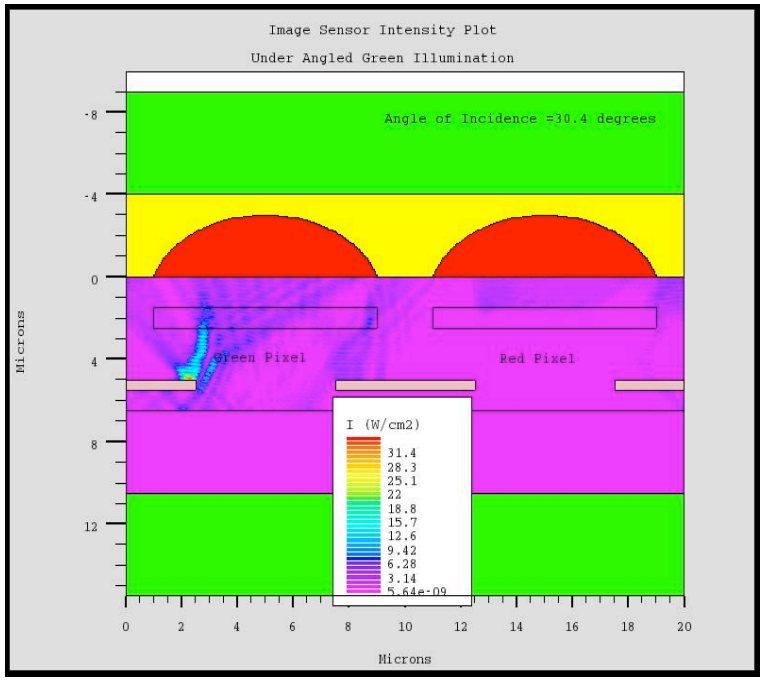




Crosstalk at Angular Incidence

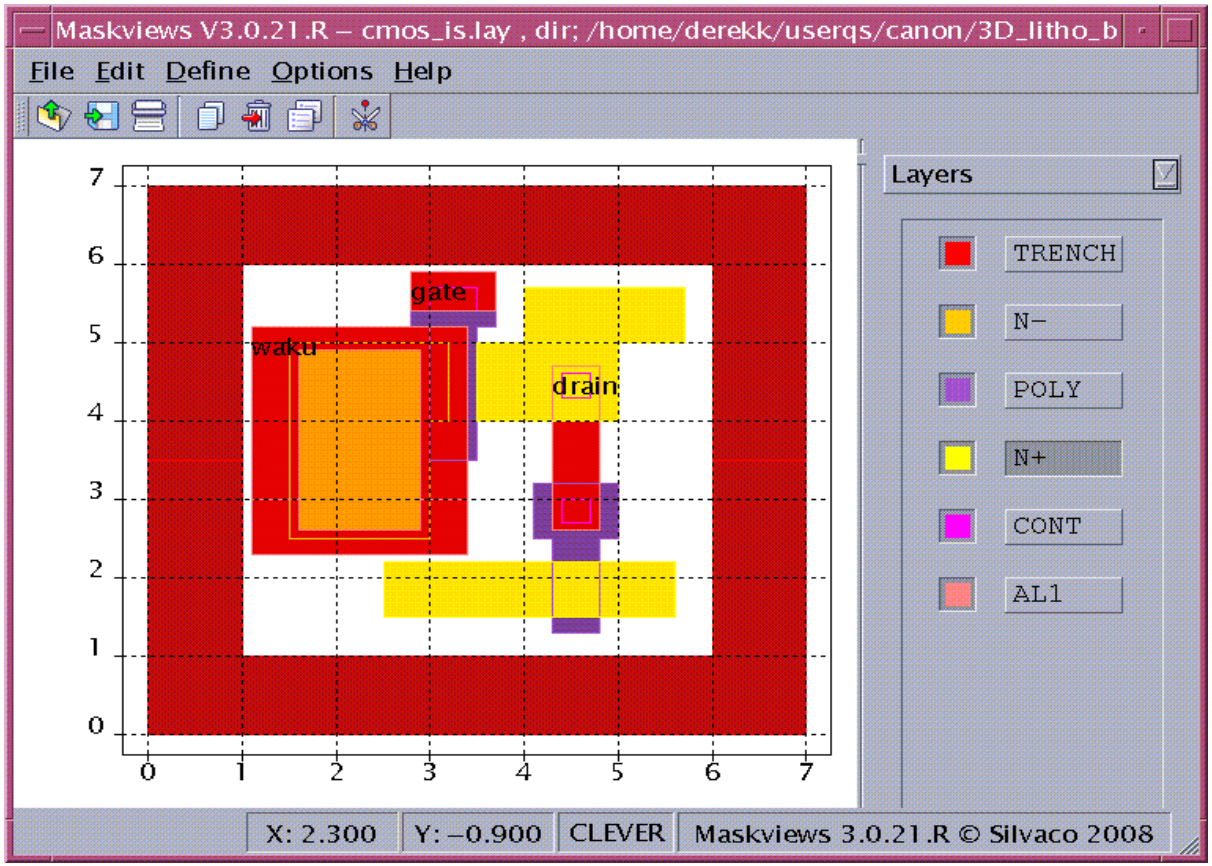
- Crosstalk between adjacent colors due to angularly incident light
- After about 20 degrees the collected Green rate decreases





