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Solidtron

Increased Pulse Rep. Rates for Solid State Thyratron Replacements

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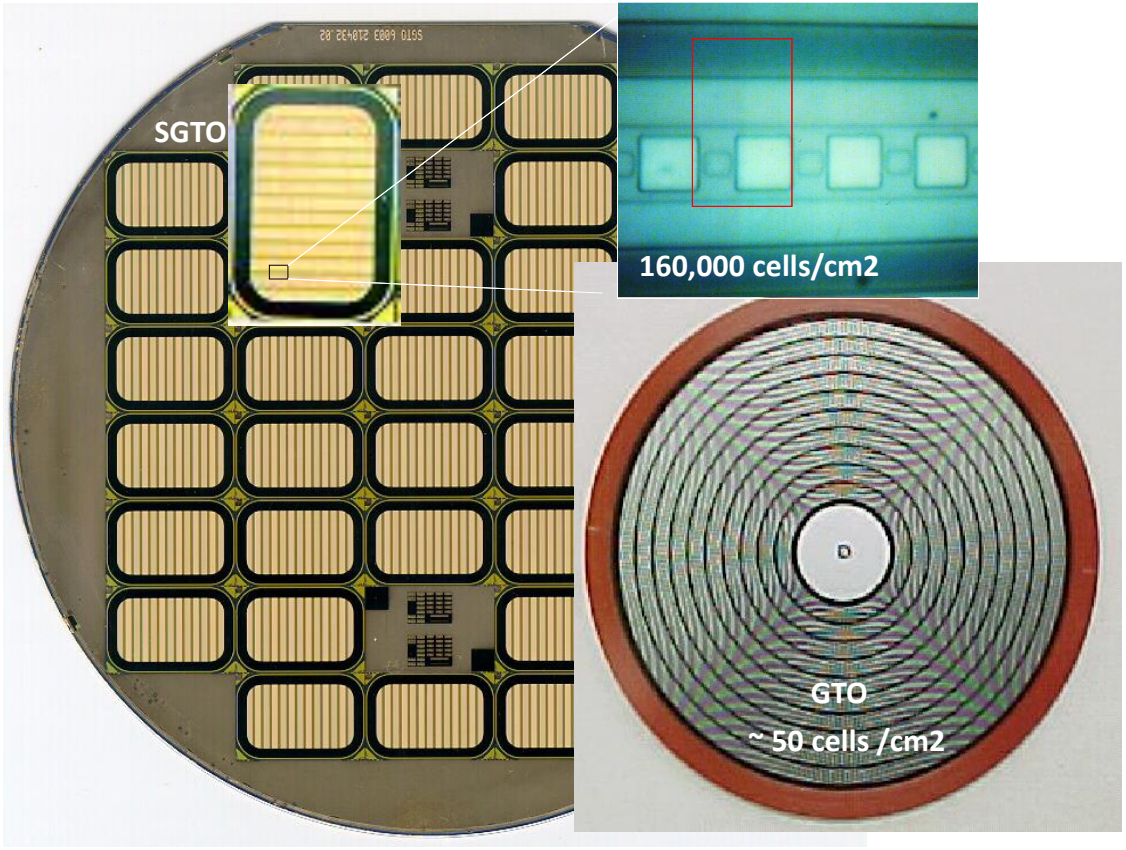
Outline

- Introduction to Solidtron's Enabling Technology
  - Pulse discharge targeted designs
- Solidtron Performance
  - Discharge Performance
  - Increased Pulse Repetition Rate Strategy/Results
- Solid State Discharge Switch Replacements
  - Motivation
  - Approach
  - Experimental results
- Summary
- Questions

Super-GTO Vs. GTO

SGTO is an IC foundry-fabricated GTO mated with Silicon Power's proprietary low inductance ThinPak package



SGTO Advantages:

