

The Ideal Switch™

Enabling the electrification of everything:
Milliwatts-to-kilowatts, DC-to-light.

Oct 2020





1879

Menlo Park, NJ

Thomas Edison patents the Circuit Breaker.

Today, switches are everywhere.

It's the most ubiquitous electronic component.

In our homes.

- Managing our heat, AC, & lights.
- Our appliances are loaded with them.
- Circuit breakers that keep it all safe.

At work.

- Control the elevators, lighting, HVAC.
- All our computers, servers, comms.
- Manage factories and all equipment inside them.

In our cars.

- Unlock the doors and start the engine.
- Turn on and tune the radio.
- Control the wipers, windows.
- Manage the battery.

The world at large.

- Switches control the electricity flowing from power plants to the grid to our homes.
- Switches control the data zipping around the world to our computers and smartphones.



Two types of switches power today's world.

But, they're full of compromises.

ELECTROMECHANICAL

RF



High Power RF Coax
High Isolation
Low Insertion Loss



RF Surface Mount
High Isolation
Low Insertion Loss

POWER



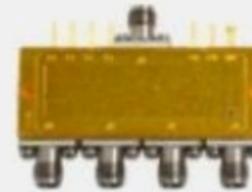
AC/DC Power Relay



Surface Mount Signal Relay

SOLID STATE

RF



PIN diode
High Power
Fast Switching
Long Life



CMOS
Low Power
Fast Switching
Long Life

POWER



AC/DC SSR w/heatsink
High Voltage
High Current



DC SSR w/heatsink
High Current

The Good: Can handle lots of power

- Metal contacts: low loss and great linearity for RF signals.
- Can handle high power, eg circuit breakers or RF relays.
 - "On" - doesn't generate heat under high currents.
 - "Off" - air-gap open, fully isolated.

The Bad: Big, slow, clunky and expensive

- Moving parts limit switch rate, speed and reliability.
- Manufacturing inconsistencies (some are still assembled by hand).
- Sensitive to mechanical shock, vibration and humidity.



The Good: Small, fast

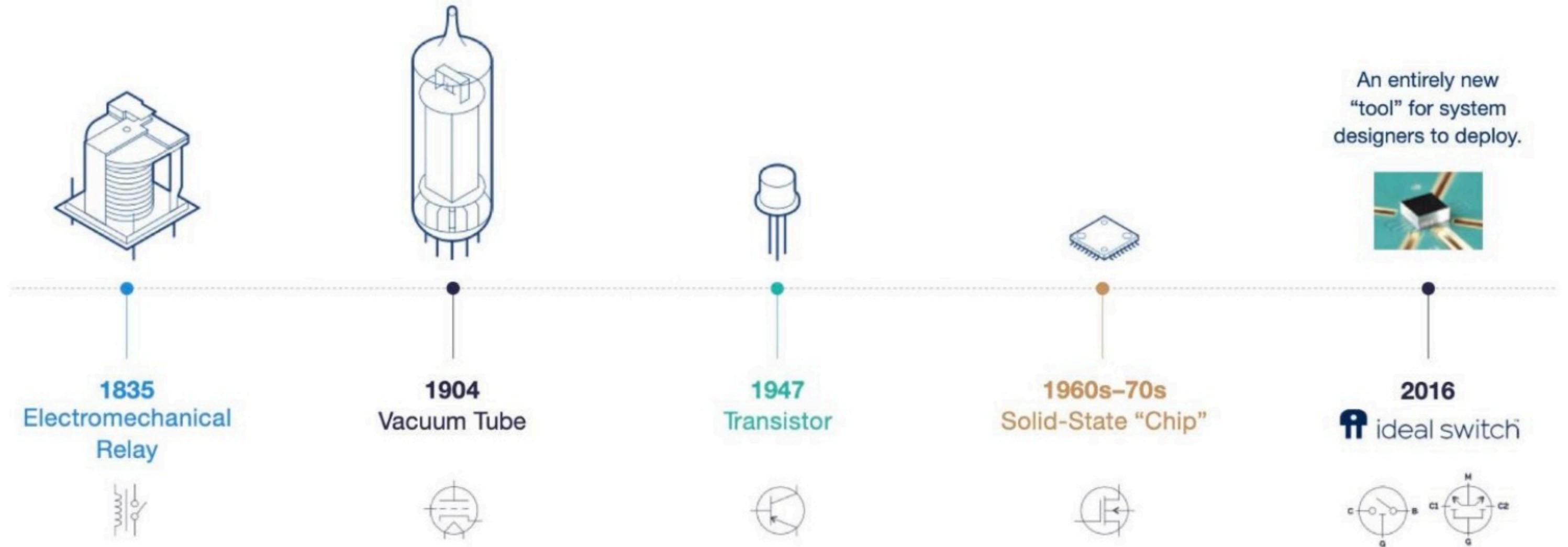
- Small size allows for lightweight, tighter packing.
 - Inexpensive to manufacture at scale.
 - Fast, silent switching.
- Immune to mechanical shock, vibration, humidity.

