

New magnetic and dielectric materials for compact and reliable micro-inverters

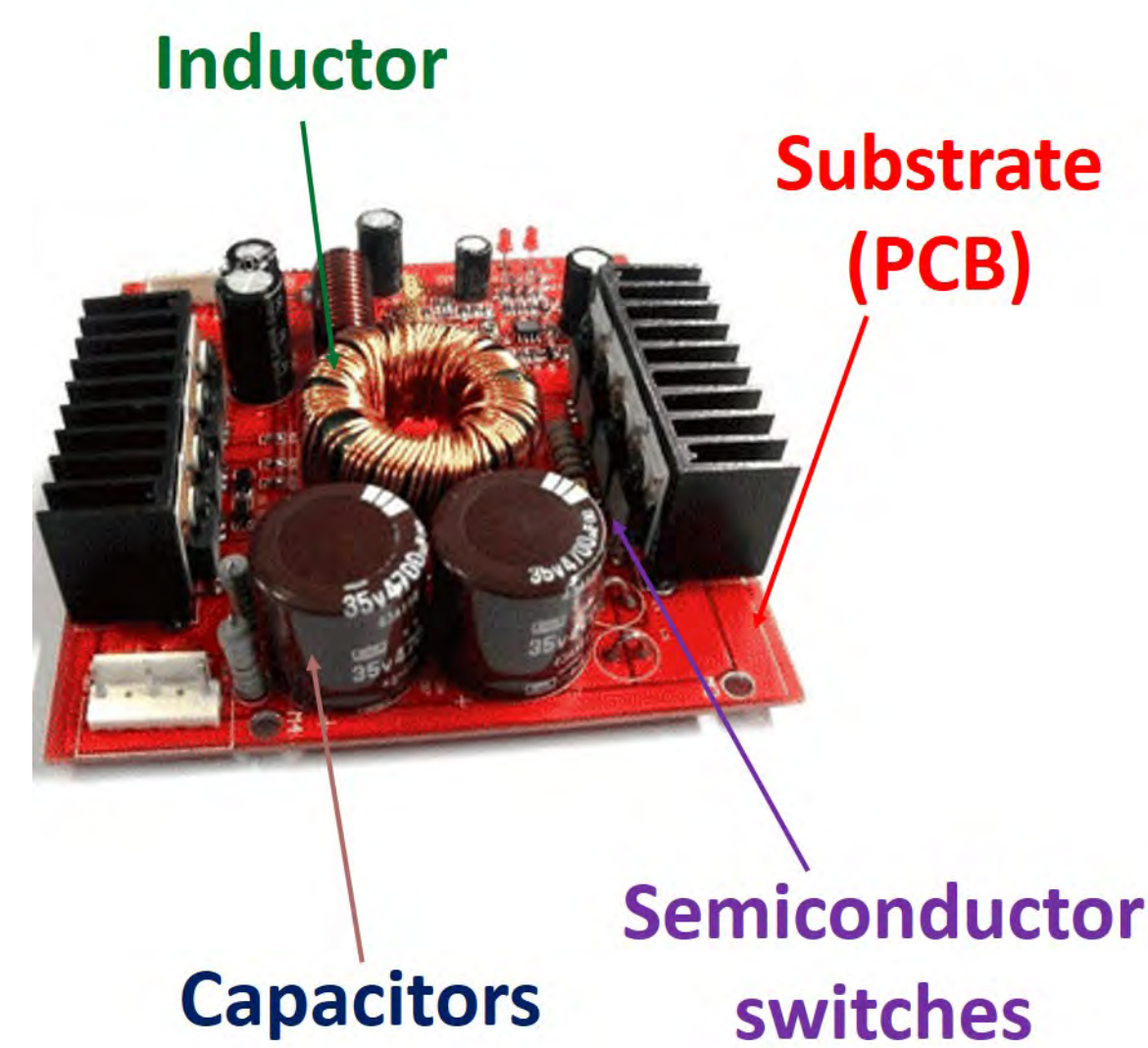
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Motivation

