Considerations for Junction Terminal Edge of the APD Sensor

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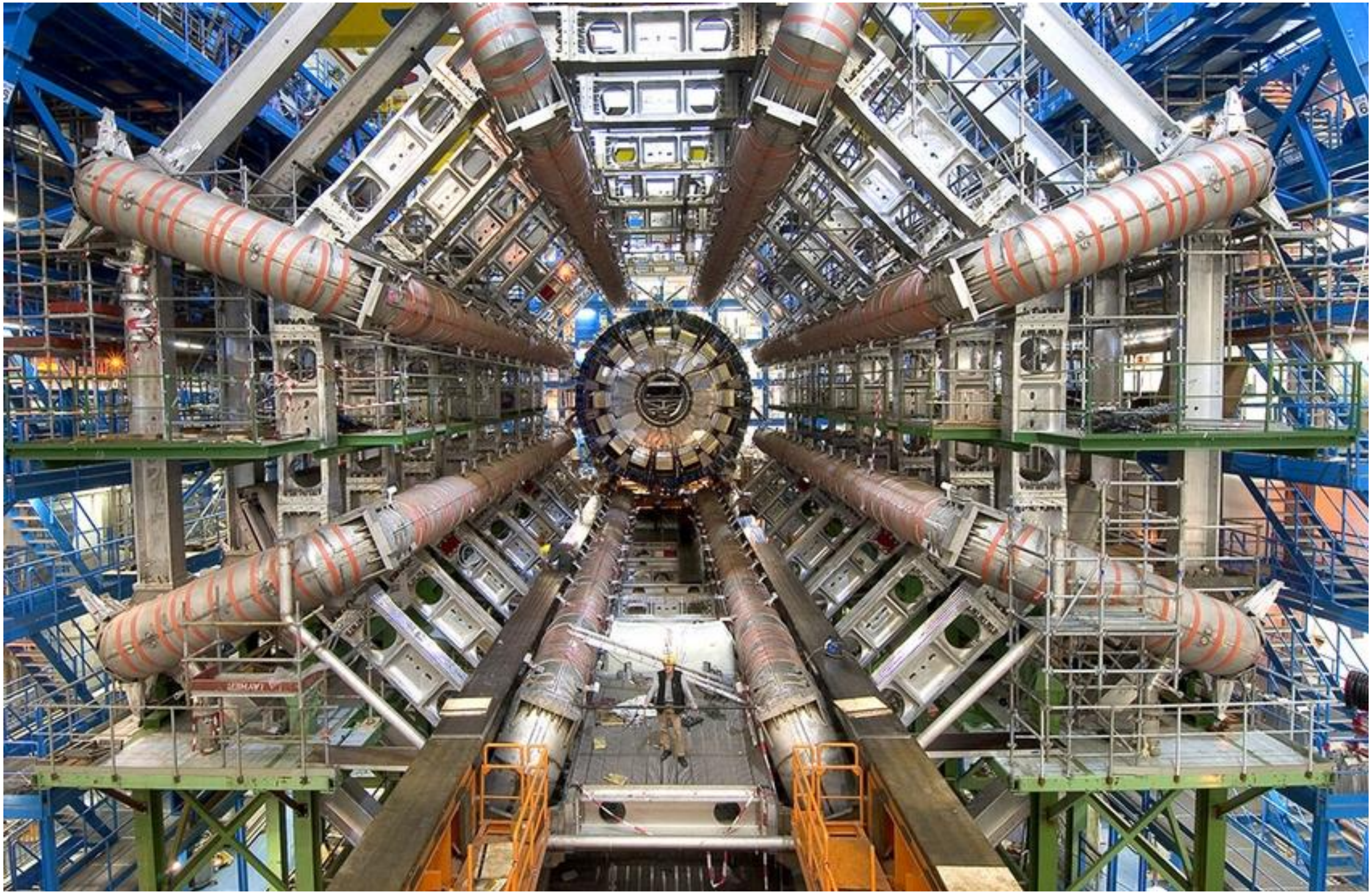
Contents