The Bad: It's a semiconductor, not a conductor

- "On" - non-zero losses, generates heat requiring large heatsinks.
 - "Off" - always on, leakage currents, waste power.
- Non-linear effects of transistor distorts RF signal integrity.

But we're still using technology from the 1830s.

And the last major step-change is from the 1970s.



The perfect switch:

In theory

VS

 **ideal switch**TM

When "ON" it's a wire with zero resistance.

As low as 0.005Ω (5 Milli-Ohms).

When "OFF" it's an open circuit, with infinite resistance.

Greater than $10,000,000,000\Omega$ (10 Giga-Ohms).

It takes no power to turn it on and keep it on.

Less than 0.000000000025 (25 Pico-amps).

It handles signals from DC to any frequency.

DC to 50GHz+.

It's small, fast, silent, and lasts forever.

Small, fast, silent, and can switch 3B+ actuations.

Costs \$0 to make.

Built with low-cost, scalable **semiconductor** process . . .
...but is a true metal **conductor**.

Menlo's "Rule of 99"

The Ideal Switch delivers game-changing improvements to Size, Weight, Power and Cost (SWAP-C)

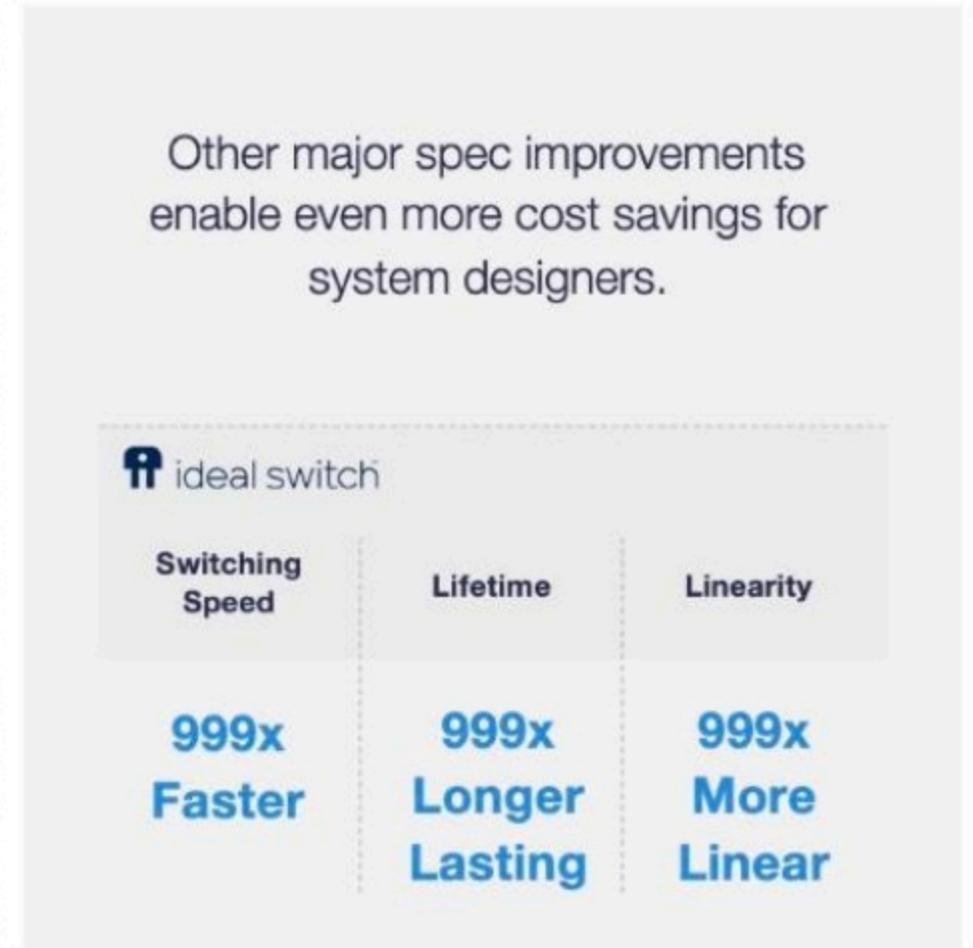
Size & Weight



Power Consumption



Total Cost of Ownership



The Ideal Switch story.

It starts, as most things do, with Thomas Edison.



1879

Edison patents the circuit breaker.



1892

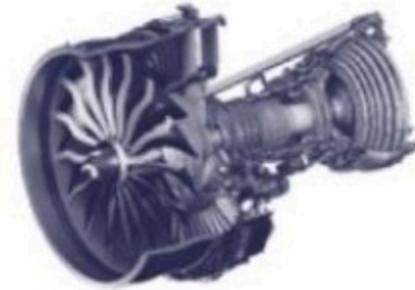
General Electric formed, combining Edison's various companies.