Cell structure 3000 x denser

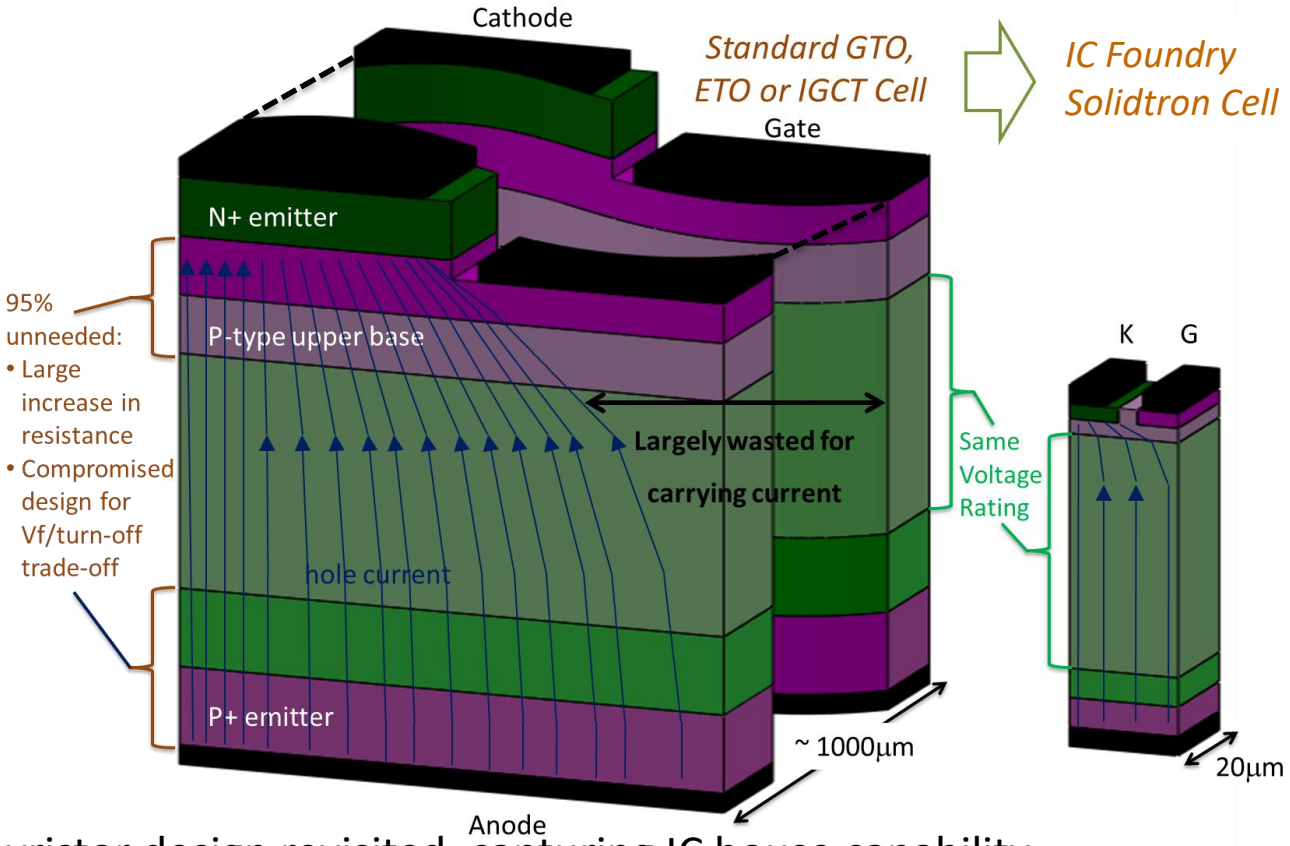
Upper transistor >100x improved

- Forward drop greatly reduced
- Three times lower turn-off switching loss
- ***Turn-on improved by 2 orders of magnitude***

Die sizes from 3x3mm to 15x22mm in 200mm IC foundry providing very high yield, repeatability and uniformity!