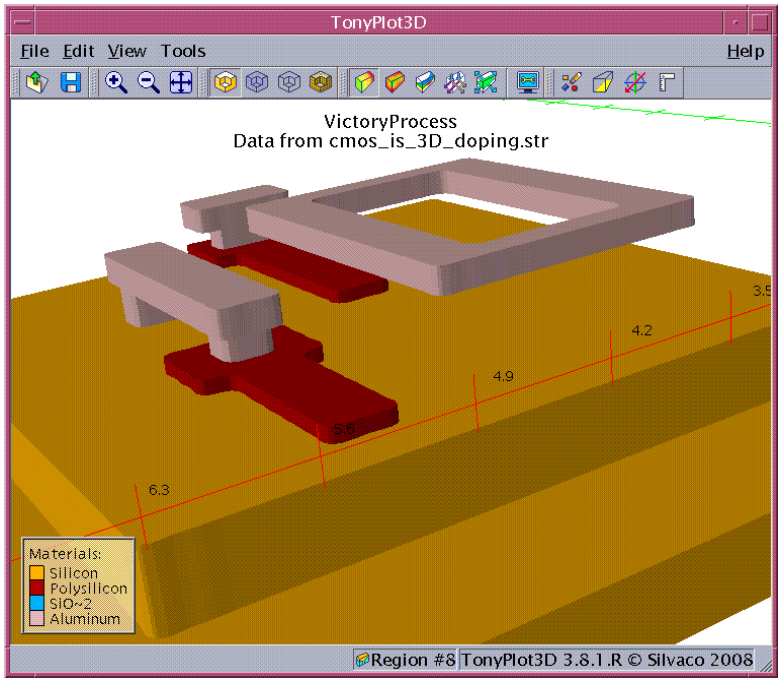
3D CMOS Image Sensor Simulation Example

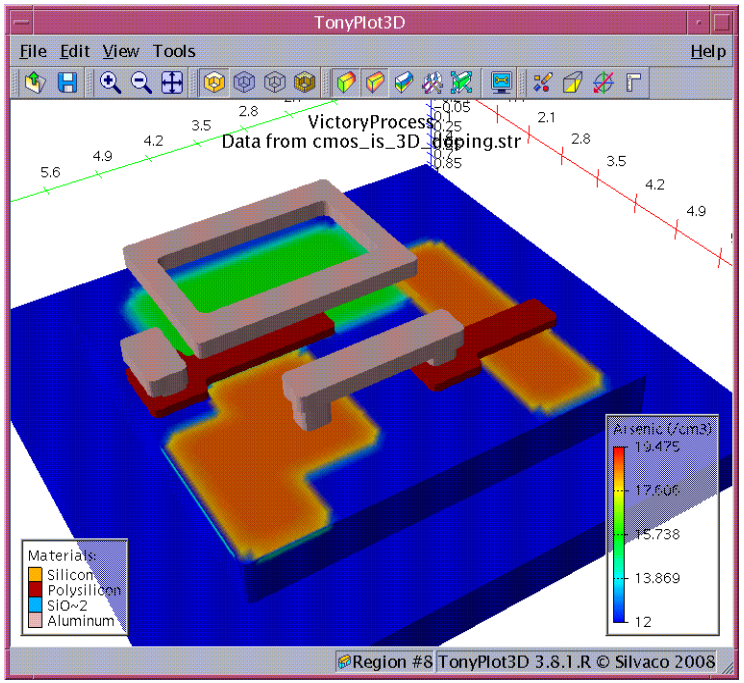
- Layout – GDSII or Silvaco Layout Format (MaskViews)



