U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

PACE ACCELERATING ELECTRIFICATION

Enabling Soft Magnetics for Power Conversion Applications

Principal Investigator: Jagannath Devkota[1], Darryl Shockley[1]
Team Members: Paul Ohodnicki[2], Subhashish Bhattacharya[3], Mark Nations[3]
[1]National Energy Technology Lab, [2]University of Pittsburgh, [3]North Carolina State University

Project Status: Ongoing **Project Term: 7/01/2022 to 6/30/2024** **Award Amount: $500,000**
Partners: University of Pittsburgh, North Carolina State University

Project Summary

The commercialization of wide bandgap silicon carbide (SiC) and gallium nitride (GaN) power semiconductors has enabled power electronic converters to operate at previously unattainable voltage and frequency levels. This has led to a step change power density for emerging technologies such as solid-state transformers, electric vehicle (EV) fast charges, hybrid transformers, medium frequency active filters, and more. However, existing soft magnetic materials and dielectric materials are often not characterized or perform inadequately under the conditions present in wide bandgap systems. Soft magnetic and dielectric material characterization and soft magnetic material development are under way to meet the needs of cutting-edge power electronic systems.

Technical Approach

First, application-relevant characterization on soft magnetic core materials and insulation materials is carried out. Recommended templates for standardized datasheets for both dielectric and soft magnetic materials are developed. Second, novel soft magnetic materials and processing techniques are investigated to reduce loss under medium frequency excitation.

Accomplishments

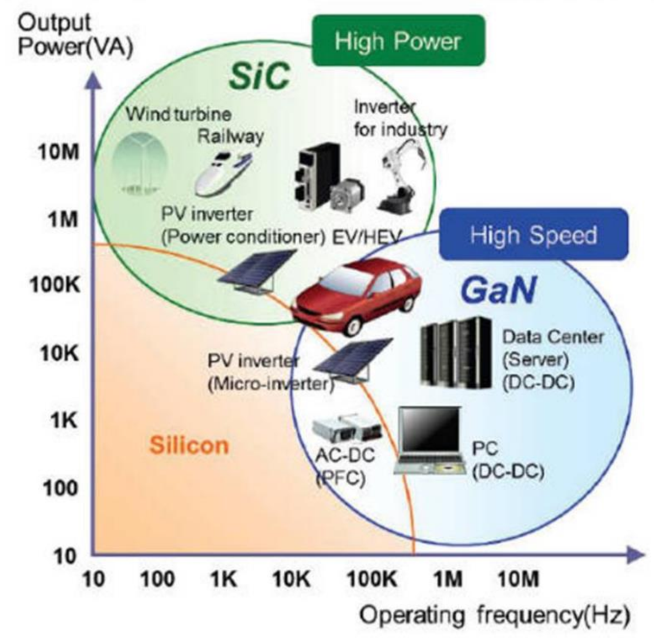
An initial datasheet has been developed for a representative nanocrystalline magnetic core using square voltage excitation up to 1.2kV. Several novel low-permeability powder cores have been developed and tested under low voltage sinusoidal excitation. A $NiFe_2O_4$/Fe soft magnetic composite (SMC) has been synthesized using a scalable wet chemistry-procedure and evaluated for its mechanical and magnetic properties. A model of laser-based core processing has been developed which includes laser power variation, laser travel velocity, and material properties.