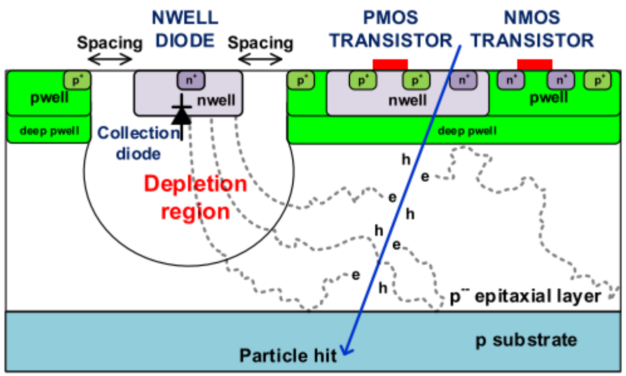
- Target of the Device (APD)
- Effect of the Injected Carrier
- Electrical Isolation of the Junction
- Cross Section View of the Presented APD
- Reference

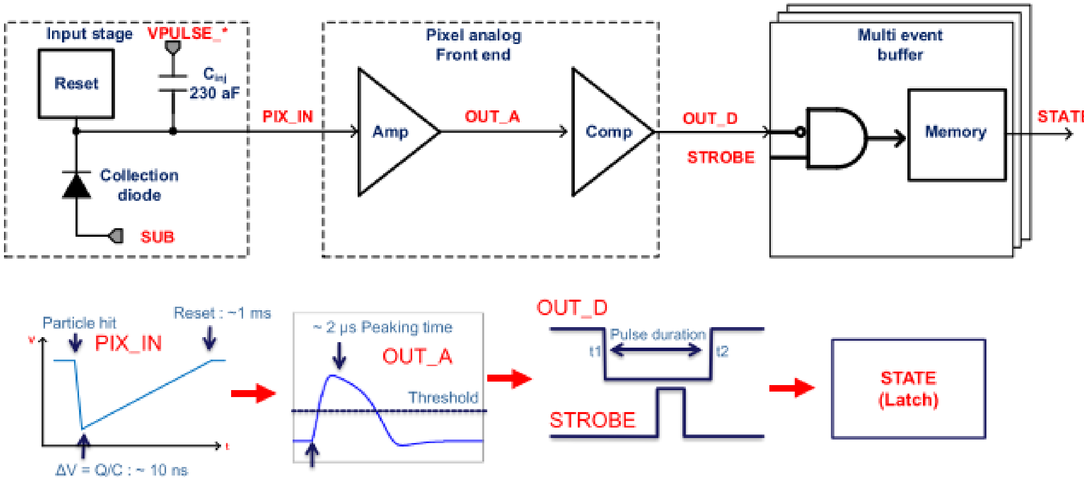
Target of the Device (APD)



Target of the Device (APD)

- Current Version of the ALICE Inner Tracking System (ITS)
  - Photo-diode for conventional CIS purpose
  - Particle hit causes the analog pulse signal ($v_{pix} = \frac{Q}{C_{sensor}}$)
  - Peripheral circuit is needed for A-to-D conversion (degrades the jitter performance)

