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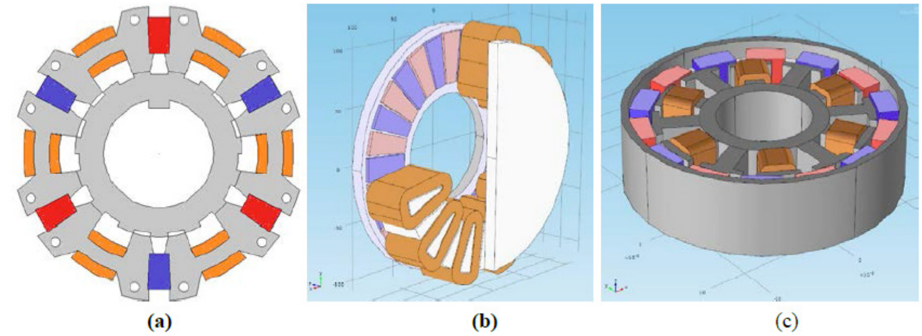


Schematic illustrating the MANC high speed motor topologies at different orientations: (a) parallel path, (b) radial, and (c) axial. *Graphic image courtesy of CMU*

# Amorphous and Nanocomposite Magnets for High Efficiency, High Speed Motor Designs

Enabling high-efficiency, high-speed motors through the development of novel soft magnet materials

Electric motors are essential to the U.S. manufacturing sector, consuming approximately two-thirds of the sector's electricity. Recent advances in wide bandgap power electronics materials have enabled more advanced motor capabilities and high frequency motor operation. However a motor's magnetic core, typically consisting of silicon steel with an established supply chain, suffers from large energy losses when switching at high frequencies above 1 kHz.

This project will develop a metal amorphous nanocomposite (MANC) soft magnet material (SMM)-based high speed motor (HSM) that will be able to operate at higher frequencies with reduced losses and higher power densities. The project will also model the most effective motor supply chain (from mining to motor production) for a prototype in given applications.

Development of MANC alloys target appropriate alloys (primarily Fe-, Co-, and newly-based compositions) for low losses when operating at 1-10 kHz frequencies, low cost, and high saturation induction. A new manufacturing technique to develop the amorphous nanocomposite material will be developed. The material will be wound into a motor, analyzed via an efficient motor controller, and then tested. The motor prototype will gradually be developed for a 5kW-scale design, using incremental smaller scale demonstrations.

## Benefits for Our Industry and Our Nation

The successful development of MANC SMM materials for motor applications has many benefits, including:

- Increasing energy efficiency for high frequency motor operation.
- Eliminating gear reductions that can lower energy efficiency by 2-3%.
- Reducing installation and compressor maintenance costs.
- Enabling motor scalability based on design and material specifications.

## Applications in Our Nation's Industry

The highly efficient motor that is expected to result from this application will be suitable for general industrial applications. In addition, the technology is expected to be easily scaled to higher speeds and rated power based on its application. The greatest energy savings potential can be realized for higher power applications greater than 10 kW. In addition, lower power motors will also benefit as the integrated motor-controller resulting from this project will be designed to limit adverse effects on local power grids.

## Project Description

The project objective is to develop, build, validate, and model metal amorphous nanocomposite (MANC) soft magnetic materials (SMM) for next generation electric machines. The materials in the proposed high speed motor (HSM) are expected to contain no rare earth elements. The project outcomes address supply chain steps: (a) metal to alloy processing & magnet core production; (b) soft magnetic laminate & core post- processing; and (c) production of a 2.5 kW motor thereby advancing the technology readiness of MANC motor materials. Casting technology will be transferred to a domestic company positioned to scale production of MANCs to provide for projects targeting higher power density motors.

### Barriers

- Minimizing core losses at high frequency motor operation.
- Ensuring sufficient motor torque and power densities.
- Cutting and shaping technologies that produce the required mechanical properties.

### Pathways

The project is organized into six components. It will begin by (1) modeling motor designs for the MANCs to identify promising rare earth free HSM topologies. Once identified, (2) rapid solidification and post-processing will be scaled to produce large insulated magnetic cores. If the modeling indicates a design capable of meeting motor efficiency metrics, the project will (3) focus on post processing into rotor and stator components and (4) developing winding techniques for use with new rotor and stator topologies. The feasibility of a 2.5 kW motor will be determined by (5) incorporating state-of-art motor controllers and (6) building a 2.5 kW motor from the design that operates at frequency >1 kHz. Loss partitioning between controller, copper, iron, & windings will be measured.

These project components will be divided among the project team to leverage the strengths of each team member.

### Milestones

This three year project began in 2017.

- Develop and validate alloy target metrics of the proposed high-speed motor via finite element modeling, enabling a 4% motor efficiency increase (Completed).
- Validate rotor and stator manufacturability and report winding procedure for a 2.5 kW motor component to be integrated with a controller (2018).
- Validate motor control to measure loss and efficiency metrics of a 2.5 kW motor, where magnetic material switches at a frequency in excess of 1 kHz (2019).

## Technology Transition

Technology advancement will be informed by consultation with the project industrial advisory board, which includes Intermolecular, Fort Wayne Metals, and General Electric. Fort Wayne Metals will be well-positioned to advance production of wider MANCs to provide them for projects targeting higher power density motors. Advanced Materials Corporation will then be capable of producing higher power density high-speed motors (HSMs) to take advantage of increased manufacturing capabilities. To integrate the motor's engineering specifications to market deployment, Intermolecular will be able to monitor the project and advise future applications of the MANC HSM. General Electric will advise the project team on the market potential for small motors and larger MANC HSM markets.

## Project Partners

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