Solidtron: The Enabling Technology

GTO Versus Solidtron, Fundamental Differences

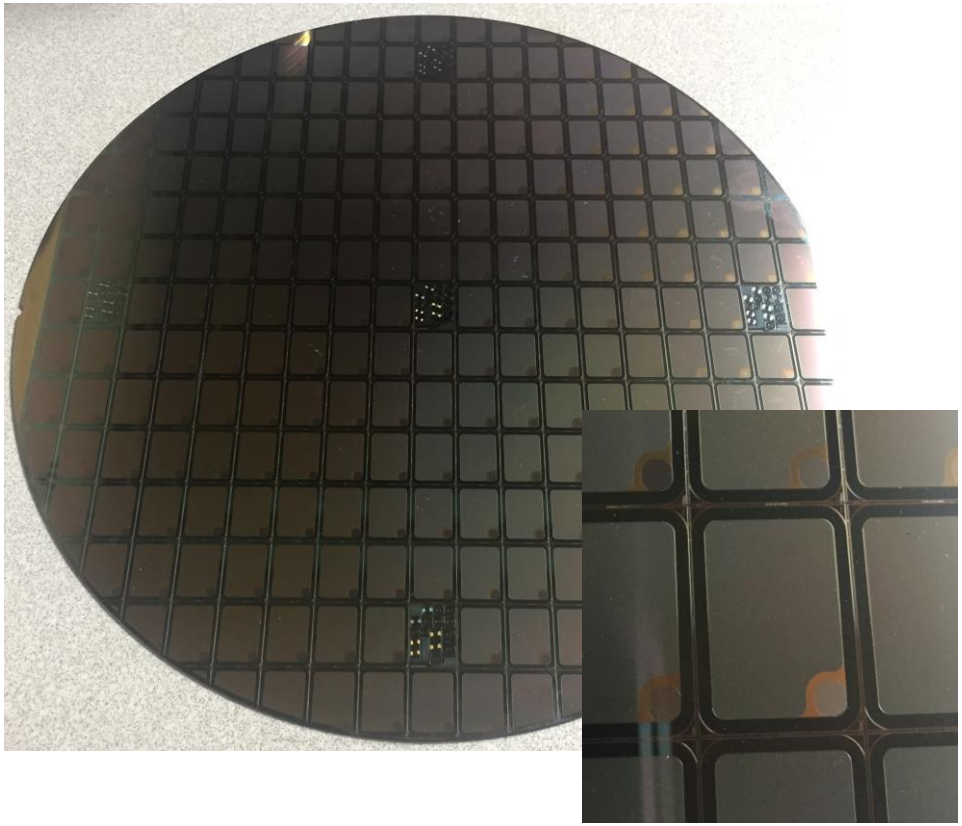


Traditional thyristor design revisited, capturing IC house capability

- Higher cell density improves current uniformity, drastically improving $^{di}/_{dt}$ capability
- Upper base doping profile improved for higher gain
- Metal interconnects improved, increased upper transistor gain and electrode bonding area

Solidtron Vs. Super-GTO

Solidtron follows SGTO strategy, focusing on pulse discharge versus turn-off applications



Solidtron Advantages

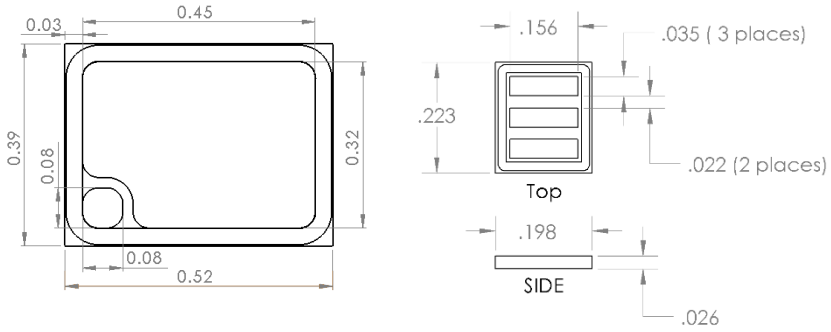
- Cell density further enhanced
- Emitter area maximized
- Internal metal interconnect density improved
- Upper transistor gain further improved
- Increased cathode bonding pad area

8 inch starting material and improved manufacturing process further improving yield while driving cost down

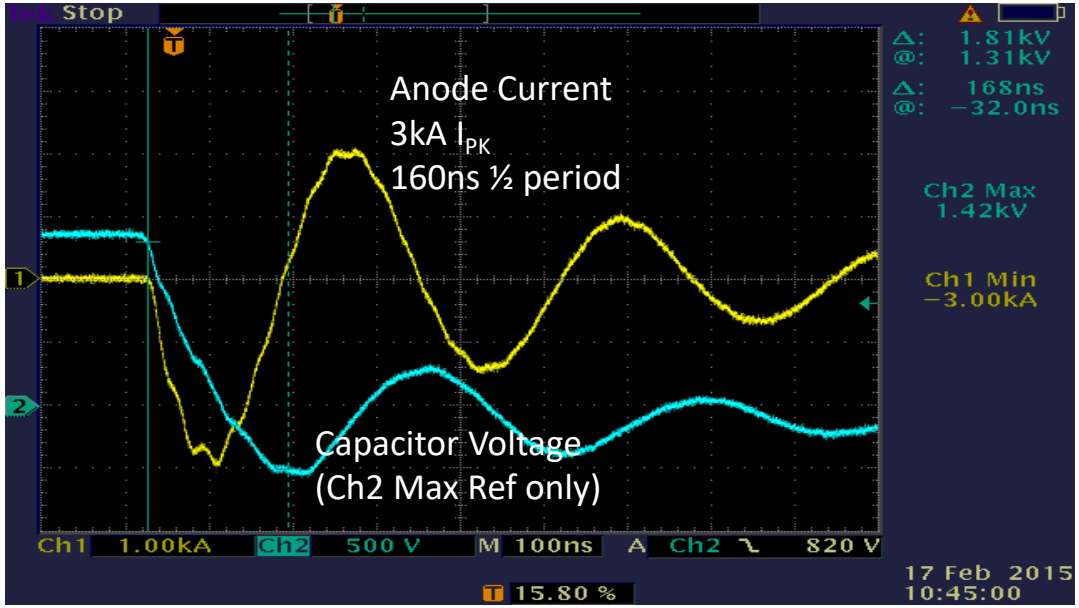
Solidtron Performance: Hyper-Fast

1600V Solidtron Product line:

- Simple gating schemes (low power, easy isolation)
- Unmatched $^{di}/_{dt}$ capability (>200kA/µs observed)
- Easily implemented in series/parallel configurations