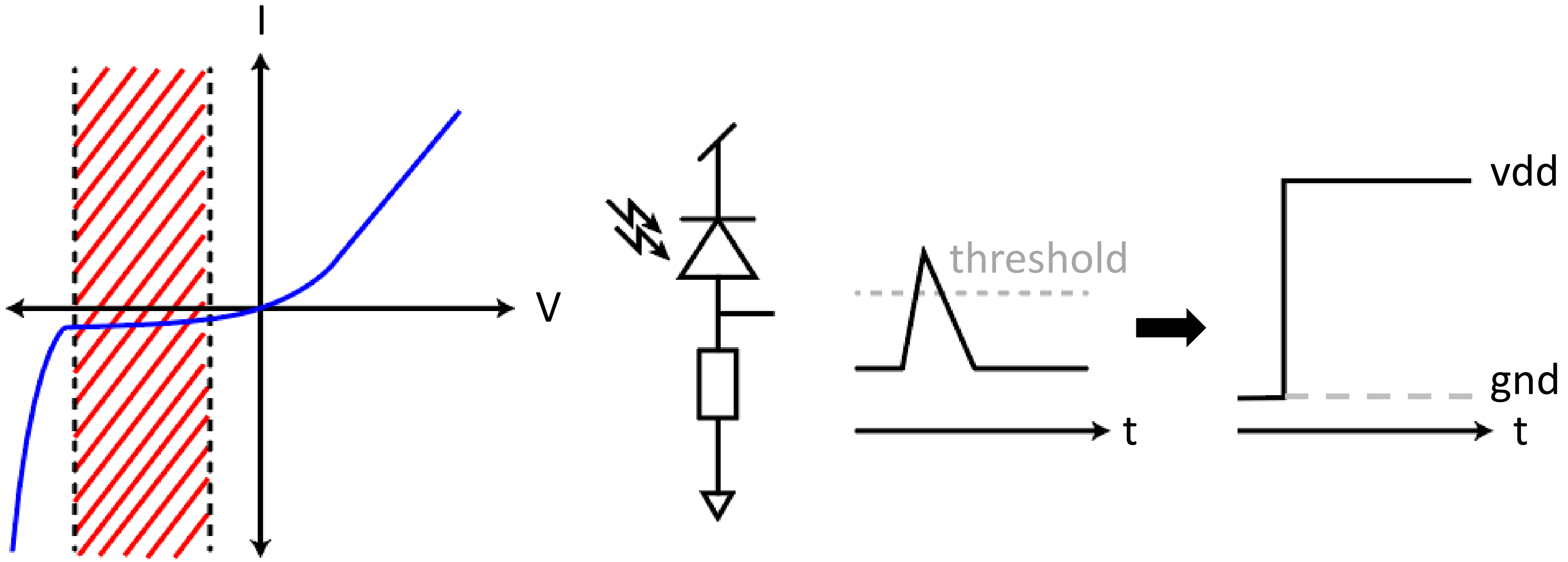




<Cross Section View and Block Diagram of the ITS Pixel>

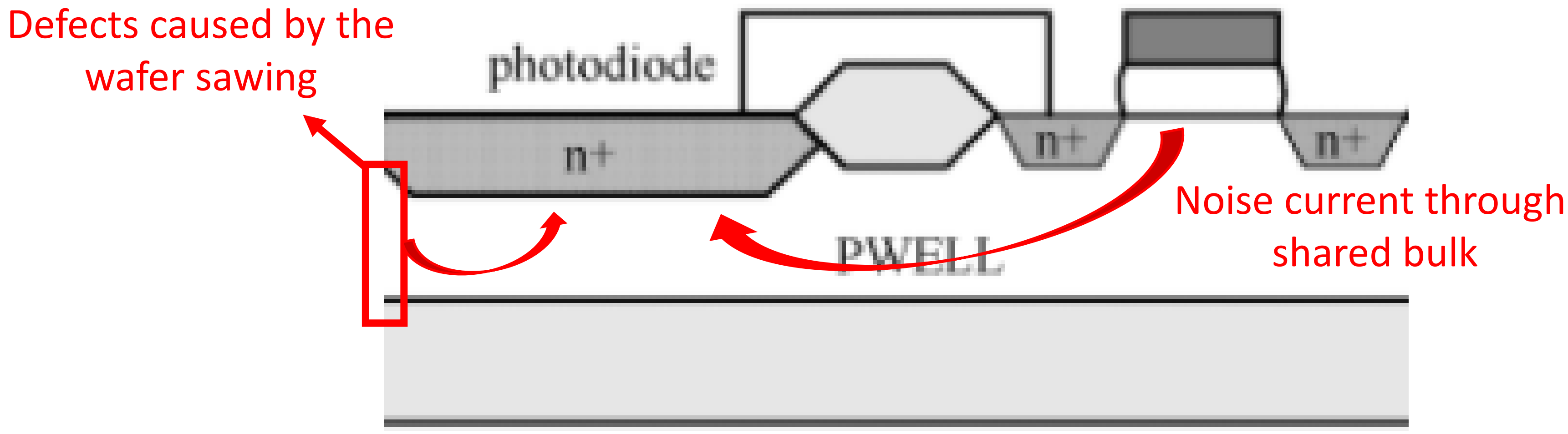
Target of the Device (APD)

- Avalanche Photo Diode (APD)
  - Linear region of the photo diode
  - Low gain operation for incident light
  - Digital output without any peripheral circuit (<100ps jitter performance)