Over 100 years of experience in **high voltage, high reliability** industrial controls.

2004

GE starts effort to reinvent the circuit breaker with a MEMS switch.



GE develops core IP, including **high temperature, high reliability** metal alloy science.

2016

Menlo Micro is formed

Why now? Why Menlo?

We're a company engineered to build the Ideal Switch.

- **Why Menlo was formed**

To scale manufacturing and drive down costs by selling into applications beyond GE's businesses.

- **Capitalized for growth**

Over \$77M raised since founding in 2016

- **Strategic partners for scaling**

GE, Corning, Microsemi all Tier 1 players with strategic business opportunities.

- **Go-To-Market**

Over 100K Ideal Switches shipped to Fortune 100 customer: GE Healthcare. Qualified GE supplier, ISO 2015 certified.

- **Achieved high bar for high-value medical applications**

MRI proof-of-concept leads to Defense, Communications, Test & Measurement contracts.

- **Currently sampling from new 8-inch commercial fab, production qualification Oct 2020**

Bringing high-power, high-reliability, low-loss switches to multiple end markets, beyond medical.


PALADIN

 **Microsemi**

 GE VENTURES

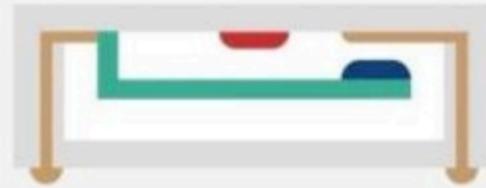
CORNING



Each GE MRI machine replaces over 100 PIN diodes with our Ideal Switch

Introducing the Ideal Switch.

Technology platform with
breakthrough innovations
in materials and processing.