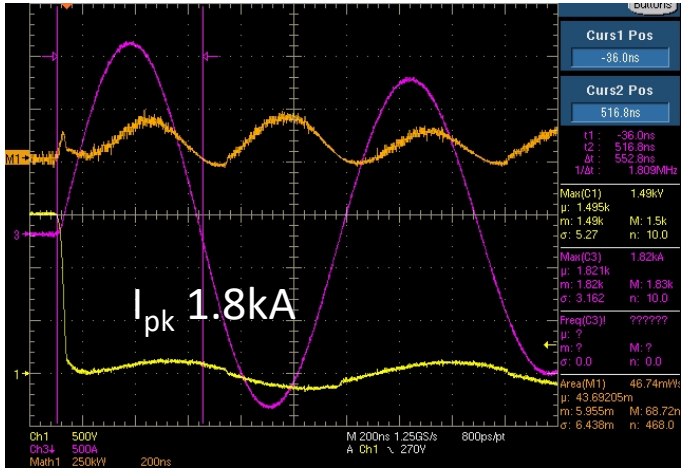
Turn-on delay	<90ns
Jitter	<500ps
Fall time	<40ns
di/dt	>200kA/µs



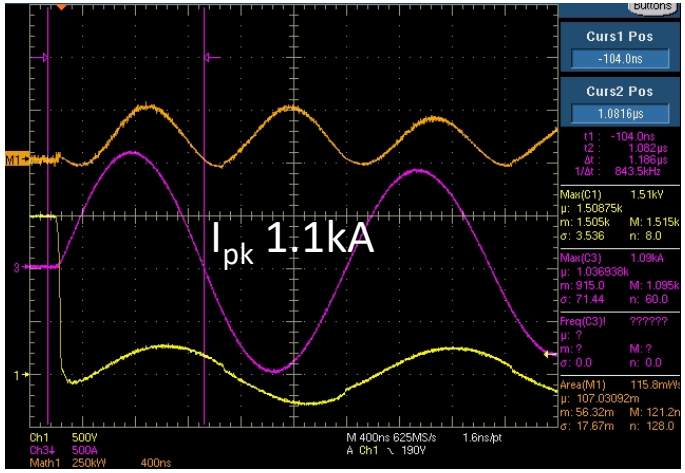
170ns ½ cycle ring down – Yellow = Anode Current, Cyan = Capacitor Voltage

Solidtron Performance: Hyper-Fast

550ns ½ pulse width ring down

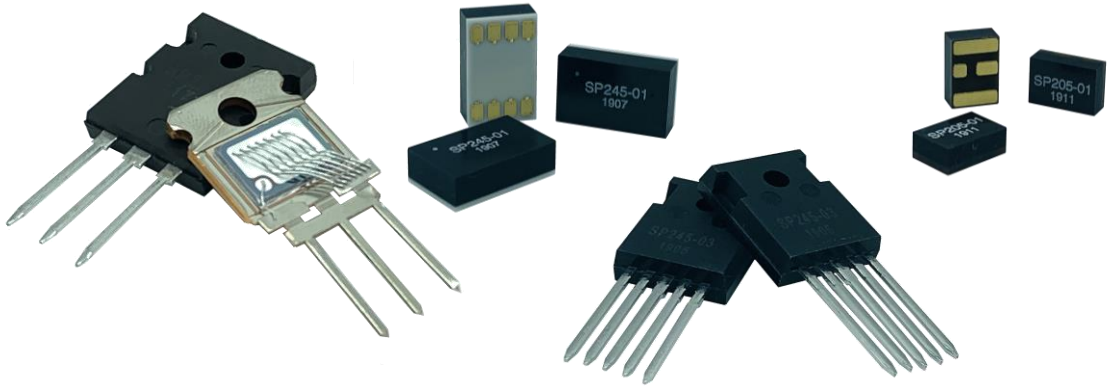


1µs ½ pulse width ring down



Solid state discharge switch offers:

- Rugged yet simple gate trigger
- Repeatable fabrication and performance
- Bidirectional current flow capability
- Very high MTBF, minimizing down time

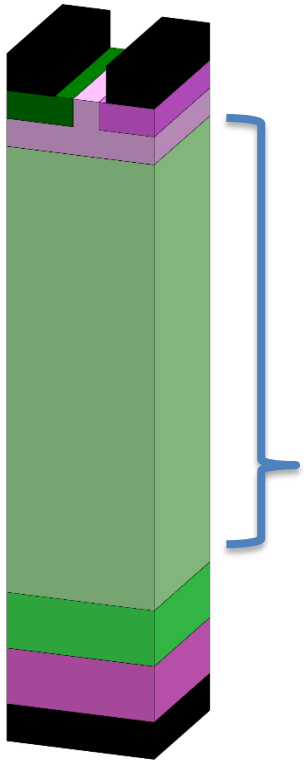


Hyper-Fast 1600V Solidtron Discrete products

Available in:

- TO-247
- TO-264
- Custom SMT packages

Solidtron: Increased Switching Speed



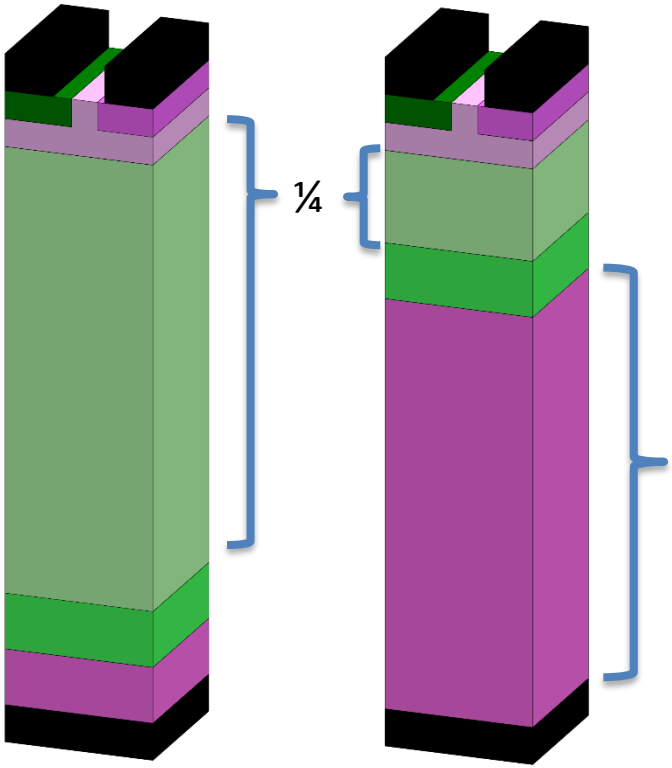
Lower-base width and doping concentration determines BV

Punch-through design:

- Higher BV for given device thickness
- Allows bipolar current conduction
- Improves turn-on speed
- Reduces commutation time

Solidtron: Increased Switching Speed

Physically narrower lower-base is employed



Implementing lower voltage devices improves commutation time

Can be thinned after processing to reduce R_{on}

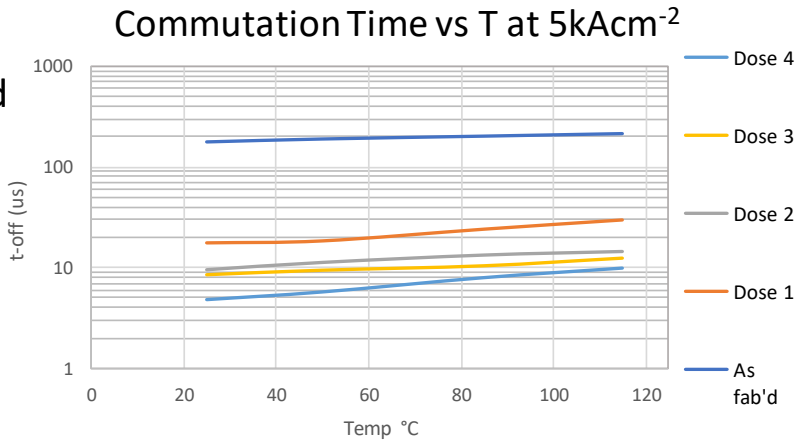
One factor contributing to commutation time is stored charge remaining in lower-base

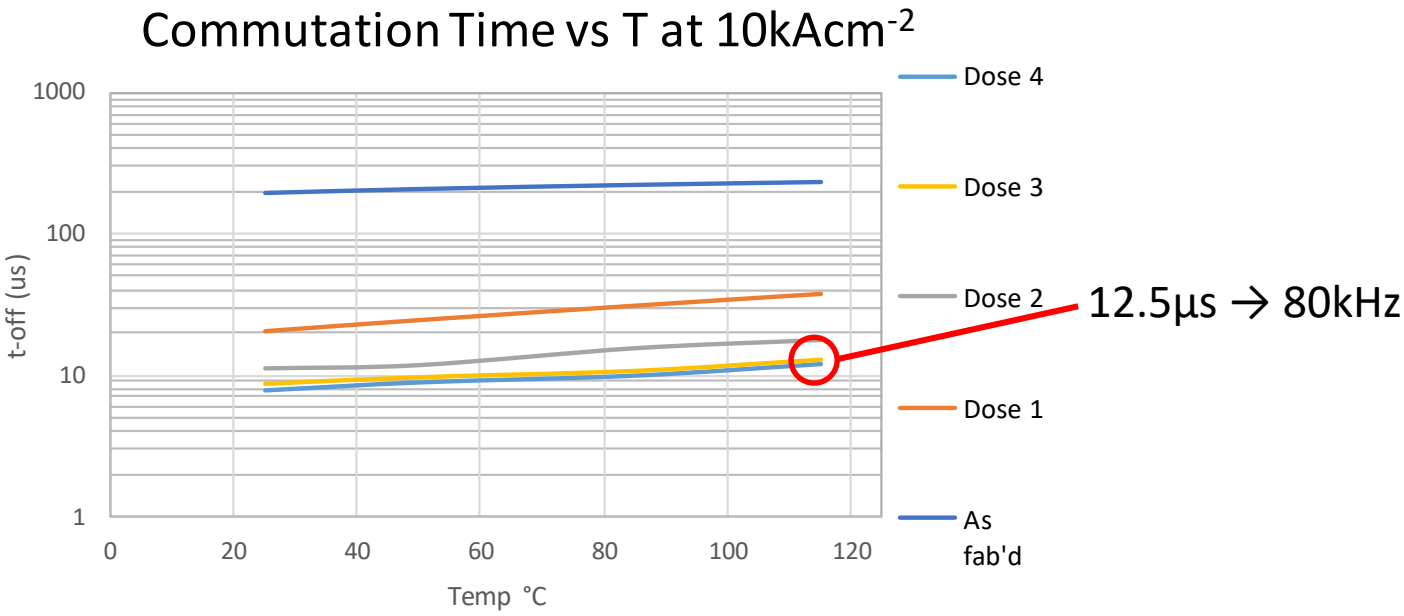
- Thinner lower-base results in less stored charge
- Thinner lower-base reduces distance required for diffused carrier to reach emitter