Developments in high temperature wide bandgap (WBG) switching technology can enable high-reliability, compact micro-inverters but have placed higher demands on passive electronic components like capacitors, inductors, resistors, and packaging

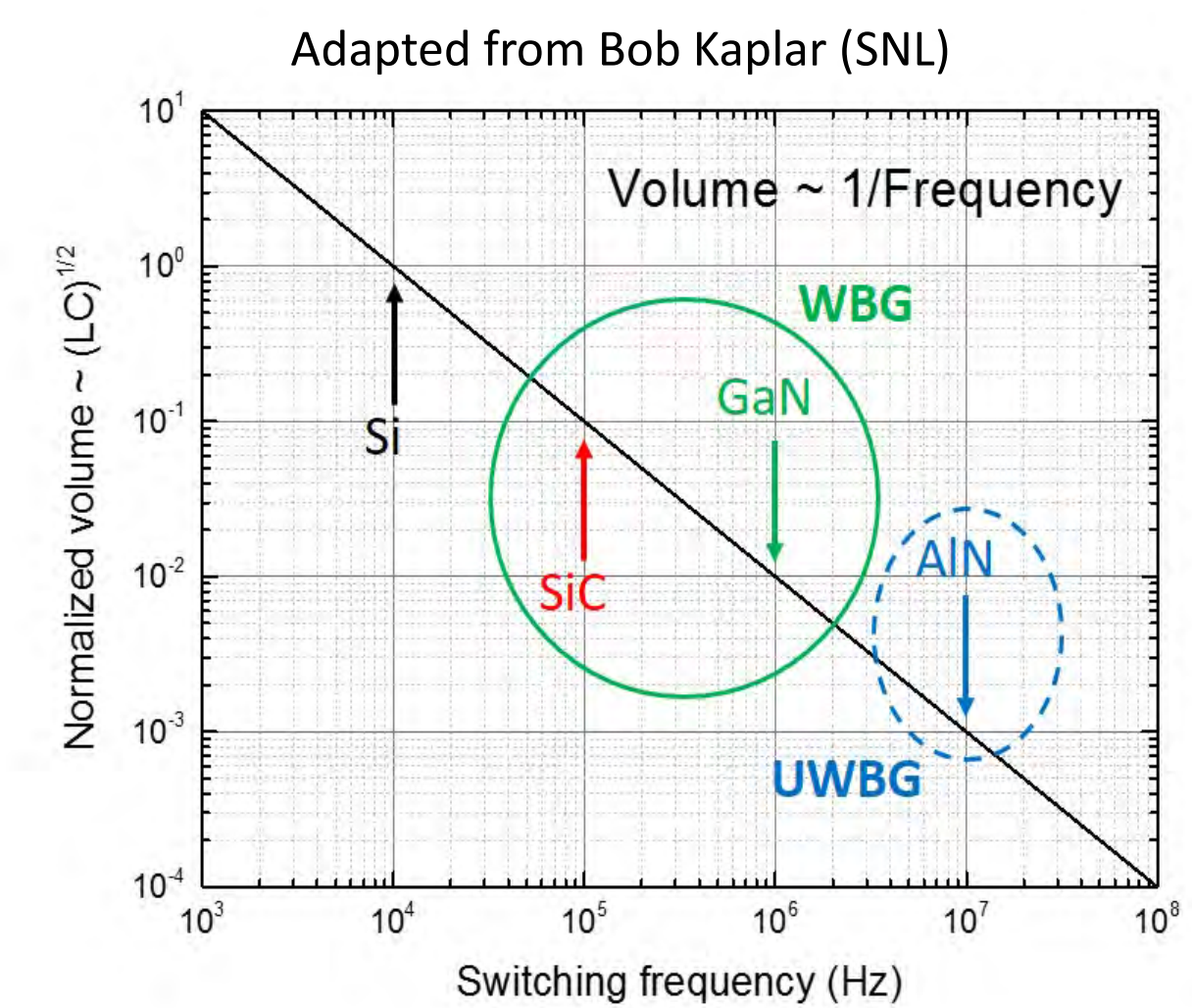
- Silicon switches operate at 6-12kHz with a maximum operating temperature of ~200°C
- WBG (SiC and GaN) switches operate >100kHz and >250°C
- Higher operating temperatures and voltages reduce the lifetime of passive components.