Glass Cap

Beam

Contact

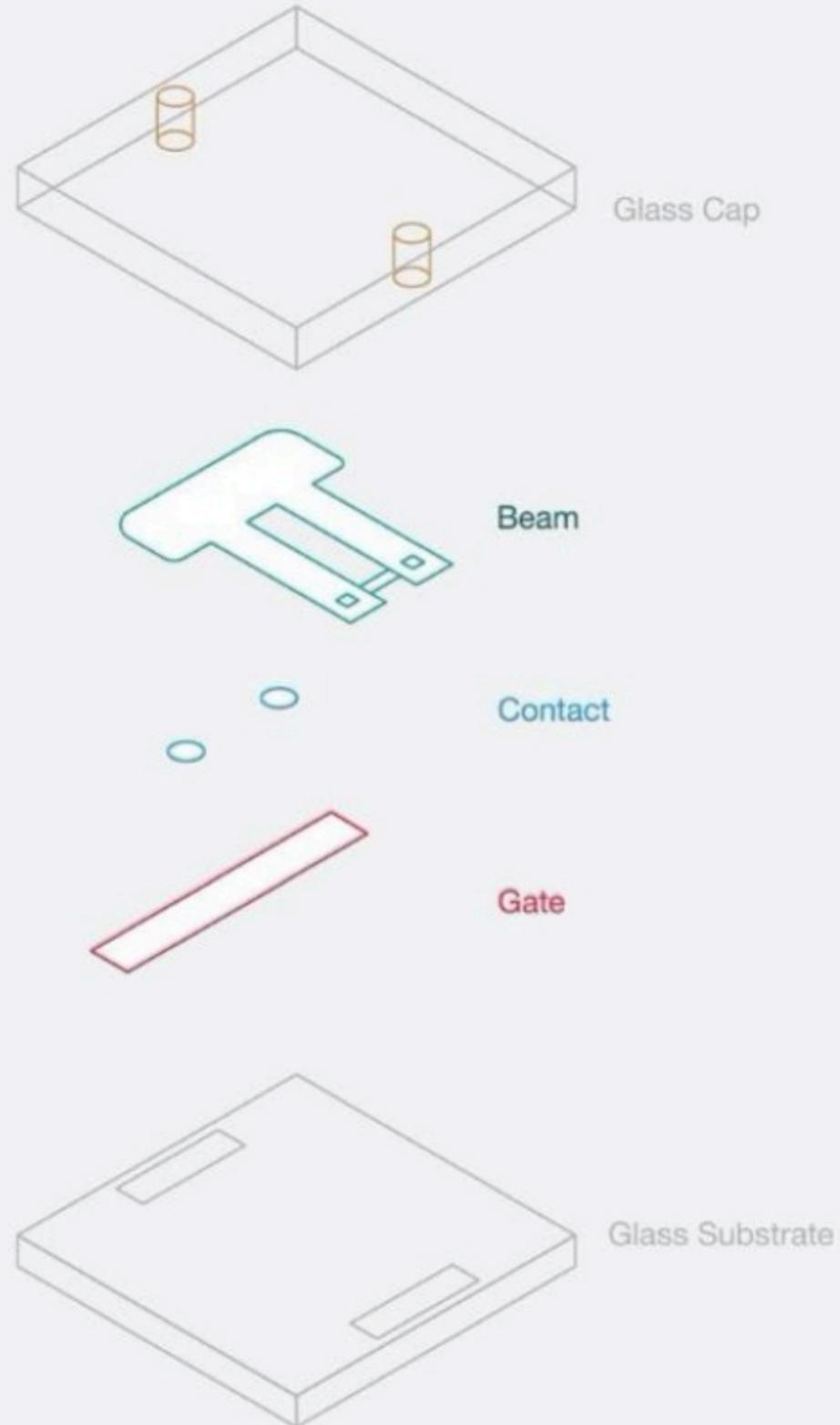
Gate

Through-Glass-Via

Glass Substrate

Introducing the Ideal Switch.

Technology platform with breakthrough innovations in materials and processing.