Post-Fabrication Speed Enhancement

Reducing Minority Carrier Lifetime:

- Increases pulse repetition capability
  - Decreases commutation time without the need for complicated gate drive
- Post-fabrication process
  - Enables 1 design to cover range of applications
- Low-cost, high-volume capable process
- Demonstrated an 18x improvement in commutation time at 110°C and 10kAcm^{-2}
- Favorable tradeoff for R_{on} and $I_{Leakage}$

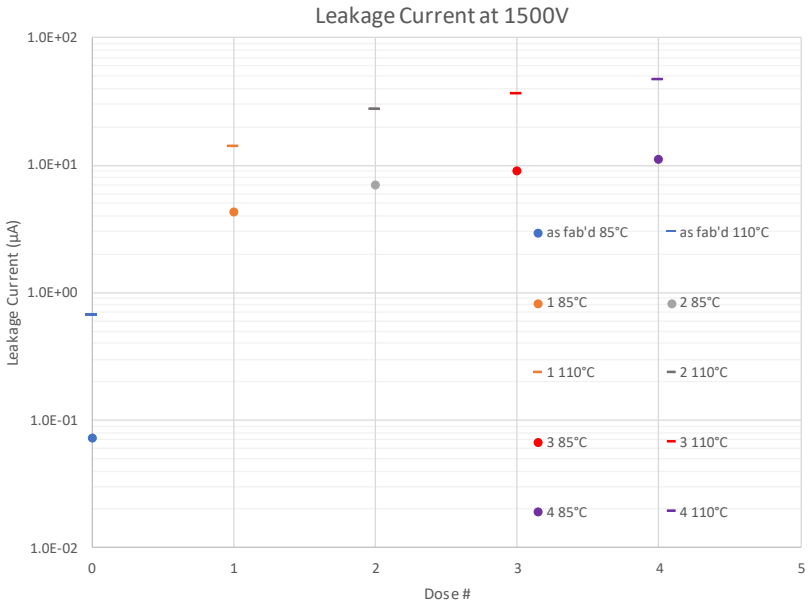


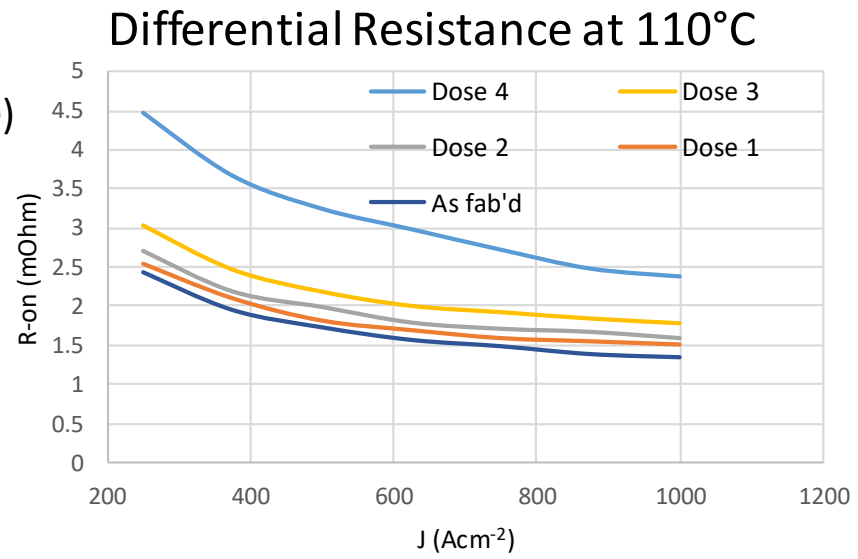


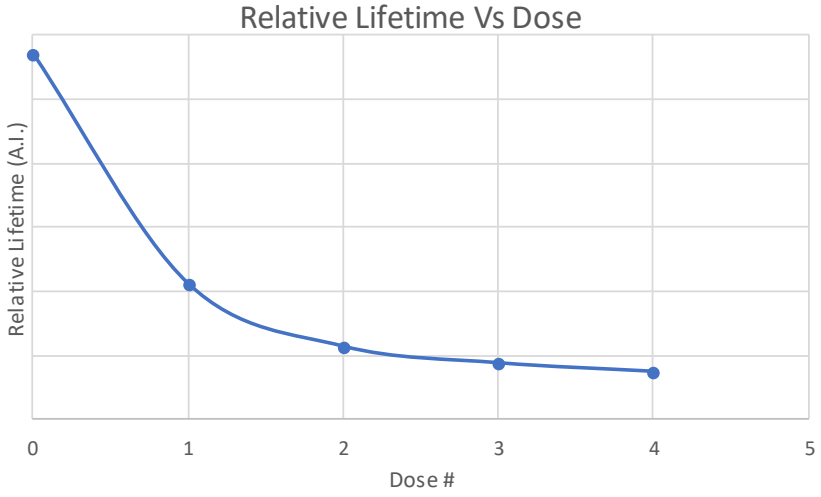
Post-Fabrication Speed Enhancement

Reducing Minority Carrier Lifetime Tradeoffs:

- Lower base gain is reduced, ↑ R_{ON}
- Lower τ increases generation current (↑leakage)
- However, small ↑R_{ON} (<2x) for almost 20x improvement in pulse rep rate







Solid State Discharge Switches

Motivation

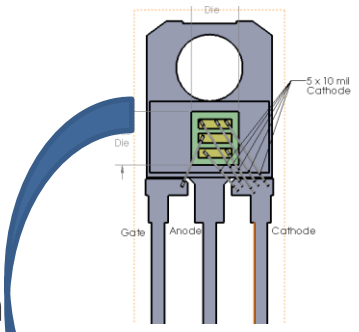
- **Compliance with RoHS**
