Small business conducting research, development and deriving applications for advanced technology in innovative *manipulation of the electron*, in all media, gas (vacuum), liquid, and solids to provide *extreme performance* electronics, sensors, power systems, energy storage and management, biological femtosystems and other highly advanced technologies.
Diamond Resistors

Power density of 12.4 MW/cm²  Operation at > 600 °C

Extreme operation thermistor
Designs

Chip Capacitor

*Metal-Diamond*

Volume Density of Capacitance

\[20 \, \mu F/cm^3\]

Comb Structured Capacitor

*All Diamond*

Volume Density of Capacitance

\[19 \, \mu F/cm^3\]

Present Power Capacitors in Industry \(\sim 0.03 \, \mu F/cm^3\)
DIAMOND MEMS PRESSURE SENSOR

• 30 square resistor configuration for high temperature environment
• Metal etch mask
• O₂ RIE of diamond film
• Layer uniformity

DPS OPERATED AT > 500 °C

Packaging limited

4x4 array of undiced complete sensors
Each DPS is ~ 2mm in diameter
Diamond-Based MIS and CAIS Gas Sensor Structures


Diamond Gas Sensor Structures

OPERATING AT 300 C
VERY RAPID RESPONSE, RECOVERY, SENSITIVITY
MULTIPLE SPECIES, LAYER SELECTION, SELECTIVITY
DIAMOND
VACUUM EMITTER
MICROELECTRONICS
Carbon/diamond electron emission device forms
Diamond-Based *Vacuum* microTip Emitter Devices

**Simplified Electron Emission Process**

*Fowler-Nordheim cold cathode tunneling*

**Micro-Tip Emitter**

Diamond is the best electron emitter material.

{ lightning rod ‘in reverse’, a nano-vacuum tube }

*Replace solid state*  Extreme operational limits

vertical
Nanodiamond lateral device

High magnification SEM image of the lateral device structure
Diamond Emitter Diode

- Low turn-on voltage
- High emission current
- *Extremely low reverse leakage current (less than 1pA, noise level)*
- High breakdown voltage of more than 2000 V

I-V plot of diamond emitter diode

Diamond Emitter Diode
High Temperature Characteristics

- Emission current is *unaffected* by temperature changes
- Turn-on voltage is unaffected by temperature changes
- Negligible reverse leakage current

![Graph showing temperature characteristics](chart.png)
Nanodiamond lateral device  Radiation Hardness

Neutron radiation test:

- \(4.4 \times 10^{13}\) neutrons/cm\(^2\) high fluence irradiation
- No discernable difference in physical size or appearance (dilation/expansion/change in anode-cathode spacing) of diamond devices (SEM)
- No change in resistivity of nanodiamond film
- No significant difference in the I-V emission behavior before and after neutron exposure

Diamond Vacuum Microelectronics technology capable of operating efficiently at both low & high temperatures (350 °C), with an inherent “hardness” to high radiation exposure, for Extreme Environment Electronics
3 TERMINAL DEVICE

**DVFET**

(a) Nanodiamond lateral triode, 2 μm gate-cathode spacing & 0.5 mm anode-cathode spacing;
(b) SEM micrograph of a nanodiamond lateral double triode with a common emitter.
Diamond VFET

- Low turn-on voltage of 22 V
- High emission current 200 µA
- Low anode saturation voltage (40V) for large anode-cathode spacing (1mm)
- High dc voltage gain of 800

- High ac voltage gain of 70
- Capable of producing large AC output voltage (>100 V peak to peak)

**Graphs:**
- DC characteristic
- AC characteristic
CONCLUDING

THE TECHNOLOGIES DISCUSSED:
R, C, SENSORS, DIODES, TRANSISTORS, and more,
PERFORM AT SUCH EXTREMES (T, RAD, etc.)
THEY OUTPACE CONVENTIONAL PACKAGE/ASSEMBLY TECHNOLOGY

There is an essential need for packaging/assembly technology for extreme environments

APEI, Inc. is a state-of-the-art high performance electronics company with capabilities from inception through manufacturing of fully qualified systems.

IFSI and APEI, Inc. are collaborating to arrive at components, sensors and devices that operate at unprecedented extreme ambient conditions

Prototype, depicting an exploded view of a diamond vacuum device packaged inside the integrated high temperature vacuum package
Diamond Emitter Diode forward characteristics

- Lateral Planar Device
- 6 Finger Device

- 184 uA/Tip at 495 volts
- 91 mW/Tip
- 85A/sq cm * 495V = 42 kW

(* refers to active surface area of device)
Emission current scaling in lateral devices