3D CMOS Image Sensor Simulation Example

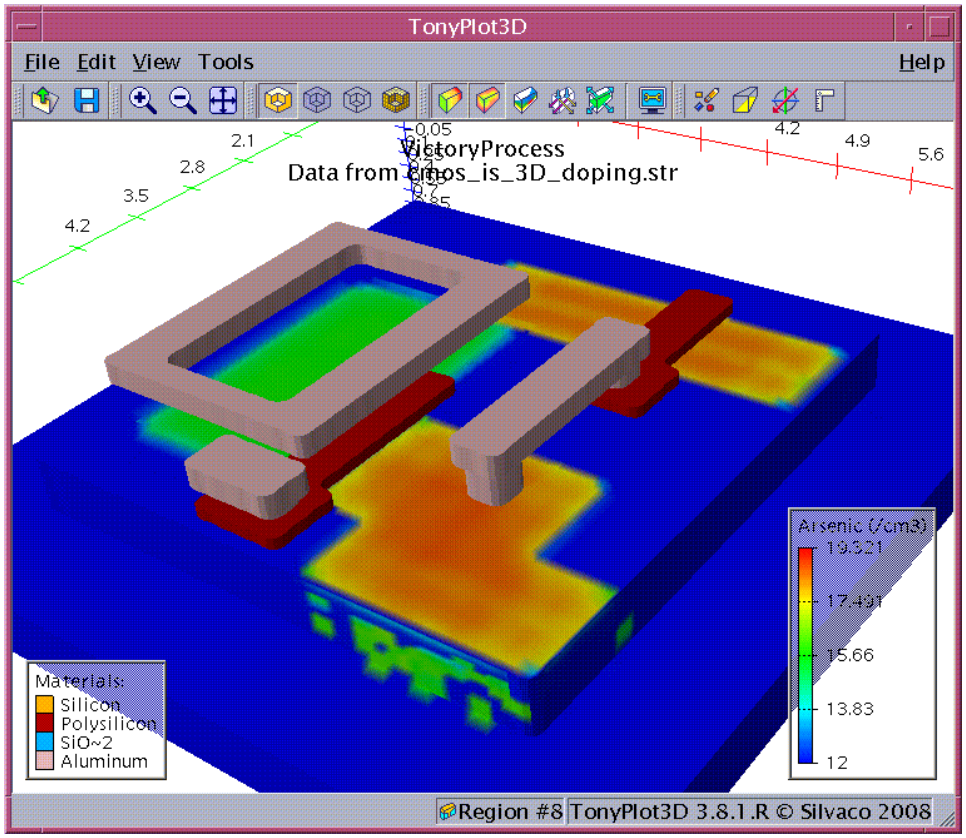
- All 8 Masks using Lithography Simulation using VICTORY CELL