- **Eliminate conditioning requirements**
- **Eliminate requisite heaters**
- **Simplify gating**
  - Built in gating requires TTL/Optical trigger and DC power supply
- **Improve efficiency**
  - In both energy transfer and off-state conditions
- **Improve turn-on delay and jitter**
- **Increase usable lifetime**
  - No terminal erosion
- **Eliminate liquid cooling requirements**
- **Increase mechanical installation flexibility**
- **Improved performance over IGBT/SCR-based solid state switch replacements**

Hyper-Fast Solid State Thyratron Replacement

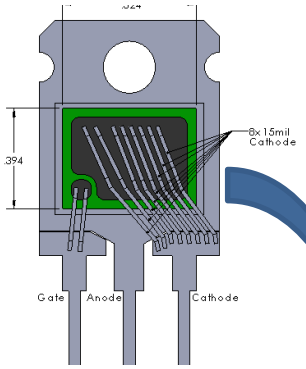
40kV SSTR-1 (Twin Stack)

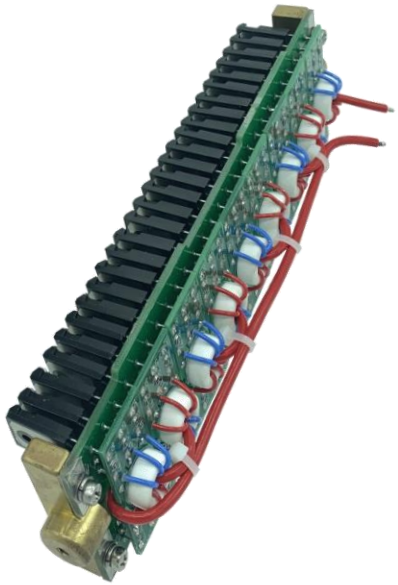
- Initial TO-247 version demonstrated 365k pulses
  - 3kA, 300ns square wave
- Similar 20kV and 60kV derivatives planned to complete the product offering
- Negligible power dissipation in off-state (snubber resistors much higher in value)
- TO-264 version offers up to **30x** increase in action