Effect of the Injected Carrier

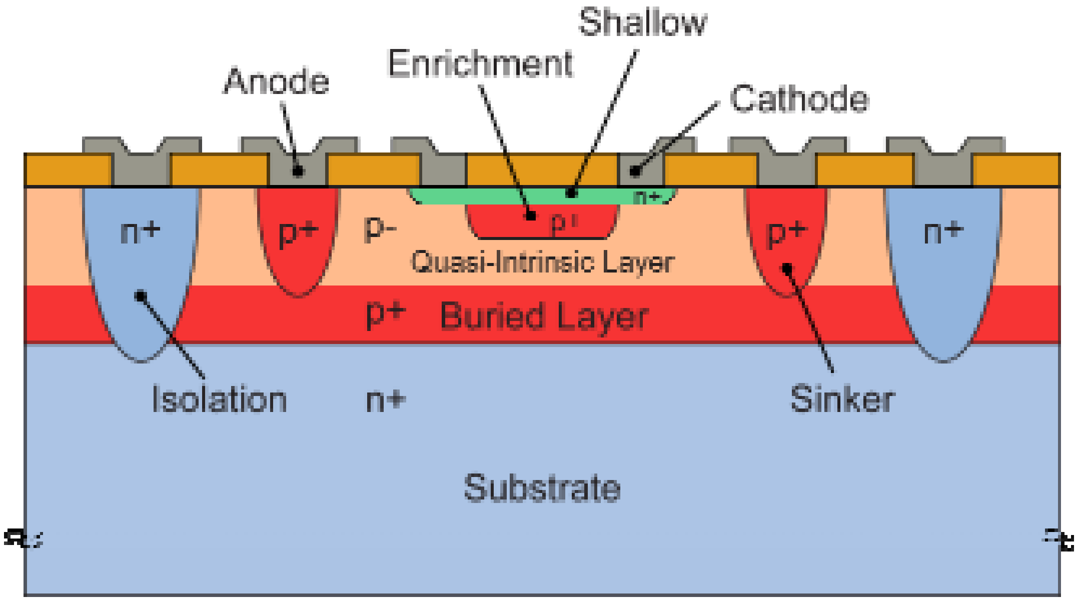
- Noise Source of the Silicon Device
    - Wafer sawing cause the defects at the side of the device
    - Semiconductor surface has many defects due to stress during process
    - Shared bulk cause the noise current from the integrated circuit to device
    - **Causing the avalanche multiplication without any incident light (isolation is needed)**