Unique Glass Packaging

- Better thermals & better power handling, improved RF performance

Highly Reliable

- >3B cycles spec, w/roadmap to >20B
- High-power capability

Through-Glass-Via

- Lower parasitics, lower resistance, small-size package, lowest cost

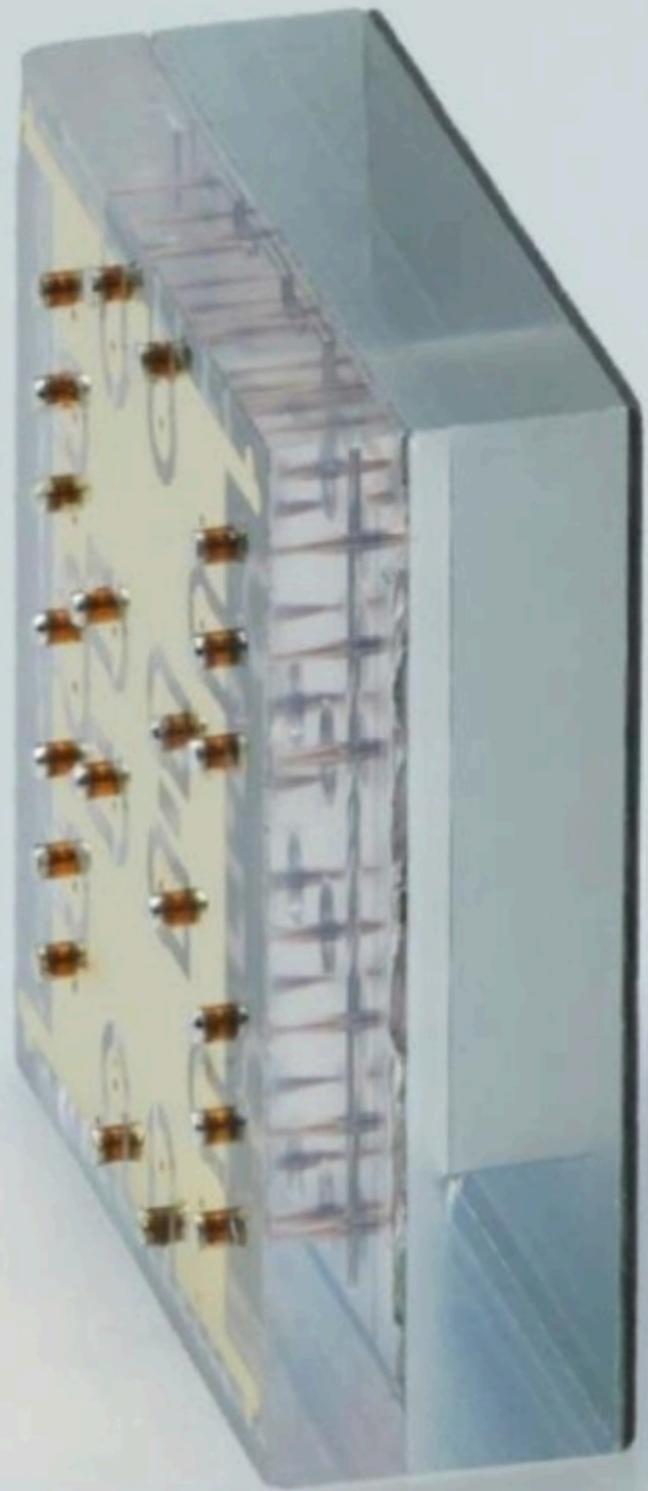
Simple & Scalable

- Simple design → lets us go very small (50 μ m \times 50 μ m unit cell)
- Small size → allows easy scaling for high power through massive switch arrays