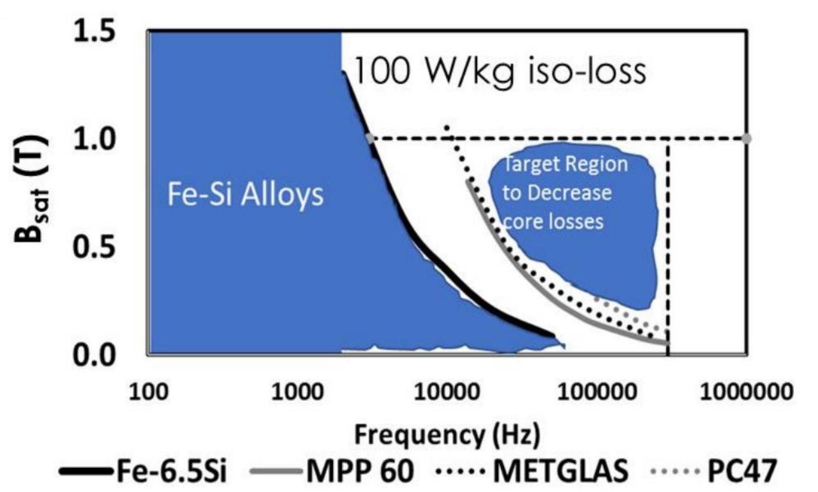
Impact/Commercialization

Medium voltage transformer datasheets (<2.5kV), an insulation material datasheet, and a nanocrystalline core (<1.2kV) are being published. Two journal papers have been published on induction and flash annealing techniques. Two more journal papers are being developed on each advanced induction processing techniques and wet-chemistry synthesis of SMC. Several conference presentations have been made at TMS Annual 2023, MMM/Intermag 2022, and ANPA 2022.