Example: Electrolytic and film capacitors cannot operate >250°C!



Passive elements comprise the bulk of the volume and mass of a power converter

WBG/UWBG materials enable higher switching frequency and better thermal management



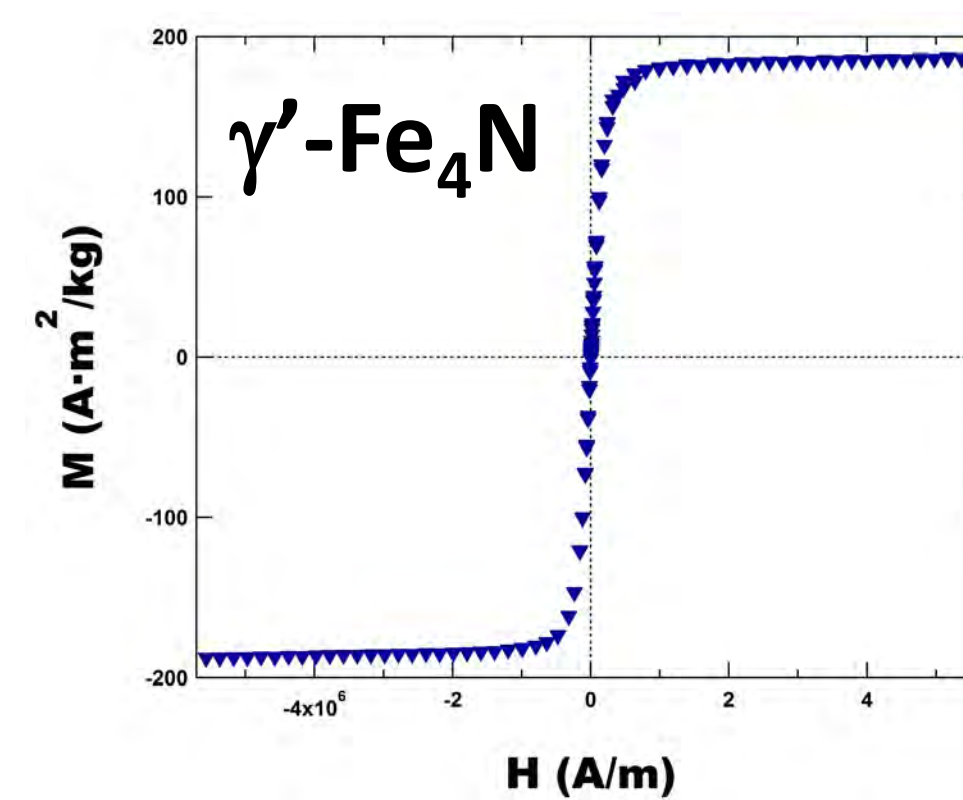
Adapted from: J. Neely, J. Flicker, B. Kaplar (SNL)



