



TECHNOLOGY SOLUTION

Materials and Coatings

Soft Magnetic Nanocomposite for High- Temperature Applications

New material operates at up to 400°C with low losses

Innovators at NASA's Glenn Research Center developed a novel nanocomposite soft magnetic material for use in power electronics. The material maintains near room-temperature attributes of available soft magnetics, such as Hitachi Metals' FINEMET®, while surpassing these materials in temperature capability.

In the present state-of-the-art, soft magnetic nanocomposites have an upper temperature limit rating of 150°C before core loss occurs. By adjusting the composition and fabrication, innovators at Glenn increased the operating temperature range to 400°C with minimal increase in core loss. While operating at high temperatures, the material exhibits high permeability and saturation flux density desirable in soft magnetics. Test cores of the novel material show improved temperature performance compared to available materials. NASA's development expands the application of soft magnetic material, enabling efficient power electronics that are smaller and lighter due to the reduced need for cooling.

BENEFITS

- Robust: capable of operating at temperatures up to 400° C, which is over 200°C higher than the maximum operating temperature of current materials
- Stable: exhibits minimal core loss in comparison to state-of-the-art materials when operating at high temperatures (150°C and greater)
- Inductive: maintains the high permeability required for optimal use of soft magnetic cores in high frequency applications
- Efficient: enables the development of lighter and smaller power electronics through the improved temperature capability
- Simple: reduces the need of implementing cooling capabilities in the design of power electronics

APPLICATIONS

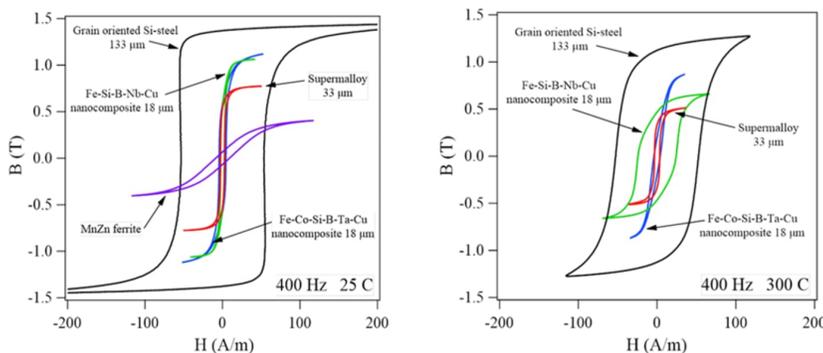
The technology has several potential applications:

- Aerospace: power electronics for electrified aircraft systems
- Energy: power converters for solar energy power systems
- Power electronics: medium frequency (1-1000kHz) energy conversion devices, such as inductors, transformers, and chokes

THE TECHNOLOGY

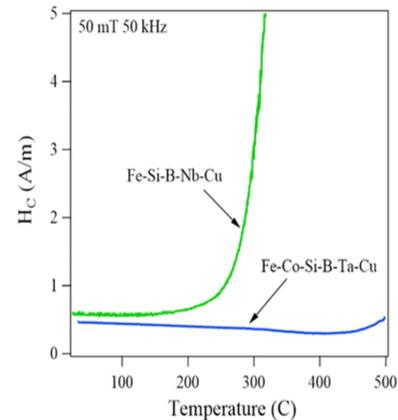
Commercial soft magnetic cores used in power electronics are limited by core loss and decreased ferromagnetism at high temperatures. Extending functional performance to high temperatures allows for increased power density in electric systems with fixed power output and elevated operating temperature. The innovators at Glenn developed a unique composition and process to improve the temperature capability of the material.

Nanocomposite soft magnetic materials are typically comprised of a combination of raw materials including iron, silicon, niobium, boron, and copper. Instead of niobium, NASA's material utilizes small cobalt and tantalum additions. The raw materials are combined to form an amorphous precursor through melt spinning. NASA's innovation with the fabrication lies in the thermal annealing step, which nucleates and crystallizes the precursor to form the composite structure of the material. By adjusting the temperature and magnetic field of the thermal annealing step, Glenn's process results in good coupling between the crystalline and amorphous matrix phases. Innovators at Glenn demonstrated the temperature robustness using small test cores of their material and are investigating additional quality attributes compared to other well-known soft magnetic materials (see two Figures below).



Hysteresis loops comparing the magnetic flux density of state-of-the-art materials (Fe-Si-Nb-B-Cu; Si-steel; Supermalloy) and NASA's novel material (Fe-Co-Si-Ta-B-Cu).

Hysteresis loops compare the materials at room temperature (left) and high-temperature (right).



Measurement of core loss with increasing temperature of state-of-the-art materials (Fe-Si-Nb-B-Cu) and NASA's novel soft magnetic nanocomposite material (Fe-Co-Si-Ta-B-Cu).

PUBLICATIONS

Patent Pending

Leary, A. M., Ohodnicki, P. R., & McHenry, M. E. (2012). Soft magnetic materials in high-frequency, high-power conversion applications. *JOM*, 64(7), 772-781.

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