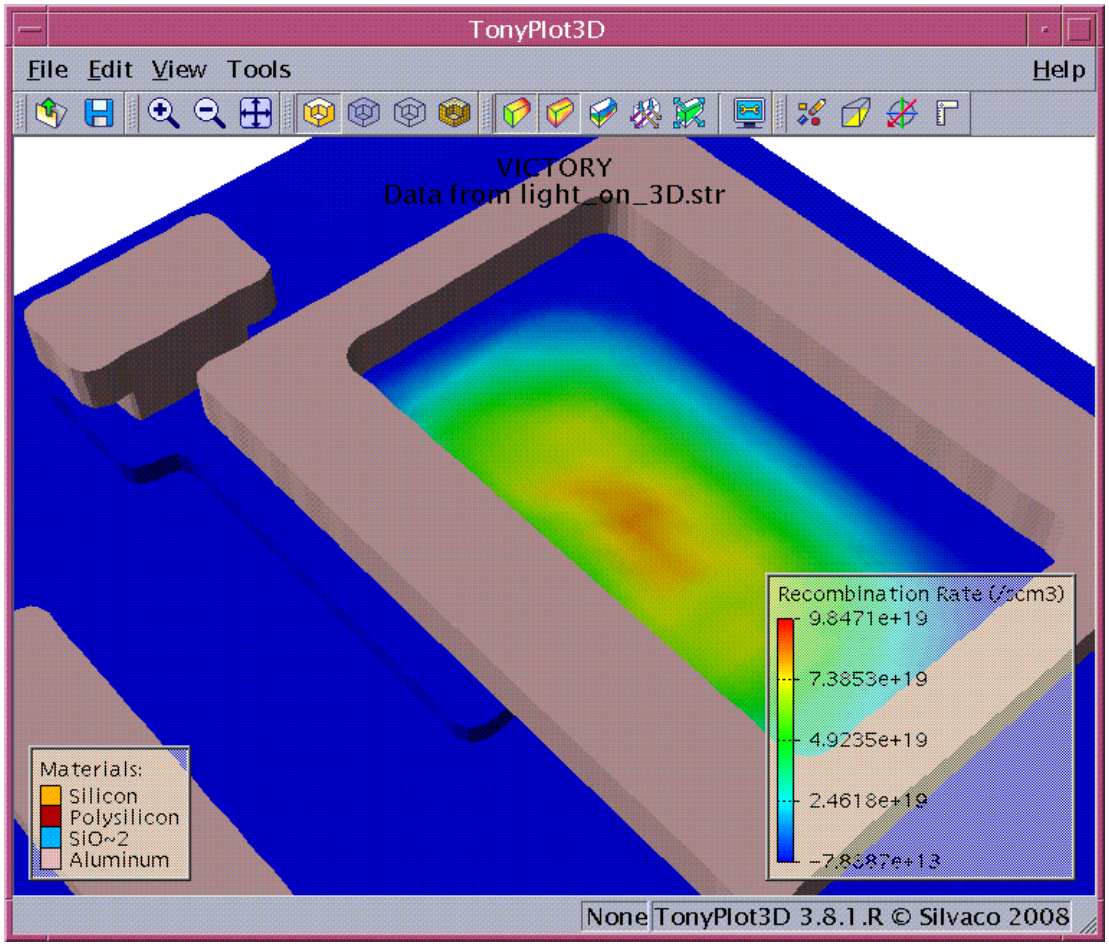
3D CMOS Image Sensor Simulation Example

- All 4 Implants using 4 Million Trajectories for Each Implant using VICTORY CELL



Showing shadowing of the photoresist for the high angle implants and scattering effects.