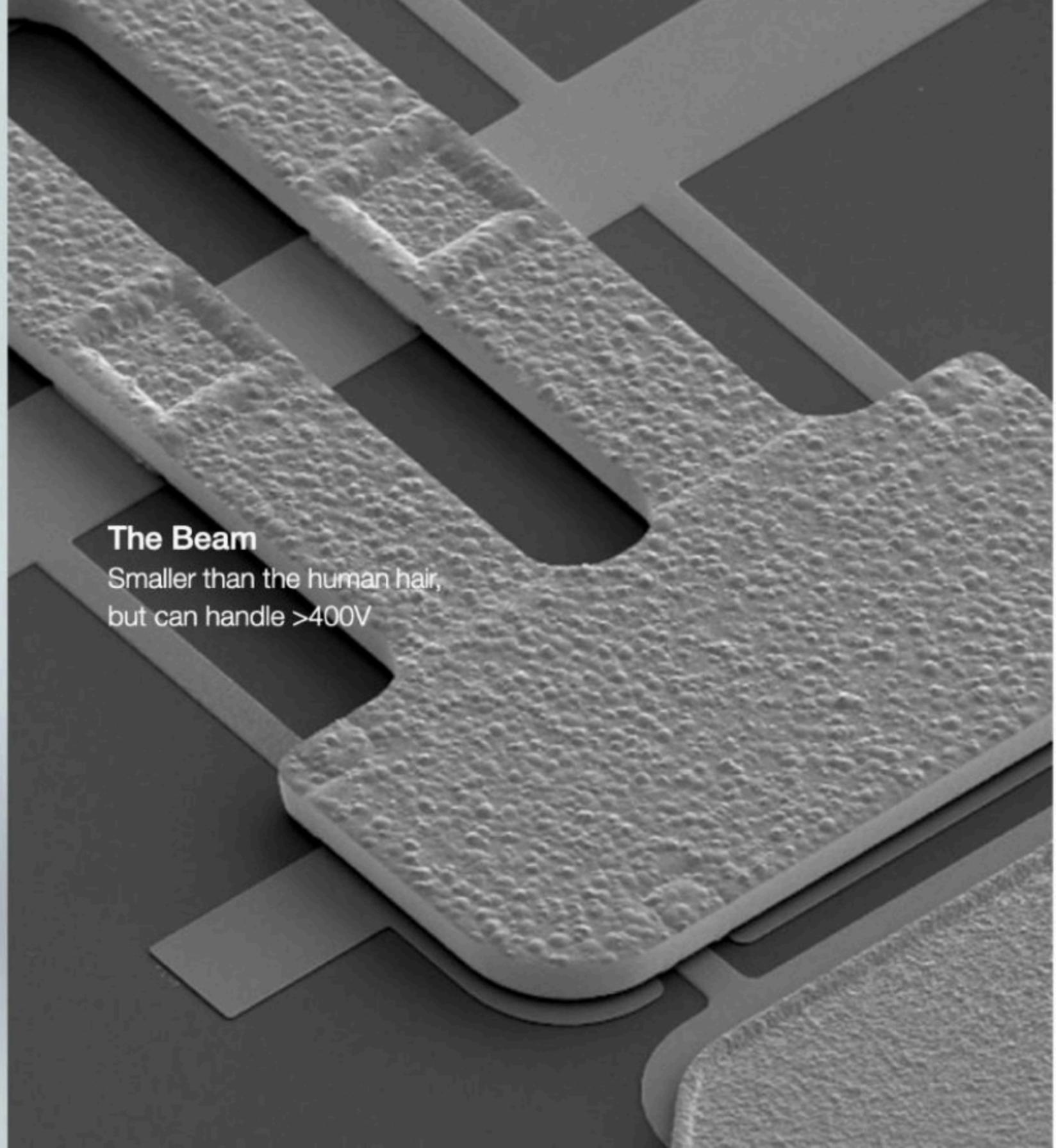
Scalable & Versatile

- Small size → easy to scale costs down with production volume
- Standard Process Design Kit to create many products
- Short design cycles → faster time to market

The Packaging
Close-up of
Through-Glass-Via



The Beam
Smaller than the human hair,
but can handle >400V



Fab-Friendly advanced materials

The secret sauce – highest reliability, superior performance, no compromises.

Menlo's beam's unique alloy goes well beyond existing ratings on:

- Power
- Reliability
- Temp
- Mechanical Strength
- Conductivity



Menlo's glass substrate and TGV-enhanced glass cap deliver high:

- Conductivity
- Manufacturability
- Isolation
- Design Flexibility



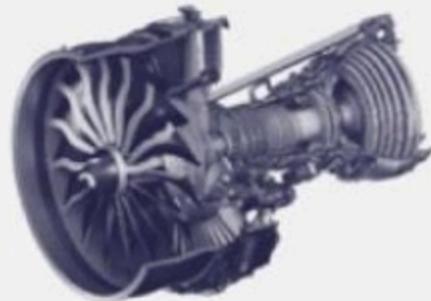
Leveraging GE's experience



Over 100 years of industrial power & controls: high voltage, high amps, high reliability.