<Cross Section View of the Integrated Circuit and Photodiode>

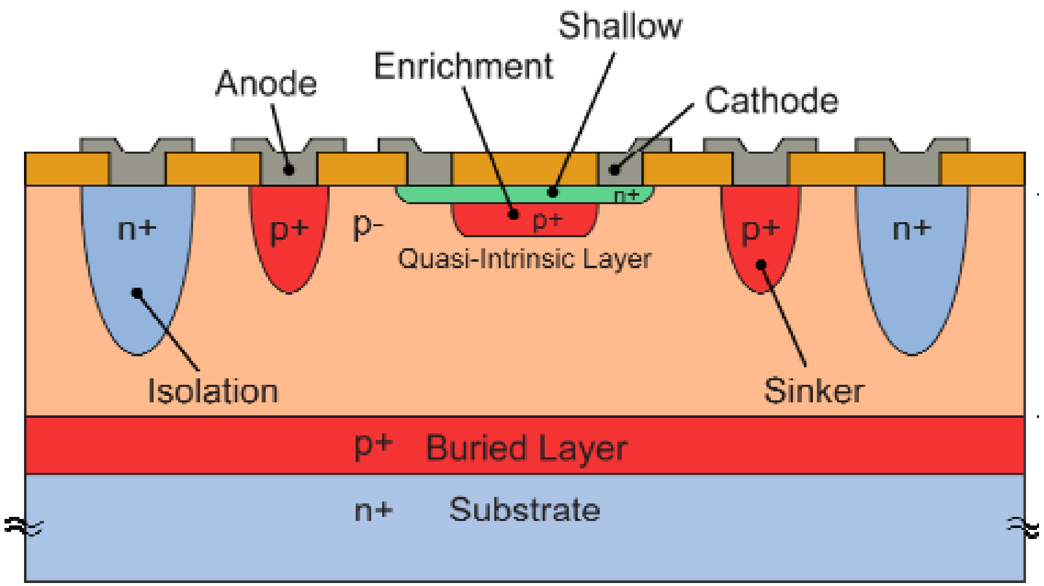
Electrical Isolation of the Junction

- Isolation for Double Epitaxial Avalanche Photodiode
  - P+ buried layer and sinker makes the low resistivity path (active region -> anode)
  - N+ isolates the anode with reverse biasing the isolation-anode junction
  - Shallow quasi-intrinsic layer can be fully isolated with the shallow diffusion



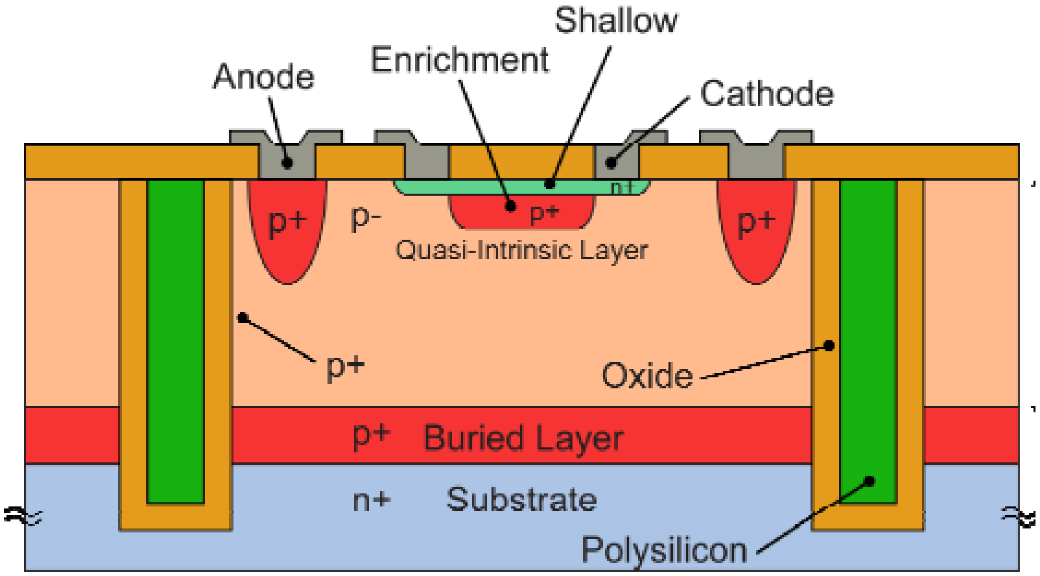
Electrical Isolation of the Junction

- Deeper Quasi-Intrinsic Layer
  - Photon efficiency can be improved with thicker quasi-intrinsic layer
  - Depth of the shallow diffusion is not enough for full isolation
  - Deep trench isolation can be the solution