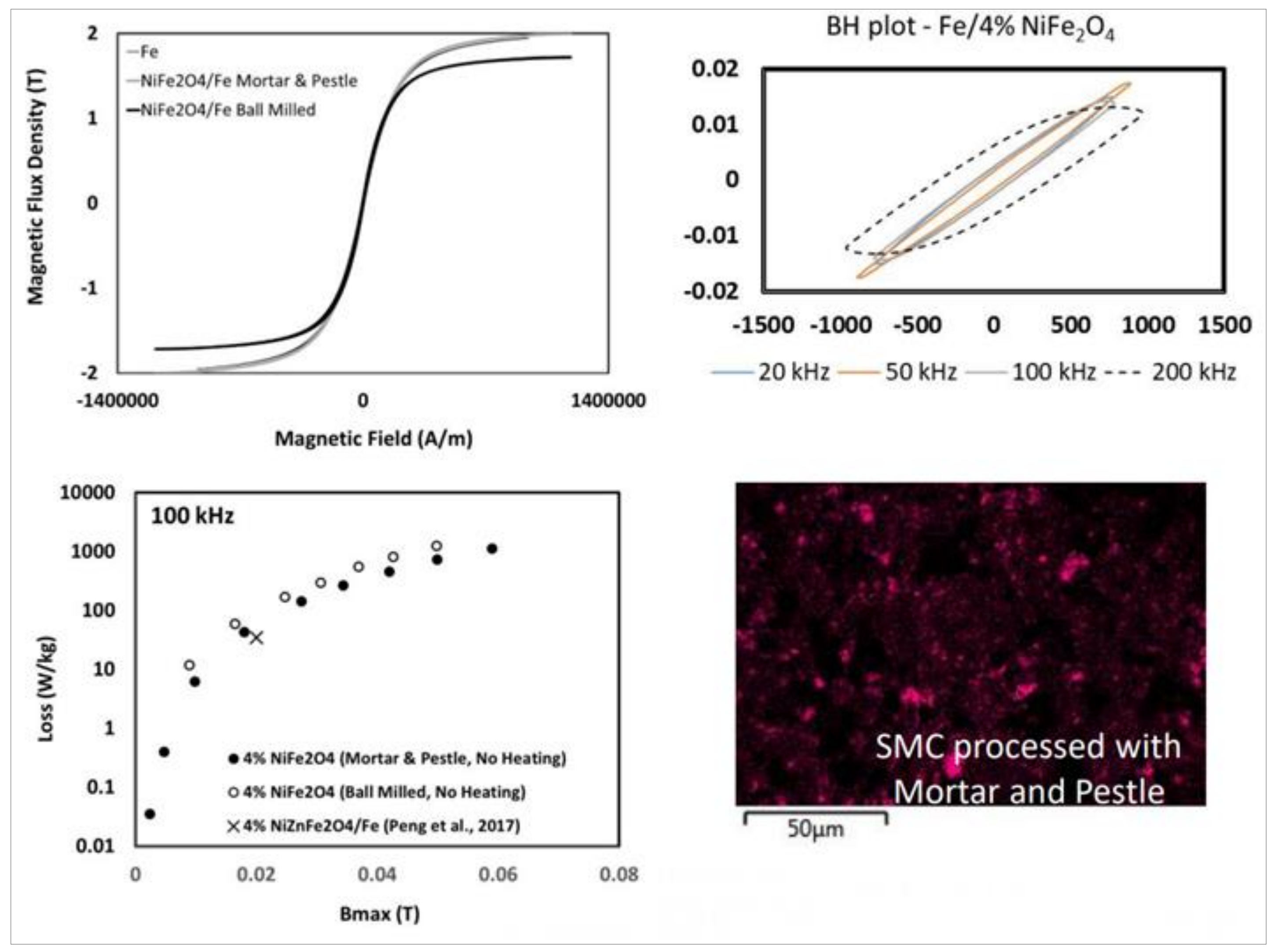
Future Work

Work will continue to expand the capability of existing core loss testing systems to perform medium frequency sinusoidal excitation. Datasheet of insulation materials will be expanded to include aging effects on partial discharge and breakdown behavior. New SMC materials will be benchmarked against existing materials. Scalable electromagnetic processing of techniques for amorphous and nanocrystalline soft magnetic alloys are under development. The differing magnetic properties of nanocrystalline materials subjected to electromagnetic annealing techniques and conventional annealing will be compared.

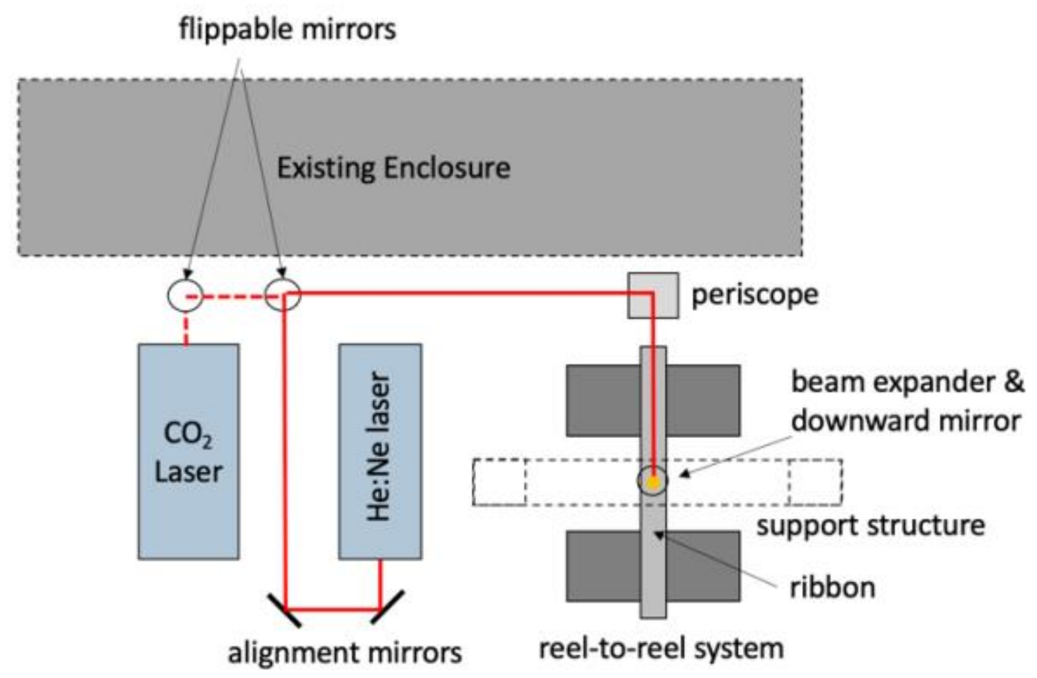




Losses of popular soft magnetic materials
(MPP60 – molypermalloy and PC47 - MnZn ferrite)



SMC synthesis and characterization



Proposed laser processing system