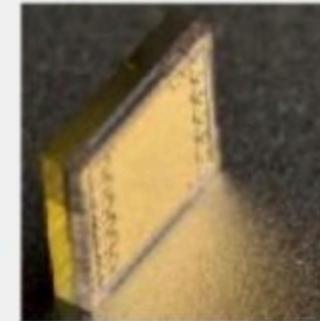
Decades developing alloys for extreme conditions: high temp, high mechanical demands, high reliability.



Leveraging Corning's partnership

CORNING

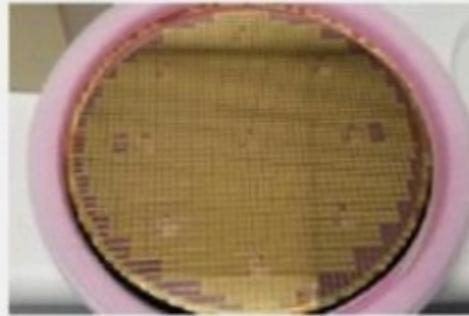
Over 100 years of industrial power & controls: high voltage, high amps, high reliability.



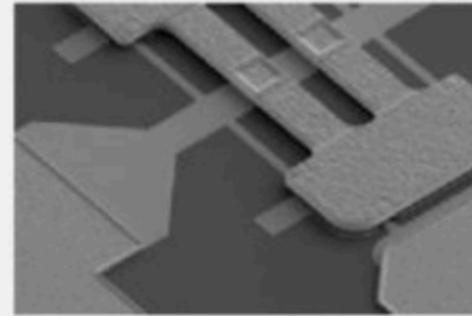
How is it made?

Revolutionary materials and processes combined with scalable semiconductor manufacturing techniques.

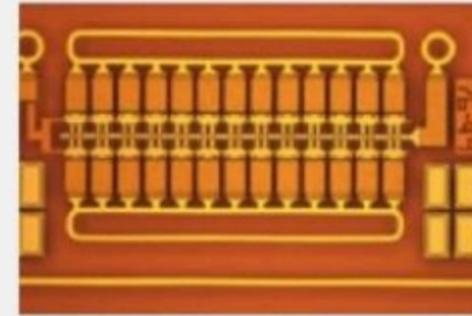
WAFER-LEVEL MANUFACTURING



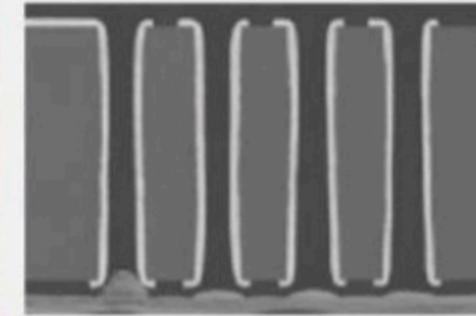
Wafer-scale manufacturing
on 8 in (200mm) glass substrates



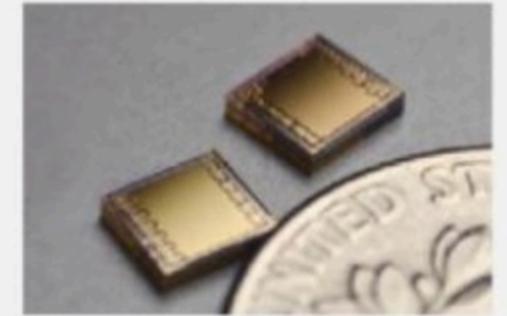
The unit cell:
Menlo's "mechanical transistor"
- only 50µm x 50µm



Multiple arrays of unit cells
infinite combinations to
scale up to 1000V+ and 10A+