Exceptional service in the national interest

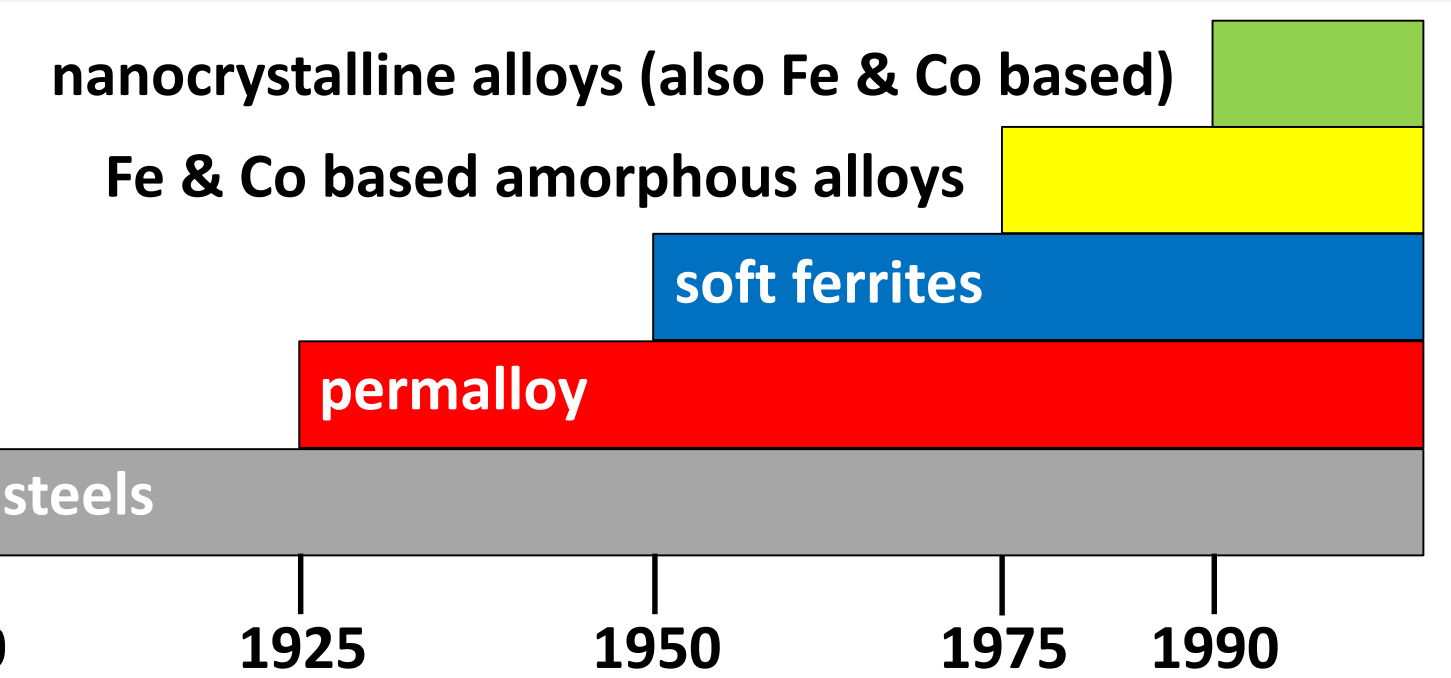
Inductors

New soft magnetic materials are required to enable high frequency micro-inverters



γ'-Fe₄N can meet all requirements of high frequency power electronics!

Magnetic Material	J _s (T)	ρ(μΩ·m)	Cost
VITROPERM (Vacuumschmelze)	1.20	1.15	High
Metglas 2605SC	1.60	1.37	High
Ferrite (Fexxocube)	0.52	5x10 ⁶	Low
Si steel	1.87	0.05	Low
γ'-Fe₄N	1.89	> 200	Low



History of soft magnetic material development

adapted from: L.A. Dobrzański, M. Drak, B. Ziębowicz, Materials with specific magnetic properties, Journal of Achievements in Materials and Manufacturing Eng., 17, 37 (2006).

First ever bulk γ'-Fe₄N!



