



ADVANCED MAGNETIC MATERIALS

FOR HIGH FREQUENCY LINK CONVERTERS AND AN AGILE GRID

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PROJECT PROFILE

Topic: Power Electronics | Vertical: Materials and System Innovation

Strategic Pathway: [Grow]

Project start and finish: FY24-FY27

PROBLEM

Critical materials, such as nickel, are common in most competitive magnetic materials used in high frequency applications.

- Critical materials are expensive and are tied to high-risk supply chains
- MPP (Molypermalloy Powder), is a common competitive magnetic material used in high frequency cores, but contains 79% nickel
- Magnetic materials are essential to energy applications

SOLUTION: Iron is an affordable, non-critical material. Develop iron nitride (γ' -Fe₄N) materials with magnetic properties competitive with MPP alloys.

APPROACH

Material requirements: Low losses over 10-100 kHz frequency range

- Increase permeability $\mu_r \rightarrow$ Decrease grain size by ball milling powder.
- Lower core loss $\rightarrow$ Laminate with insulating layers of magnetite.
- Scalable & Affordable $\rightarrow$ Fabricate using spark plasma sintering (SPS).

Prepare Powder

Ideal grain size < 10 nm

ref [1]

SPS Powder

• Rapid solidification
• Higher Productivity

Figures modified from ref [2] and ref [3]

Laminated Core

No laminations
Laminated core
Fine grained Fe₄N

RESULTS

As received powder Ball milled 6 hours Grain structure of Fe₄N core

Core Loss of bulk and laminated toroids, at 10 V

CONCLUSIONS & IMPACT

- Sintering conditions maintain phase and microstructure.
- Ball milling reduces particle size but causes some deformation.
- Lamination process shows promising results, moving Fe₄N closer to being competitive with nickel based alloys.

FUTURE DIRECTIONS

- Continue reducing particle size through ball milling.
- Replace oxide layers with insulating epoxy.