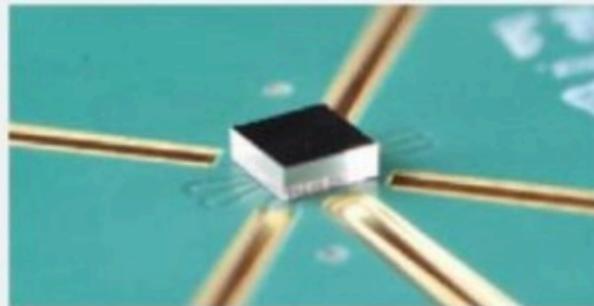


Through Glass Vias
Miniaturized packaging
with highest performance



**Wafer-level
Chip-Scale-Package**
from 16mm² to <1mm²

APPLICATION-SPECIFIC CONFIGURATIONS



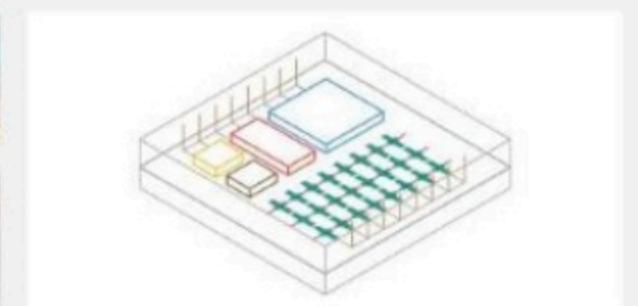
Core Switch
Simplest, smallest building block for multiple
power or RF applications.



Switch with integrated controls
Simpler control for high channel counts,
decreased need for external components.



Multiple switch die, with routing & control
For matrix and high-density switching
systems.



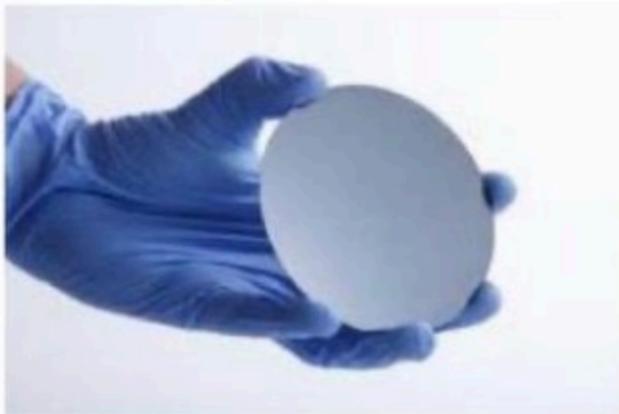
RF System-on-Glass
Integrate passives and other structures
directly on glass to create miniaturized RF
subsystems.

Production capacity online

Sampling out of commercial fab with capacity to support 5-year plan & COGS targets

Where we started:

2017



Fab capacity (Menlo's allotment) = 180 wafers/year (8" equivalent)

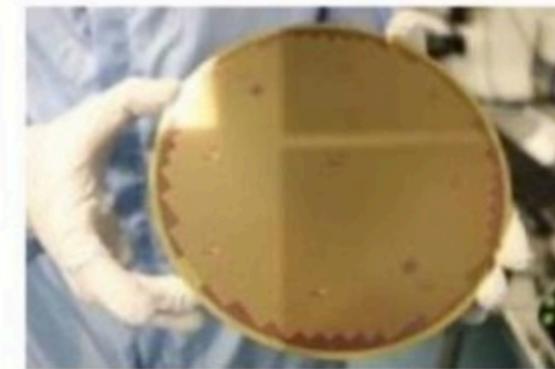
4" wafer

Low volume test infrastructure = 100K units/year w/low scalability

Research environment = R&D pricing and T&Cs

What have we accomplished:

Today



Fab capacity (Menlo's allotment) = 6K wafers/year

8" wafer = 4x increase in die/wafer = significantly reduced COGS

Scalable high-volume test infrastructure = >10M units/year

Scalable commercial fab w/volume pricing & production quality = reduced COGS