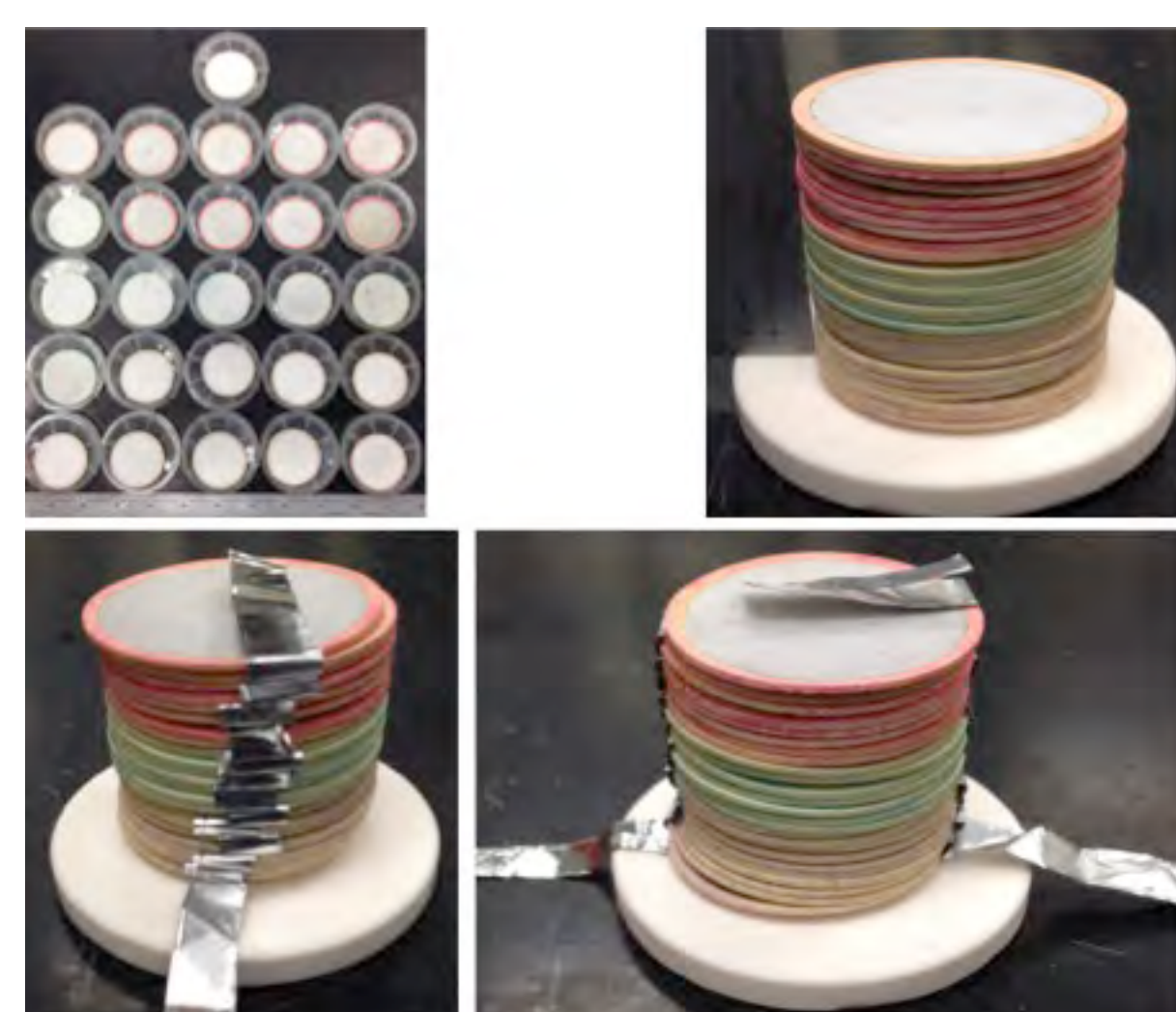
Net-shaped and sintered toroids (no machining required)