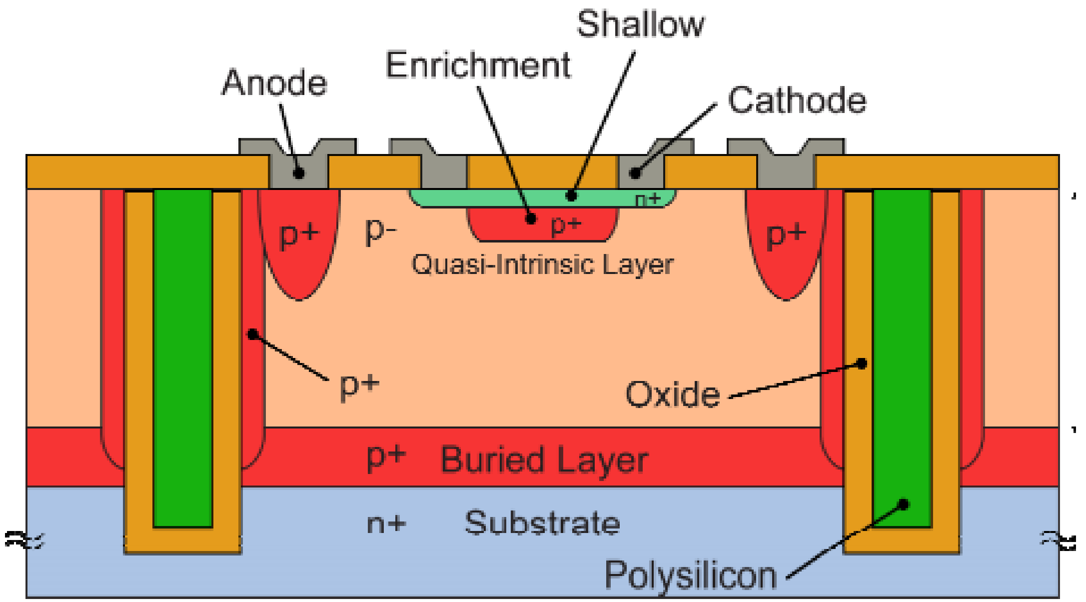
Electrical Isolation of the Junction

- Deep-trench with Dielectric Isolation
  - Deep-trench process has larger aspect ratio which leads to smaller dimension
  - But still, there is a large resistive path between active region and anode



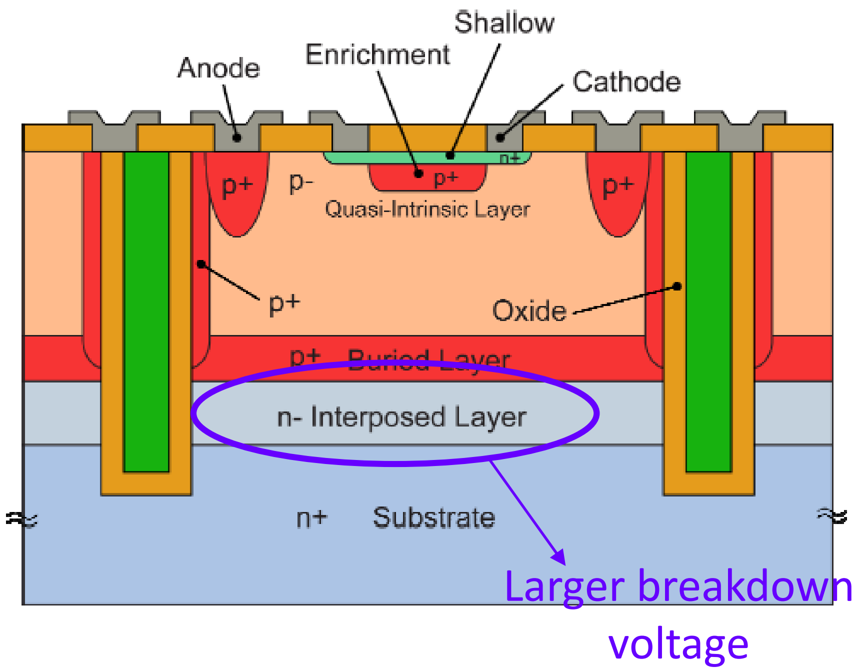
Electrical Isolation of the Junction

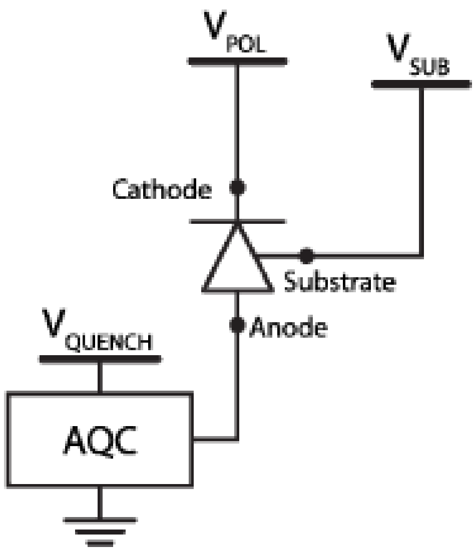
- Trench Wall Implantation
  - Increased series resistance reduce the avalanche growth rate (larger timing jitter)
  - Trench wall implantation makes the low resistive path from active region to anode