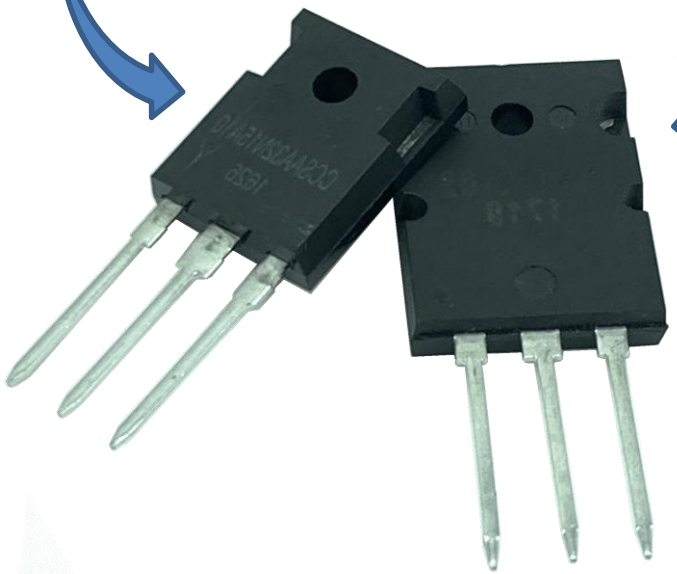
TO-247: SP245-03



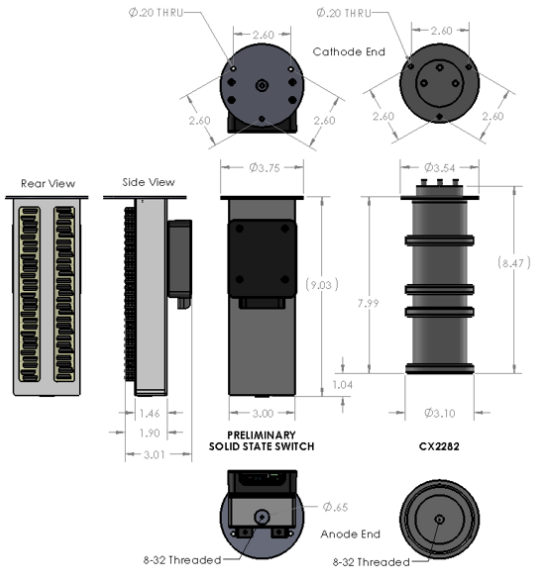
TO-264: SP275-02

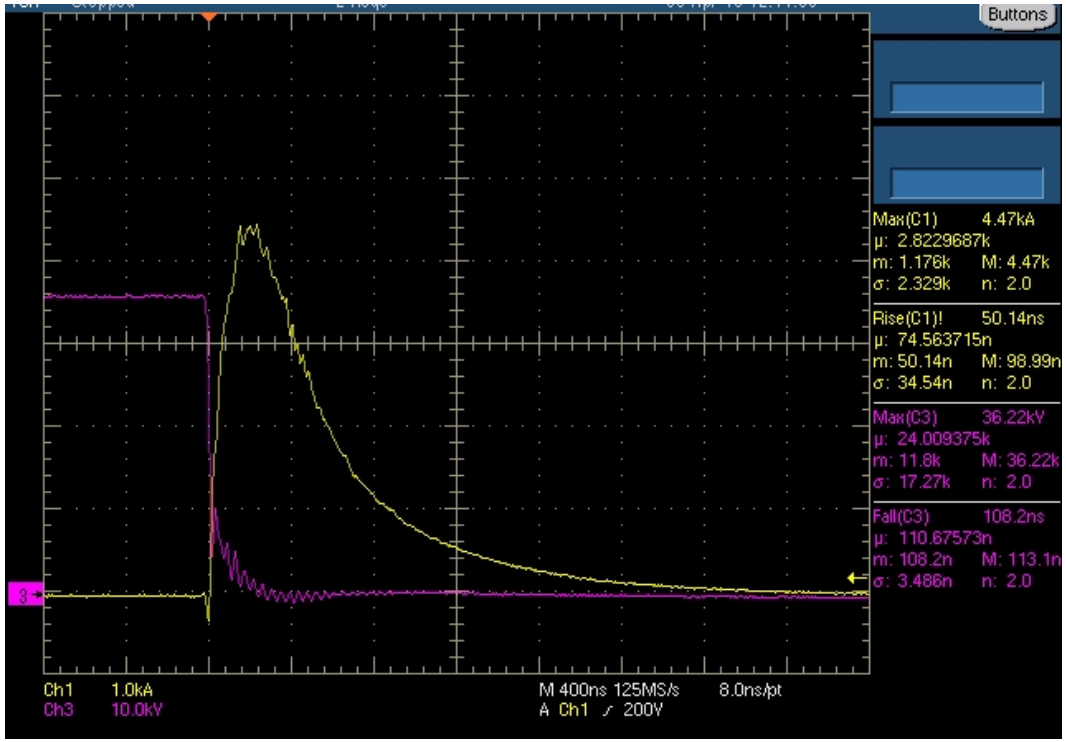






Solid State Thyratron Replacement





40kV SSTR-1 (Twin Stack) Vs. e2v CX2282

Hyper-Fast 1600V Solidtron

- $^{di}/_{dt}$ capability is >200kA/μSec
- Fiber Optically Triggered
- Small size - 9” Tall, 3.75” Base diameter
- Voltage capability of 40kV

- Yellow - 4.7kA Peak Current w/average $^{di}/_{dt}$ of ~60kA/μSec (Circuit Limited)
- Magenta - 36kV Discharge

Summary

- RoHS compliance
- Unparalleled solid state $^{di}/_{dt}$ capabilities
  - Hyper-fast demonstrated 200kA/μs
- $f(i(t), \tau)$ capability, determined by experimental and/or sim data exceeds most if not all commercially available gas or solid state thyratrons available
- Designed with modular, scalable sub-assemblies
  - Enables fitment for most thyratron or ignitron applications