Enrique Lavernia research group

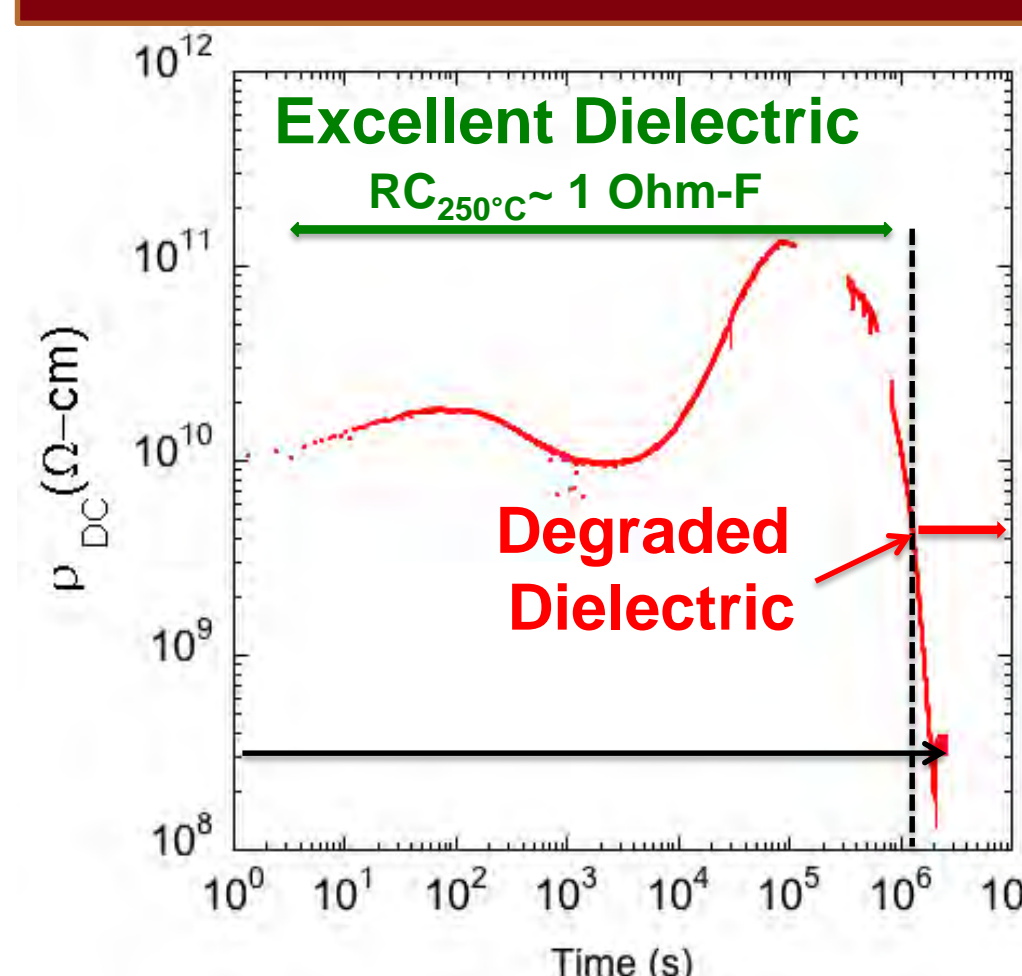
Capacitors

DC Link Capacitor Prototype



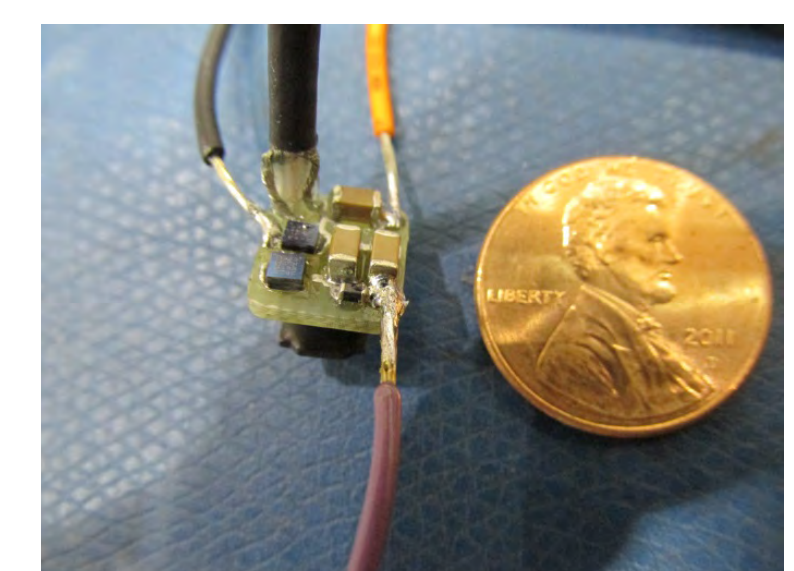
~400nF-1000V high temperature capacitor built *without* precious metal cofire

Aging of SNL capacitor for 1 month at 1000V and 250°C



High frequency, high temperature, and high voltage inverter designs favor thick dielectric layers that do not require precious metal cofire

System



Achieved: GaN ⇒ 215 W/in³
92 V, ~92 mA ⇒ 8.5 W, 215 W/in³, 1 MHz



High-power test system for evaluation of power semiconductor switches

- 10 kV, 50 A
- Packaged parts up to 400°C

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