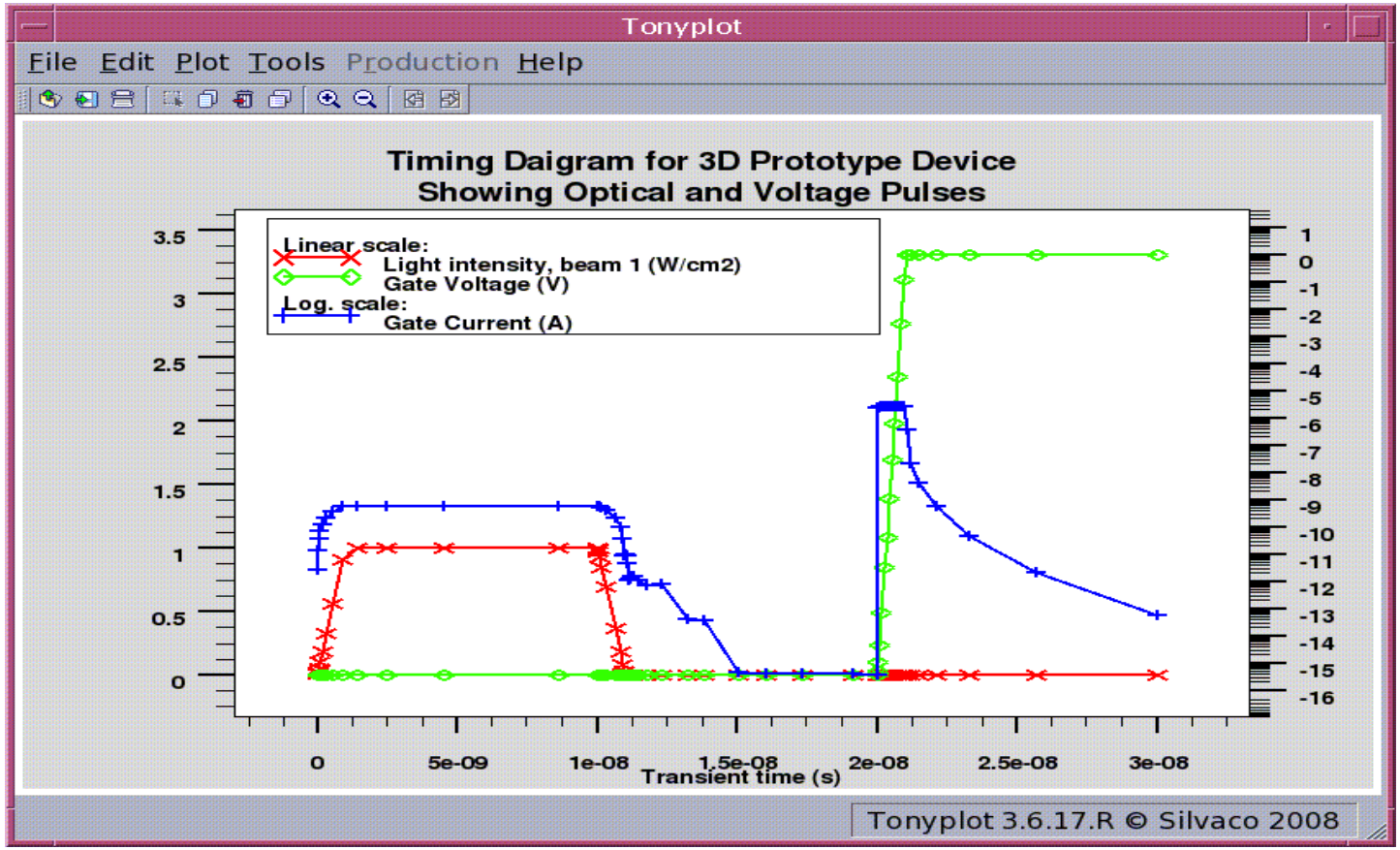
3D CMOS Image Sensor Simulation Example



Targeted light exposure only in Image Sensor active region.

3D CMOS Image Sensor Simulation Example

- 3D transient device simulation showing optical and voltage pulse



Summary

- SILVACO TCAD tools provide a complete solution for researchers interested in CMOS Image Sensor (CIS) technology. It enables researchers to study the electrical properties of CIS under illumination in both two and three dimensional domains.
- 3D process simulation, not just 3D structure editing
- Can be used for fast prototyping of large structures or detailed analysis of intricate details
- The software is capable of simulating any type of CIS and the calibration task is now very convenient and easy thanks to VWF
- Silvaco is the one-stop vendor for all companies interested in CIS technology simulation solutions