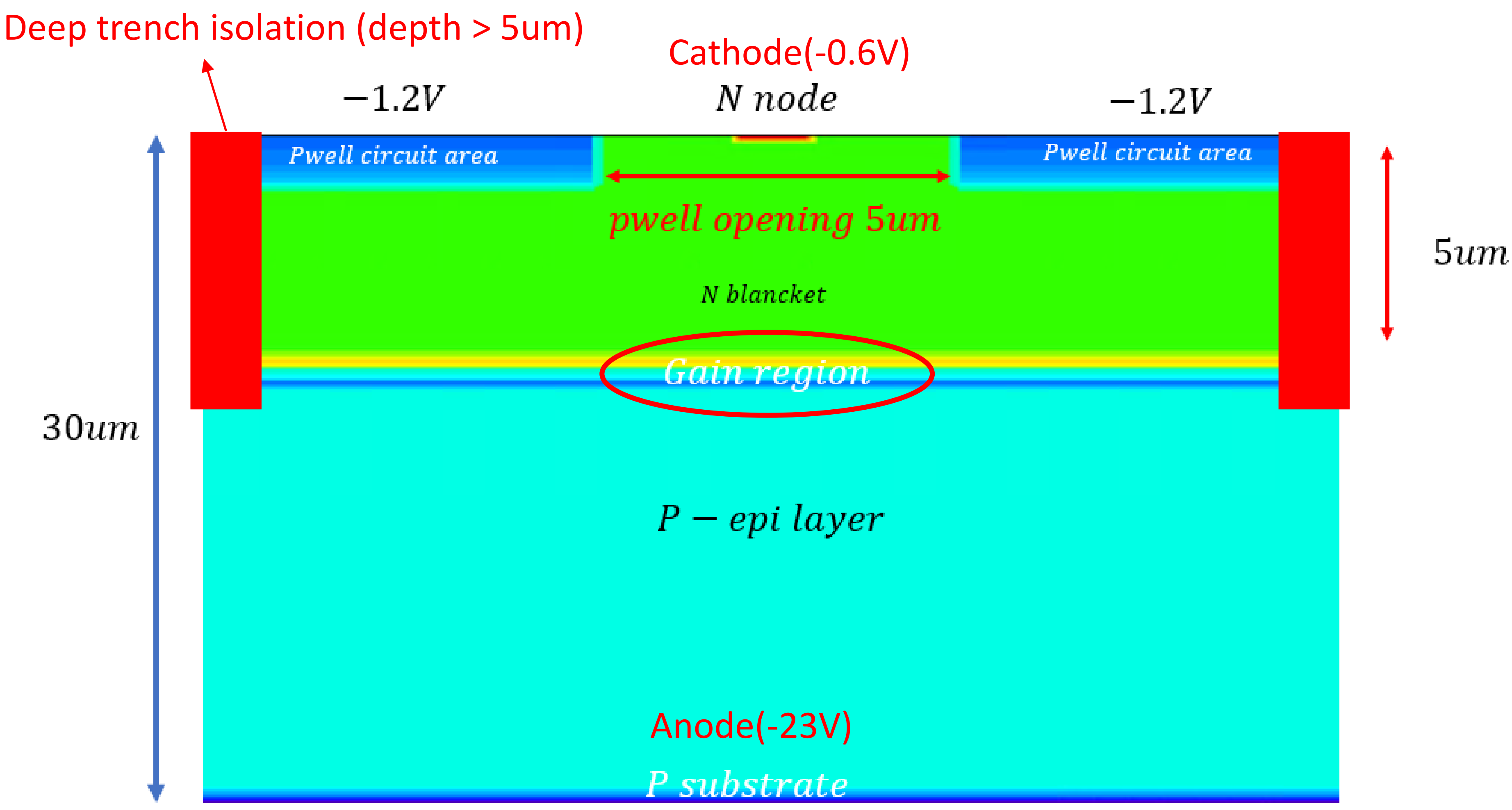
Electrical Isolation of the Junction

- Reverse bias and the breakdown voltage issue
  - $V_{quench} < V_{sub}$ → maintaining the reverse bias between the **n-sub** and **p-buried**
  - $V_{sub} < V_{BD,a-sub}$ → preventing the breakdown of the junction itself





Cross Section View of the Presented APD



Proposed APD can be isolated with the deep trench isolation

Reference

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